C. Ker

BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

ANNUAL MEETING, 1932
(102ND YEAR)

YORK
AUGUST 31—SEPTEMBER 7

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

1932

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British Association for the Advancement of Science.

OFFICERS & COUNCIL, 1932-33.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT, 1932.

Sir ALFRED EWING, K.C.B., LL.D., D.Sc., F.R.S.

PRESIDENT, 1933.

Sir F. GOWLAND HOPKINS, LL.D., D.Sc., Pres.R.S.

VICE-PRESIDENTS FOR THE YORK MEETING.

The Rt. Hon. the LORD MAYOR OF YORK, 1931–32 (Alderman R. H. VERNON WRAGGE, J.P.).

The RECORDER OF YORK (the late Rt. Hon. Sir HERBERT NIELD, K.C.).

The SHERIFF OF YORK, 1931–32 (ARNOLD S. ROWNTREE).

His Grace the LORD ARCHBISHOP OF YORK (The Most Rev. WILLIAM TEMPLE, D.Litt.).

The Very Rev. the DEAN OF YORK (Dr. H. N. BATE).

The Most Honourable the MARQUESS OF ZETLAND, P.C., G.C.S.I., G.C.I.E., F.B.A.

The Rt. Hon. the EARL OF CHESTERFIELD, K.G., P.C., G.C.V.O.

The Rt. Hon. LORD IRWIN, K.G.

The Rt. Hon. LORD DANESFORT, K.C.

The LORD LIEUTENANT OF THE WEST RIDING OF YORKSHIRE AND THE CITY OF YORK (The Rt. Hon. the EARL OF HAREWOOD, K.G., D.S.O., T.D.).

The LORD LIEUTENANT OF THE EAST RIDING OF YORKSHIRE (The Rt. Hon. LORD DERAMORE, T.D.).

The LORD LIEUTENANT OF THE NORTH RIDING OF YORKSHIRE (The Hon. GEOFFREY HOWARD).

The HIGH SHERIFF OF YORKSHIRE (Major F. H. FAWKES, J.P.).

General the Hon. Sir J. F. GATHORNE-HARDY, C.B., C.M.G., D.S.O.

ROGER LUMLEY, M.P.

F. G. BURGESS.

J. W. COULTHURST.

Sir WILFRID THOMSON, Bt., J.P.

W. H. ST. QUINTIN, D.L., J.P. (President of the Yorkshire Philosophical Society).

FRANK GREEN.

The Rt. Hon. the LORD MAYOR OF YORK, 1930–31 (Alderman Sir W. A. FORSTER TODD, J.P.).

The SHERIFF OF YORK, 1930–31 (WILLIAM COOPER).

The VICE-CHANCELLOR OF LEEDS UNIVERSITY (Sir J. B. BAILLIE, O.B.E., LL.D., J.P.).

The VICE-CHANCELLOR OF SHEFFIELD UNIVERSITY (A. W. PICKARD-CAMBRIDGE, D.Litt.).

The PRINCIPAL, HULL UNIVERSITY COLLEGE (Prof. A. E. MORGAN).

VICE-PRESIDENTS ELECT FOR THE LEICESTER MEETING, 1933.

The Lord Lieutenant of Leicestershire (Sir Arthur Hazlerigg, Bt., J.P.).
The Rt. Worshipful the Lord Mayor of Leicester (Councillor A. Hawkes, J.P.).
The Lord Bishop of Leicester (The Rt. Rev. C. C. B. Bardsley, D.D.).
The High Sheriff of Leicestershire (Major E. G. Gillilan).
His Grace the Duke of Rutland.
The Rt. Hon. the Earl Ferrers, F.S.A.
The Rt. Hon. Lord Belper.
The Visitor of University College, Leicester (Prof. Gilbert Murray, M.A., LL.D., D.Litt., F.B.A.).
The Principal of University College, Leicester (F. L. Attenborough, M.A.).
The President of the Leicester Literary and Philosophical Society (H. Percy Gee, J.P.).
C. J. Bond, C.M.G., F.R.C.S.
Councillor Astley V. Clarke, M.A., M.D., D.L., J.P.
George Farnham, F.S.A.
Lt.-Col. R. E. Martin, C.M.G., D.L., M.A.
Alderman Sir Jonathan North, D.L., J.P.
The Rev. Bernard Uffen, A.T.S.

GENERAL TREASURER.

Sir Josiah Stamp, G.B.E., D.Sc.

GENERAL SECRETARIES.

Prof. P. G. H. Boswell, O.B.E., D.Sc., F.R.S.
Prof. F. J. M. Stratton, D.S.O., O.B.E., M.A.

SECRETARY.

O. J. R. Howarth, O.B.E., Ph.D.

ASSISTANT SECRETARY.

H. Wooldridge, B.Sc.

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Dr. H. S. Hele-Shaw, F.R.S.
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Prof. J. F. Thorpe, C.B.E., F.R.S.
H. T. Tizard, C.B., F.R.S.
Prof. A. M. Tyndall.
Prof. F. E. Weiss, F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

Past-Presidents of the Association, the President for the year, the President and Vice-Presidents for the ensuing Annual Meeting, past and present General Treasurers and General Secretaries, and the Local Treasurers and Local Secretaries for the Annual Meetings immediately past and ensuing.

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Prof. J. L. Myres, O.B.E., F.S.A., F.B.A.

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Prof. W. W. Watts, F.R.S.

HON. CURATOR OF DOWN HOUSE.

Sir Buckston Browne, F.R.C.S., F.S.A.

LOCAL OFFICERS FOR THE YORK MEETING, 1932.

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(Alderman R. H. Vernon Wragge, J.P.).

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Percy J. Spalding, B.A., LL.M.
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H. E. Bloor.
J. L. Brockbank.
Major S. Brook.
G. Laycock Brown.
The Very Rev. Canon Chadwick.
Councillor F. W. Chapman.
J. A. Cooper.
Councillor J. W. Dow.
C. E. Elmhirst.
D. Gray.
Mrs. Edwin Gray, J.P.
Sir James Hamilton.
Rev. F. Harrison.
G. S. Hughes.
Sir John J. Hunt.
A. Hurst.
Ald. J. B. Inglis.
G. Johnson.
Lt.-Col. Kirby.
S. Melmore.
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Mrs. J. B. Morrell (Lady Mayoress).
J. R. F. Robinson.
A. S. Rowntree (Sheriff).
Mrs. A. S. Rowntree, J.P.
B. S. Rowntree.
Ald. C. W. Shipley.
S. H. Smith.
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S. M. Toyne.
P. J. Vinter.
S. Walker.
Miss Waller.
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H. J. Wilkinson.
G. Wilson.

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Secretary.—F. W. Spurr.

Excursions.
Chairman.—Councillor J. W. Dow.
Secretary.—P. A. Harverson.

Lodgings and Hospitality.
Chairman.—C. E. Elmhirst.
Secretaries.—Geoffrey Thompson.
Councillor A. Wilkinson.

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Chairman.—Sir Wilfrid Thomson, Bt.

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CHAIRMAN OF LOCAL EXECUTIVE COMMITTEE.

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LOCAL HON. SECRETARIES.

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Colin D. B. Ellis.

ASSISTANT LOCAL SECRETARY.

H. Purt.

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Secretary.—Prof. W. M. Tattersall.

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Local Secretary.—Dr. H. D. Anthony.

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Local Secretary.—A. A. Harrower.

A Department of Industrial Co-operation—*Chairman*, Dr. J. A. Bowie; *Secretary*, R. J. Mackay—arranged a special programme in connection with this and other Sections.

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Recorder.—J. S. Wilson.

Secretaries.—Dr. S. J. Davies; J. E. Montgomrey.

Local Secretary.—H. R. Lupton.

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Vice-Presidents.—Dr. Axel Boethius; L. H. Dudley Buxton; Capt. T. A. Joyce; I. A. Richmond; Prof. V. Suk.

Recorder.—Miss R. M. Fleming.

Secretaries.—Dr. S. Bryan Adams; V. E. Nash-Williams.

Local Secretary.—Rev. A. E. Baker.

I.—PHYSIOLOGY.

(There were no meetings of Section I (Physiology) at York in view of the XIVth International Physiological Congress at Rome.)

J.—PSYCHOLOGY.

President.—Prof. Beatrice Edgell.

Vice-Presidents.—Dr. W. Brown; Dr. S. Dawson; Prof. J. Drever; Prof. W. McDougall, F.R.S.; Dr. C. S. Myers, C.B.E., F.R.S.; Prof. C. W. Valentine; Prof. R. H. Wheeler.

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Local Secretary.—A. W. Ping.

L.—EDUCATIONAL SCIENCE.

President.—W. Mayhowe Heller.

Vice-Presidents.—Sir J. B. Baillie, O.B.E. ; J. H. Hallam ; Dr. A. W. Pickard-Cambridge ; His Grace the Lord Archbishop of York.

Recorder.—G. D. Dunkerley.

Secretaries.—H. E. M. Icely ; E. R. Thomas.

Local Secretary.—J. L. Brockbank.

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President.—Prof. R. G. White.

Vice-Presidents.—Prof. N. M. Comber ; T. S. Dymond ; Major F. H. Fawkes ; Sir E. John Russell, O.B.E., F.R.S. ; Prof. R. S. Seton.

Recorder.—Dr. E. M. Crowther.

Secretary.—W. Godden.

Local Secretary.—J. Strachan.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES.

President.—Lt.-Col. Sir David Prain, C.I.E., C.M.G., F.R.S.
Secretary.—Dr. C. Tierney.

TABLE OF

Date of Meeting	Where held	Presidents	Old Life Members	New Life Members
1831, Sept. 27	York	Viscount Milton, D.C.L., F.R.S.	—	—
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	—	—
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	—	—
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L., F.R.S.	—	—
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D., F.R.S.	—	—
1836, Aug. 22	Bristol	The Marquis of Lansdowne, F.R.S.	—	—
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	—	—
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland, F.R.S.	—	—
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt, F.R.S.	—	—
1840, Sept. 17	Glasgow	The Marquis of Breadalbane, F.R.S.	—	—
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton, F.G.S.	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D., F.R.S.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart., F.R.S.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart., F.R.S.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart., F.R.S.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton, Pres. R.S.	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D., F.R.S.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H., F.R.S.	235	9
1851, July 2	Ipswich	G. B. Airy, Astronomer Royal, F.R.S.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeney, M.D., F.R.S.	182	14
1857, Aug. 26	Dublin	The Rev. H. Lloyd, D.D., F.R.S.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L., F.R.S.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A., F.R.S.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Professor Willis, M.A., F.R.S.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B., F.R.S.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A., F.R.S.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D., F.R.S.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B., F.R.S.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L., F.R.S.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D., F.R.S.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D., F.R.S.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.	221	35
1877, Aug. 15	Plymouth	Prof. A. Thomson, M.D., F.R.S.	173	19
1878, Aug. 14	Dublin	W. Spottiswoode, M.A., F.R.S.	201	18
1879, Aug. 20	Sheffield	Prof. G. J. Allman, M.D., F.R.S.	184	16
1880, Aug. 25	Swansea	A. C. Ramsay, LL.D., F.R.S.	144	11
1881, Aug. 31	York	Sir John Lubbock, Bart., F.R.S.	272	28
1882, Aug. 23	Southampton	Dr. C. W. Siemens, F.R.S.	178	17
1883, Sept. 19	Southport	Prof. A. Cayley, D.C.L., F.R.S.	203	60
1884, Aug. 27	Montreal	Prof. Lord Rayleigh, F.R.S.	235	20
1885, Sept. 9	Aberdeen	Sir Lyon Playfair, K.C.B., F.R.S.	225	18
1886, Sept. 1	Birmingham	Sir J. W. Dawson, C.M.G., F.R.S.	314	25
1887, Aug. 31	Manchester	Sir H. E. Roscoe, D.C.L., F.R.S.	428	86
1888, Sept. 5	Bath	Sir F. J. Bramwell, F.R.S.	266	36
1889, Sept. 11	Newcastle-on-Tyne	Prof. W. H. Flower, C.B., F.R.S.	277	20
1890, Sept. 3	Leeds	Sir F. A. Abel, C.B., F.R.S.	259	21
1891, Aug. 19	Cardiff	Dr. W. Huggins, F.R.S.	189	24
1892, Aug. 3	Edinburgh	Sir A. Geikie, LL.D., F.R.S.	280	14
1893, Sept. 13	Nottingham	Prof. J. S. Burdon Sanderson, F.R.S.	201	17
1894, Aug. 8	Oxford	The Marquis of Salisbury, K.G., F.R.S.	327	21
1895, Sept. 11	Ipswich	Sir Douglas Galton, K.C.B., F.R.S.	214	13
1896, Sept. 16	Liverpool	Sir Joseph Lister, Bart., Pres. R.S.	330	31
1897, Aug. 18	Toronto	Sir John Evans, K.C.B., F.R.S.	120	8
1898, Sept. 7	Bristol	Sir W. Crookes, F.R.S.	281	19
1899, Sept. 13	Dover	Sir Michael Foster, K.C.B., Sec. R.S.	296	20

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

[*Continued on p.* xiv.

ANNUAL MEETINGS.

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
—	—	—	—	—	353	—	—	1831
—	—	—	—	—	—	—	—	1832
—	—	—	—	—	900	—	—	1833
—	—	—	—	—	1298	—	£20 0 0	1834
—	—	—	—	—	—	—	167 0 0	1835
—	—	—	—	—	1350	—	435 0 0	1836
—	—	—	—	—	1840	—	922 12 6	1837
—	—	—	1100*	—	2400	—	932 2 2	1838
—	—	—	—	34	1438	—	1595 11 0	1839
—	—	—	—	40	1353	—	1546 16 4	1840
46	317	—	60*	—	891	—	1235 10 11	1841
75	376	33†	331*	28	1315	—	1449 17 8	1842
71	185	—	160	—	—	—	1565 10 2	1843
45	190	9†	260	—	—	—	981 12 8	1844
94	22	407	172	35	1079	—	831 9 9	1845
65	39	270	196	36	857	—	685 16 0	1846
197	40	495	203	53	1320	—	208 5 4	1847
54	25	376	197	15	819	£707 0 0	275 1 8	1848
93	33	447	237	22	1071	963 0 0	159 19 6	1849
128	42	510	273	44	1241	1085 0 0	345 18 0	1850
61	47	244	141	37	710	620 0 0	391 9 7	1851
63	60	510	292	9	1108	1085 0 0	304 6 7	1852
56	57	367	236	6	876	903 0 0	205 0 0	1853
121	121	765	524	10	1802	1882 0 0	380 19 7	1854
142	101	1094	543	26	2133	2311 0 0	480 16 4	1855
104	48	412	346	9	1115	1098 0 0	734 13 9	1856
156	120	900	569	26	2022	2015 0 0	507 15 4	1857
111	91	710	509	13	1698	1931 0 0	618 18 2	1858
125	179	1206	821	22	2564	2782 0 0	684 11 1	1859
177	59	636	463	47	1689	1604 0 0	766 19 6	1860
184	125	1589	791	15	3138	3944 0 0	1111 5 10	1861
150	57	433	242	25	1161	1089 0 0	1293 16 6	1862
154	209	1704	1004	25	3335	3640 0 0	1608 3 10	1863
182	103	1119	1058	13	2802	2965 0 0	1289 15 8	1864
215	149	766	508	23	1997	2227 0 0	1591 7 10	1865
218	105	960	771	11	2303	2469 0 0	1750 13 4	1866
193	118	1163	771	7	2444	2613 0 0	1739 4 0	1867
226	117	720	682	45‡	2004	2042 0 0	1940 0 0	1868
229	107	678	600	17	1856	1931 0 0	1622 0 0	1869
303	195	1103	910	14	2878	3096 0 0	1572 0 0	1870
311	127	976	754	21	2463	2575 0 0	1472 2 6	1871
280	80	937	912	43	2533	2649 0 0	1285 0 0	1872
237	99	796	601	11	1983	2120 0 0	1685 0 0	1873
232	85	817	630	12	1951	1979 0 0	1151 16 0	1874
307	93	884	672	17	2248	2397 0 0	960 0 0	1875
331	185	1265	712	25	2774	3023 0 0	1092 4 2	1876
238	59	446	283	11	1229	1268 0 0	1128 9 7	1877
290	93	1285	674	17	2578	2615 0 0	725 16 6	1878
239	74	529	349	13	1404	1425 0 0	1080 11 11	1879
171	41	389	147	12	915	899 0 0	731 7 7	1880
313	176	1230	514	24	2557	2689 0 0	476 8 1	1881
253	79	516	189	21	1253	1286 0 0	1126 1 11	1882
330	323	952	841	5	2714	3369 0 0	1083 3 3	1883
317	219	826	74	26 & 60 H.§	1777	1855 0 0	1173 4 0	1884
332	122	1053	447	6	2203	2256 0 0	1385 0 0	1885
428	179	1067	429	11	2453	2532 0 0	995 0 6	1886
510	244	1985	493	92	3838	4336 0 0	1186 18 0	1887
399	100	639	509	12	1984	2107 0 0	1511 0 5	1888
412	113	1024	579	21	2437	2441 0 0	1417 0 11	1889
368	92	680	334	12	1775	1776 0 0	789 16 8	1890
341	152	672	107	35	1497	1664 0 0	1029 10 0	1891
413	141	733	439	50	2070	2007 0 0	864 10 0	1892
328	57	773	268	17	1661	1653 0 0	907 15 6	1893
435	69	941	451	77	2321	2175 0 0	583 15 6	1894
290	31	493	261	22	1324	1236 0 0	977 15 5	1895
383	139	1384	873	41	3181	3228 0 0	1104 6 1	1896
286	125	682	100	41	1362	1398 0 0	1059 10 8	1897
327	96	1051	639	33	2446	2399 0 0	1212 0 0	1898
324	68	548	120	27	1403	1328 0 0	1430 14 2	1899

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

[*Continued on p.* xv.

Table of

Date of Meeting	Where held	Presidents[1]	Old Life Members	New Life Members
1900, Sept. 5	Bradford	Sir William Turner, D.C.L., F.R.S. ...	267	13
1901, Sept. 11......	Glasgow	Prof. A. W. Rücker, D.Sc., Sec. R.S.	310	37
1902, Sept. 10......	Belfast	Prof. J. Dewar, LL.D., F.R.S.	243	21
1903, Sept. 9	Southport	Sir Norman Lockyer, K.C.B., F.R.S.	250	21
1904, Aug. 17......	Cambridge	Rt. Hon. A. J. Balfour, M.P., F.R.S. ...	419	32
1905, Aug. 15......	South Africa	Prof. G. H. Darwin, LL.D., F.R.S. ...	115	40
1906, Aug. 1	York	Prof. E. Ray Lankester, LL.D., F.R.S.	322	10
1907, July 31	Leicester	Sir David Gill, K.C.B., F.R.S.	276	19
1908, Sept. 2	Dublin.................	Dr. Francis Darwin, F.R.S.	294	24
1909, Aug. 25......	Winnipeg	Prof. Sir J. J. Thomson, F.R.S.	117	13
1910, Aug. 31......	Sheffield	Rev. Prof. T. G. Bonney, F.R.S.	293	26
1911, Aug. 30......	Portsmouth	Prof. Sir W. Ramsay, K.C.B., F.R.S.	284	21
1912, Sept. 4	Dundee	Prof. E. A. Schäfer, F.R.S.	288	14
1913, Sept. 10......	Birmingham	Sir Oliver J. Lodge, F.R.S.	376	40
1914, July–Sept.	Australia..............	Prof. W. Bateson, F.R.S.	172	13
1915, Sept. 7	Manchester	Prof. A. Schuster, F.R.S.	242	19
1916, Sept. 5	Newcastle-on-Tyne	Sir Arthur Evans, F.R.S.	164	12
1917	(No Meeting)		—	—
1918	(No Meeting)		—	—
1919, Sept. 9	Bournemouth.........	Hon. Sir C. Parsons, K.C.B., F.R.S. ...	235	47
1920, Aug. 24......	Cardiff	Prof. W. A. Herdman, C.B.E., F.R.S.	288	11
1921, Sept. 7	Edinburgh	Sir T. E. Thorpe, C.B., F.R.S.	336	9
1922, Sept. 6	Hull	Sir C. S. Sherrington, G.B.E., Pres. R.S.	228	13
1923, Sept. 12......	Liverpool	Sir Ernest Rutherford, F.R.S.	326	12
1924, Aug. 6	Toronto	Sir David Bruce, K.C.B., F.R.S.	119	7
1925, Aug. 26......	Southampton	Prof. Horace Lamb, F.R.S.	280	8
1926, Aug. 4	Oxford	H.R.H. The Prince of Wales, K.G., F.R.S.	358	9
1927, Aug. 31......	Leeds	Sir Arthur Keith, F.R.S..................	249	9
1928, Sept. 5	Glasgow	Sir William Bragg, K.B.E., F.R.S. ...	260	10
1929, July 22	South Africa	Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S.	81	1
1930, Sept. 3	Bristol	Prof. F. O. Bower, F.R.S.	221	5
1931, Sept. 23......	London	Gen. the Rt. Hon. J. C. Smuts, P.C., C.H., F.R.S.	487	14
1932, Aug. 31......	York	Sir Alfred Ewing, K.C.B., F.R.S.	206	1

[1] Including 848 Members of the South African Association.
[2] Including 137 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, 10s.
[5] Including Exhibitioners granted tickets without charge.

Annual Meetings—(continued).

Old Annual Members	New Annual Members	Associates	Ladies	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
297	45	801	482	9	1915	£1801 0 0	£1072 10 0	1900
374	131	794	246	20	1912	2046 0 0	920 9 11	1901
314	86	647	305	6	1620	1644 0 0	947 0 0	1902
319	90	688	365	21	1754	1762 0 0	845 13 2	1903
449	113	1338	317	121	2789	2650 0 0	887 18 11	1904
937[1]	411	430	181	16	2130	2422 0 0	928 2 2	1905
356	93	817	352	22	1972	1811 0 0	882 0 9	1906
339	61	659	251	42	1647	1561 0 0	757 12 10	1907
465	112	1166	222	14	2297	2317 0 0	1157 18 8	1908
290[2]	162	789	90	7	1468	1623 0 0	1014 9 9	1909
379	57	563	123	8	1449	1439 0 0	963 17 0	1910
349	61	414	81	31	1241	1176 0 0	922 0 0	1911
368	95	1292	359	88	2504	2349 0 0	845 7 6	1912
480	149	1287	291	20	2643	2756 0 0	978 17 1	1913
139	4160[3]	539[3]	—	21	5044[3]	4873 0 0	1861 16 4[6]	1914
287	116	628[4]	141	8	1441	1406 0 0	1569 2 8	1915
250	76	251[4]	73	—	826	821 0 0	985 18 10	1916
—	—	—	—	—	—	—	677 17 2	1917
—	—	—	—	—	—	—	326 13 3	1918
254	102	688[4]	153	3	1482	1736 0 0	410 0 0	1919

Old Annual Regular Members	Annual Members: Meeting and Report	Annual Members: Meeting only	Transferable Tickets	Students' Tickets	Foreigners	Total	Amount received for Tickets	Sums paid on account of Grants for Scientific Purposes	Year
136	192	571	42	120	20	1380	1272 10 0	1251 13 0[8]	1920
133	410	1394	121	343	22	2768	2599 15 0	518 1 10	1921
90	294	757	89	235[5]	24	1730	1699 5 0	772 0 7	1922
					Complimentary[7]				
123	380	1434	163	550	308	3296	2735 15 0	777 18 6[9]	1923
37	520	1866	41	89	139	2818	3165 19 0[10]	1197 5 9	1924
97	264	878	62	119	74	1782	1630 5 0	1231 0 0	1925
101	453	2338	169	225	69	3722	3542 0 0	917 1 6	1926
84	334	1487	82	264	161	2670	2414 5 0	761 10 0	1927
76	554	1835	64	201	74	3074	3072 10 0	1259 10 0	1928
24	177	1227[11]	—	161	83	1754	1477 15 0	1838 2 1	1929
68	310	1617	97	267	54	2639	2481 15 0	683 5 7	1930
78	656	2994	157	454	449	5702[12]	4792 10 0	1146 7 6	1931
44	226	1163	45	214	125	2024	1724 5 0	1183 13 11	1932

[6] Including grants from the Caird Fund in this and subsequent years.
[7] Including Foreign Guests, Exhibitioners, and others.
[8] The Bournemouth Fund for Research, initiated by Sir C. Parsons, enabled grants on account of scientific purposes to be maintained.
[9] Including grants from the Caird Gift for research in radioactivity in this and subsequent years to 1926.
[10] Subscriptions paid in Canada were $5 for Meeting only and others pro rata; there was some gain on exchange.
[11] Including 450 Members of the South African Association.
[12] Including 413 tickets for certain meetings, issued at 5*s*. to London County Council school-teachers.

NARRATIVE OF THE YORK MEETING.

On Wednesday, August 31, at 8.30 P.M. the Inaugural General Meeting was held in the Exhibition Hall, when the Rt. Hon. the Lord Mayor of York (Alderman R. H. Vernon Wragge) welcomed the Association to York, and the President of the Association, Sir Alfred Ewing, K.C.B., F.R.S., delivered an Address (for which see p. 1), entitled *An Engineer's Outlook.*

On Friday, September 2, in the Co-operative Hall, at 8 P.M., Sir Arthur W. Hill, K.C.M.G., F.R.S., delivered an Evening Discourse on *Plant Products of the Empire in relation to Human Needs* (for an abstract of which see p. 432).

On Monday, September 5, in the Co-operative Hall, at 5.30 P.M., Mr. H. E. Wimperis, C.B.E., delivered a Public Lecture on *Speed in Flight.*

On Tuesday, September 6, in the Co-operative Hall, at 8 P.M., Mr. C. C. Paterson, O.B.E., delivered an Evening Discourse, with demonstrations, on *The Uses of Photoelectric Cells* (for an abstract of which see p. 435).

*   *   *   *   *   *

On Thursday, September 1, at 8.30 P.M., the Lord Mayor and the Sheriff (Mr. Arnold S. Rowntree) held a Reception in the Exhibition Buildings.

On Monday, September 5, the Directors of Messrs. Rowntree & Co., Ltd., received Members at a garden-party and tour of the Cocoa Works.

Numerous other works in the city and neighbourhood were visited.

Among institutions which offered facilities to Members, the Yorkshire Philosophical Society (the mother-society of the Association) gave the free use of the Yorkshire Museum and Museum Gardens to Members during the day-time. In the evenings the grounds and buildings were flood-lighted by gas.

*   *   *   *   *   *

A special service was held in the Minster on Sunday morning, September 4, when Officers and other Members accompanied the Lord Mayor, the Sheriff and the City Council in state from the Guildhall.

The palace at Bishopthorpe was open to Members by kind permission of His Grace the Lord Archbishop of York.

*   *   *   *   *   *

On Saturday, September 3, general excursions took place to Ripon, Fountains Abbey, and Aldborough; Knaresborough, Harrogate, and Nidderdale; Wensleydale; Scarborough and Whitby; Coxwold, Byland Abbey, Helmsley, and Rievaulx Abbey; Castle Howard and Kirkham Abbey; and Members were officially received at many of these points. Among other general excursions, many Members took advantage of the extension of the period of flood-lighting Fountains Abbey by electric light until Sunday, September 4, which was kindly arranged for their benefit. The numerous sectional excursions are mentioned among the Sectional Transactions in later pages.

*   *   *   *   *   *

At the final meeting of the General Committee, on Tuesday, September 6, it was resolved 'That the General Committee do thank the City of York for its hospitable reception of the Association.'

On Wednesday, September 7, the President and General Secretaries waited upon the Lord Mayor of York at the Mansion House, in order to take formal leave of him and other local officers for the Meeting.

REPORT OF THE COUNCIL, 1931–32.

Obituary.

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

Prof. A. Barr
George Barrow
Dr. W. Briggs
Major-Gen. Sir David Bruce (*ex-President*)
Dr. G. Claridge Druce
Dr. H. T. Ferrar
Dr. J. G. Garson (*ex-Assistant-General Secretary*)
Prof. Sir Patrick Geddes
Dr. J. Graham
Prof. J. W. Gregory
Dr. E. H. Griffiths (*ex-General Treasurer*)
Dr. Victoria Hazlitt
Col. Sir Duncan Johnston
Prof. A. W. Kirkaldy (*hon. Auditor*)
Dr. J. af Klercker
Prof. Carveth Read
Sir Harry Reichel
Sir William Somerville
Sir Thomas Stanton
Sir Richard Threlfall
Sir Alfred Yarrow (*benefactor and honorary member*)

The Association was represented at the memorial service for Sir David Bruce by Prof. P. G. H. Boswell, General Secretary ; at that for Sir Alfred Yarrow by Sir Alfred Ewing, President, and Prof. J. L. Myres, General Secretary ; at the funeral of Dr. E. H. Griffiths by Sir Alfred Ewing, and at that of Dr. J. G. Garson by Prof. W. W. Watts.

Prof. F. O. Bower represented the Association at the funeral of the Very Rev. Lionel Ford, Dean of York.

Representation.

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

Wild Plants Preservation Board, Council for the Preservation of Rural England	Prof. E. J. Salisbury
York Medical Society, Centenary . .	Prof. F. O. Bower
National Academy of Sciences, Washington : One hundredth anniversary of electrical discoveries of Joseph Henry	Prof. W. F. G. Swann
Royal Society of Canada : Fiftieth Anniversary	Prof. A. B. Macallum
British Medical Association : Centenary	Sir Charles Sherrington

Presidency.

III.—The revision of Statute VI, 1, made by the General Committee at the Centenary Meeting, under which the period of the presidency of the Association should coincide with the calendar year, duly received the approval of H.M. Privy Council, as provided in Article 10 of the Charter of the Association. Sir Alfred Ewing therefore assumed the presidency as from January 1, 1932.

IV.—At the Centenary Meeting, the General Committee expressed the feeling that it was undesirable that the Council's nomination to the presidency of the Association should be published. The Council therefore resolved that the nomination should not be communicated to the press, and that it should not be announced in the present report, but should be made verbally to the General Committee on the first day of the Annual Meeting. This procedure is a reversion to the practice of the Association in its earlier years.

Resolutions from the Centenary Meeting.

V.—Resolutions dealing with the Council's nomination to the presidency of the Association, and to expenditure in connection with the annual meetings, are reported upon elsewhere in this report.

Resolutions 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 1931, p. lix.

(*a*) A resolution from Section D (Zoology) dealing with the protection of the gorilla in Uganda, was forwarded to the Colonial Office as requested.

(*b*) The Council received assurance that effect would be given to recommendations from Section H (Anthropology) relating to the programme of the International Congress for Prehistoric and Protohistoric Sciences, 1932.

(*c*) The Council adopted a resolution from Section H (Anthropology) relating to the disposal of objects from the Cresswell Caves, Derbyshire.

(*d*) The Council, after careful consideration, decided to take no action upon a resolution from the Conference of Delegates of Corresponding Societies, recommending the use of durable paper for scientific publications.

VI.—A recommendation from Section E (Geography), advocating the publication of population maps in connection with the census of 1931, was forwarded immediately, by direction of the General Committee itself, to the Registrars-General for England and Wales and for Scotland ; but they regretted that they could not advocate the preparation of such maps at the present time.

VII.—The Council adopted a recommendation from the Organising Committee of Section I (Physiology), following upon a resolution by the Sectional Committee at the Centenary Meeting, that it was not advisable to hold an independent meeting of Section I at York this year, in view of the Fourteenth International Physiological Congress which is to take place simultaneously at Rome.

Down House.

VIII.—The following report for the year 1931–32 has been received from the Down House Committee :—

The Committee desire to record their gratification at the conferment of the honour of knighthood upon Sir Buckston Browne.

The number of visitors to Down House during the year ending June 6, 1932, has been 7,638, compared with 5,210 in the previous year. During the week of the Centenary Meeting of the Association, Sept. 23–30, 1931, there were 660 visitors. Three special excursions were arranged for members, a general excursion on Friday, Sept. 25, when the Hon. Curator, Mr. Buckston Browne, was present to receive the party ; a visit for the Delegates of Corresponding Societies on Monday, Sept. 28, and a visit for Section K (Botany) on Tuesday, Sept. 29. On Wednesday, Sept. 30, the President of the Association (General the Rt. Hon. J. C. Smuts) and the Hon. Curator entertained a distinguished company to tea at the house.

The Committee are glad to have in custody at Down House the valuable papers relating to early meetings of the Association, collected by John Phillips and presented by Professor W. J. Sollas, whose gift the Council has already gratefully acknowledged. They form an important addition to the historical records of the Association, for which Down House now provides a repository. The presidential banners of the Association's first century also are now deposited there.

A private fire hydrant has been installed in such position as to protect the house and adjacent buildings.

The exemption of the public rooms and the custodians' apartments from rates was secured upon a second appeal to the assessment committee for Bromley district, after a structural alteration had been carried out with the view of meeting the requirement of a 'complete severance' between the resident's quarters (which are rated) and the rest of the house. This question has involved the Association in considerable legal and other expenses; but the saving in rates amounts, under existing conditions, to nearly £40 per annum.

The following financial statement shows (*a*) receipts on account of Down House, and current expenditure (running costs) for the financial years ending June 30, 1931 and 1932; (*b*) 'capital' or non-recurrent expenditure by the Association since its acquisition of the property in 1929.

Receipts.	1931 £	s.	d.	1932 £	s.	d.
By Dividends on endowment fund	770	14	10	741	4	5
,, Income tax recovered	203	11	1	223	15	2
,, Rents	142	3	4	137	0	0
,, Donations	1	0	11	9	19	1
,, Sale of Postcards and Catalogues	10	10	1	33	16	7
	1,128	0	3	1,145	15	3
,, Balance, being excess of expenditure (running costs) as below, over receipts	115	5	5	150	13	2
	£1,243	5	8	1,296	8	5

Expenditure (running costs).	1931 £	s.	d.	1932 £	s.	d.
To Wages and National Insurance	788	10	0	840	10	11
,, Rates, Land Tax, Insurances	110	8	3	72	4	0
,, Coal, coke, etc.	119	5	6	125	16	2
,, Water	15	3	11	14	10	6
,, Lighting and Drainage Plants (including petrol and oil)	52	6	6	50	12	1
,, Repairs and Renewals	31	15	7	41	1	6
,, Garden materials	42	8	4	47	7	2
,, Household requisites	22	14	2	16	5	6
,, Transport and Carriage	5	15	6	4	4	6
,, Entertainment	6	13	0	—		
,, Auditors	13	5	1	33	10	0
,, Postcards and Catalogues (printing)	4	8	2	44	6	11
,, Postages, Telephone, Stationery, etc.	30	11	8	5	19	2
	£1,243	5	8	1,296	8	5

'Capital' Expenditure, 1929–32.

	£	s.	d.
Compensation to outgoing tenant	800	0	0
Redemption of Tithe	138	7	0
Purchase of Land	275	0	0
Renovation of house, cottages, walls, fencing, etc. . .	841	15	7
Renovation of grounds (gravelling, grass, etc.) . .	186	19	10
House equipment	228	4	1
Garden equipment	141	0	2
Legal charges (rating appeals, valuations, etc.) . .	301	16	6
Transport of library	12	2	0
Opening Ceremony (June 7, 1929)	192	0	6
Cost of Catalogues in stock, June 30, 1932 . . .	119	0	0
	£3,236	5	8

NOTE.—The cost of catalogues will, in course of time, be covered by sales.

The above phrase 'capital expenditure' is used, for want of a better, to cover charges which have fallen upon the Association apart from ordinary running costs. They include numerous items of restoration, renovation, and equipment, legal charges, etc., as the Council are already aware. The figure does not include the second mortgage of £700 granted to the outgoing tenant in 1929, which is classified as an asset, not with the Down House Fund, but among the general funds of the Association.

Those works of restoration, etc., which have been, so to say, visible liabilities since the acquisition of the property, have been materially expedited during the Secretary's leave of absence from office duties during the current year. They, and their cost, would otherwise have been spread over a longer period. So far as the Secretary is able to judge, they are now within sight of completion. Any subsequent items of restoration and renovation ought, on this view, to fall under the heading of ordinary wear and tear.

IMPORTATION OF SCIENTIFIC SPECIMENS AND APPARATUS.

IX.—As the result of a report by the Association of British Zoologists, the Council, in February 1931, appointed a committee to consider action with a view to the amelioration of the Customs Regulations affecting the importation of scientific specimens and apparatus. Following upon discussion between officers of the Association and the Custom House authorities, the latter have most kindly supplied the Association with a memorandum on the reliefs from Customs duties on scientific instruments and cinematograph films, and from the import prohibitions on plumage likely to be of use to scientific workers, together with a note on procedure in respect of the importation of scientific specimens preserved in spirit.

The memorandum on scientific instruments and cinematograph films was supplied confidentially to enable the Association to advise *bona fide* scientific workers, but not for general publication, since some of the relaxations are extra-statutory and liable to modification or withdrawal as the interests of the Revenue may demand.

The note on the importation of scientific specimens in spirit is appended hereto.

'The procedure which will apply in future is as follows :—

'It will be necessary that the person by whom the specimens are imported into this country (or the person or institution to whom they are addressed, in the case of specimens despatched by a consignor abroad) should be formally authorised to receive spirits free of duty for use in an art or manufacture, under the provisions of the Finance Act, 1902, sect. 8. Where, however, the importer or consignee does not already hold such an authority, the Collector of Customs and Excise at the port of importation will grant it, subject to the conditions in the next paragraph.

'If the specimens are imported as ship's cargo, the necessary Customs entry must describe them as specimens preserved in spirits, with a sufficient description of their nature and the approximate quantity of spirits, and must show the name and address of the importer or consignee. With the entry must be produced letters or other documents sufficiently establishing the status of the importer or consignee and the purposes for which the specimens are imported. The Collector of Customs and Excise will be at liberty to request further information, if he considers it necessary. Where specimens are imported in personal baggage, similar information will be asked for.

'If these requirements are satisfactorily complied with, the necessary authority will be granted forthwith and the specimens admitted immediately free of any charge of spirit duty.

'It is not necessary that scientists proceeding on expeditions abroad should take any action before leaving this country. It is, however, advisable, with a view to avoiding delay, that scientists returning with specimens should have the letters or other documents required to establish the facts readily available, and, in the case of specimens which are being received from senders abroad, that the forwarding agent who is entrusted with the work of clearing the goods should be supplied with the necessary information and letters, etc., in good time.'

FINANCE.[1]

X.—The Council have received reports from the General Treasurer throughout the year. His accounts have been audited and are presented to the General Committee.

XI.—As shown in the accounts, the Association has been compelled to draw upon its capital in order to meet a deficit upon the working of the Centenary Meeting. In this connection, however, it should be mentioned that the legacy of £2,000 under the will of the late Sir Charles Parsons has not yet been received. These considerations, together with the difficulties of the present general financial situation, have led the Council to review the whole financial position of the Association, and they have received from the General Treasurer full memoranda upon receipts and expenditure on the basis of the past ten years, and upon future policy. The following are extracts from his statement of policy, in so far as it deals with grants for research, the figures for the Research Fund and Contingency Fund being those adopted by the Council as stated below :

[1] The General Committee adopted this portion of the report with the proviso that the recommendation as to quasi-permanent endowment or maintenance should not be held to preclude grants to institutions at which successive researches are to be carried on under research committees of the Association.

The weakness of the Association's finance lies in the basis of its grants to research, taken together with the fluctuating financial character of its meetings. The allocations to research should not be granted on a year-to-year consideration of available balances, because those balances do not themselves result from a period of adequate length to reflect real availability. Allocations on the principle of real availability should be based upon a reasonable cycle of the Association's normal activities and expenses of meetings.

In my judgment, therefore, policy should be shaped upon a provisional five-year budget as the minimum period. This leads me to the suggestion that for the period of the next five years we should create two definite charges on the expenditure side, viz., £400 to the Research Fund (in addition, that is, to the Caird Fund) and £500 to Contingency Fund. . . . Expenditure on research [from general funds] should be definitely controlled by the General Committee on a recommendation from the Council in its Annual Report, and might be more or less than that amount in any particular year. Council might conveniently add to its recommendation a statement of the sum which it is prepared to allocate from the Caird Fund. . . . It should be a matter for the Council to lay down whether the true function of the Association is not rather the starting, launching or promotion of particular pieces of research, than the quasi-permanent endowment or maintenance of them. In some respects its past policy has fallen between two stools; it has not given those advantages which a really assured permanence of funds may confer but it has allowed a perpetuating system of old claims to take the bloom off its opportunity for substantial aid to pioneer work.

The Contingency Fund would be definitely regarded as an insurance against small, or very unprofitable meetings. . . . The adoption of a policy of budgeting ahead for a period of years, and not allowing each year's balances to be fortuitously linked up with the research work, is the essential feature of reform.

The Council have adopted, and recommend to the General Committee, the above proposal that for the next 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 Council are of opinion 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 Council recall that this view is implicit in the resolution of the General Committee, under which grants from general funds in aid of research were first established. They desire, however, to elicit the views of Sectional Committees on this point, and suggest that these should be reported by the sectional representatives to the Committee of Recommendations at the York Meeting.

The Council are impressed with the fact that at each annual meeting certain grants are applied for and made on the chance that they may be wanted during the ensuing year. The Council feel that money adjudged at the Annual Meeting to be available from general funds for grants should be made only for purposes for which it is known that money will be needed during the ensuing year. The Council, therefore, propose a new class of contingent recommendations to be addressed to themselves as administering the Caird Fund. This practice should be followed in the case of any application made at the Annual Meeting for a grant which may, but will not certainly, be required during the ensuing year. The Council, being in session throughout the year, consider that they can deal with such applications with more precision than is possible at the Annual Meeting.

In order that the Committee of Recommendations, in considering applications, may be in full possession of the necessary facts, especially in respect of the procedure outlined above, the General Officers have drafted and will issue more detailed forms of application to the Committee, and the Council request the co-operation of the Sectional Officers in completing these.

It follows from the above expression of the Council's opinion and intentions, that they do not consider that recurrent grants should have any prior claim on the Caird Fund over other grants.

XII.—The stock held on account of the Bramwell Trust, for an honorarium to be paid to an appointed speaker at the Centenary Meeting on the prime movers of 1931, has been transferred to Sir Alfred Ewing, whose presidential address to Section G (Engineering) was also the lecture under the trust. This trust has now, therefore, been discharged.

XIII.—At the Centenary Meeting, the General Committee requested the General Officers to report to the Council upon the respective expenditure of the Association and of local committees in connection with the annual meetings, with the object of reducing the total cost of the meetings, and of redistributing liabilities hitherto undertaken by the local committees. The Council received and adopted the General Secretaries' Report, in which it was recommended to effect economies by dispensing with the presidential banner and elaborate enamelled badges of membership, by incorporating the local programme with the Association's own time-table, and by reducing the bulk of the local handbook, at the same time standardising its format and making the material suitable for inclusion in the Annual Report.

Publication.

XIV.—As a natural corollary to questions of publication arising upon the financial matters dealt with in the preceding section of this report, the Council have investigated the whole field of the Association's publications, and have received the report of a Committee thereon. As a result, it is hoped to effect improvements in printing, a more adequate distribution of the Annual Report and other publications, and some economy in cost.

General Officers and Staff, Council and Committees.

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

General Treasurer, Sir Josiah Stamp.
General Secretaries, Prof. P. G. H. Boswell, Prof. F. J. M. Stratton.

The Council received last year from Prof. J. L. Myres an intimation that if then re-appointed as General Secretary, he would not offer himself this year for re-nomination. The Council have now placed upon record their deep sense of gratitude to Prof. Myres for his services to the Association as General Secretary during the years 1919–1932.

XVI.—*Assistant Secretaryship.*—The Council have established the post of Assistant Secretary, held by Mr. H. Wooldridge on probation since 1930, and have confirmed Mr. Wooldridge in the appointment.

XVII.—*Council.*—The retiring Ordinary Members of the Council are Sir Richard Gregory, Prof. T. E. Gregory, Mr. C. G. T. Morison, Prof. A. O. Rankine, and Dr. A. C. Haddon and Dr. H. S. Hele-Shaw by resignation.

The Council have nominated as new members Sir Henry Dale, Prof. R. B. Forrester, Dr. H. S. Harrison, and Sir John Russell, leaving two vacancies to be filled by the General Committee without nomination by the Council.

The full list of nominations of Ordinary Members is as follows :—

Dr. F. A. Bather
Sir Henry Dale
Prof. J. Drever
Prof. R. B. Forrester
Sir Henry Fowler
Prof. W. T. Gordon
Prof. Dame Helen Gwynne-Vaughan
Sir Daniel Hall
Dr. H. S. Harrison
Sir James Henderson
A. R. Hinks
Dr. C. W. Kimmins
Col. Sir H. G. Lyons
Sir P. Chalmers Mitchell
Prof. E. B. Poulton
Dr. C. Tate Regan
Sir John Russell
Prof. A. C. Seward
Dr. N. V. Sidgwick
Dr. G. C. Simpson
Prof. J. F. Thorpe
H. T. Tizard
Prof. A. M. Tyndall

XVIII.—*General Committee.*—The following have been admitted as members of the General Committee : Dr. S. G. Barker, Dr. P. H. Buxton, Dr. G. S. Carter, Dr. R. Gurney, Mr. E. Horton, Mr. T. H. Reade, Dr. W. K. Spencer, Dr. J. Stephenson.

XIX.—*Corresponding Societies Committee.*—The Corresponding Societies Committee has been nominated as follows : The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Treasurer, the General Secretaries, Mr. C. O. Bartrum, Dr. F. A. Bather, Sir Richard Gregory, Mr. J. V. Pearman, Sir David Prain, Sir John Russell, Prof. W. M. Tattersall.

RATES OF SUBSCRIPTION.

XX.—The Council have adopted the following report of a Committee on rates of membership subscription, the price of the *Annual Report*, etc., and recommend the proposals and consequent changes in the Statutes to the General Committee.

The Committee appointed by the Council to consider the scale of subscriptions to the Association, and to recommend amendments thereto if any appear desirable, report as follows.

The Committee recommend no change from the present subscriptions of £1 10*s*. for attendance at the Meeting and receipt of the *Report*, of £1 5*s*. for transferable tickets (Meeting only), and of 10*s*. for student membership (Meeting only).

They recommend that the present life composition of £15 be reduced to £10 10*s*. This recommendation is based upon the fact that, before 1919, when the life composition was £10, 23 new life members were enrolled annually on an average over 10 years; after 1919, when the life composition was raised to £15, this average number fell to 8·3.

A majority of the Committee recommend that the subscription of £1, entitling to attendance at the Meeting only, be raised to £1 1*s*. This recommendation is made with a view to balancing any reduction of receipts which might result from giving effect to other recommendations of the Committee. The class of members paying the £1 subscription is the largest; on average figures the proposed increase would yield an addition of £70–80 annually, and it is believed that it would not cause any diminution in the number of members.

The Committee consider that the *Annual Report* is too highly priced, and recommend that the prices should be as follows:

Published price, 15*s*. instead of £1 5*s*.

Library subscription, 10*s*., if paid regularly, instead of 12*s*. 6*d*. now charged to approved libraries.

They further recommend that back numbers of the *Report* should be offered at 10*s*., and back numbers of the *Advancement of Science* at 3*s*. 6*d*., and that this offer should be made known among members and others whose names are on the books of the Association.

Finally, they recommend that it should be similarly made known that on regular payment of 10*s*. on a banker's order, the *Report* will be supplied (as well as papers relating to forthcoming meetings).

The Committee make these recommendations concerning the *Report* with a view to ensuring its wider distribution, and giving effect to previous recommendations of the Publications Committee. Further, they think that the principle of the banker's order, put forward in the final recommendation, should assist in mitigating 'the insecurity inherent in the Association's finances,' which, as shown in a memorandum laid before them, is 'connected primarily' with the fluctuating number of subscriptions for annual membership.

Dates of Financial Year.

XXI.—The Council have received from the Hon. Auditors a reasoned proposal that the financial year of the Association should run from April 1 to March 31, instead of from July 1 to June 30, and they recommend this change to the General Committee, together with a consequent change in the Statutes.

GENERAL TREASURER'S ACCOUNT

1931–32

THE expenses of the Centenary Meeting (1931), so far as they can be distinguished, are set out separately in the following accounts, but ordinary items of expenditure, such as stationery, postages, and printing, were also necessarily increased beyond the normal. It should be remembered that there was no 'local fund,' as usually there is to meet costs of meeting-rooms, entertainment, etc., and the Centenary Fund initiated by the Association itself, primarily in order to cover the costs of the Meeting, did not do so. It was stated in last year's Report that the general financial situation did not admit of pressing the appeal for the Centenary Fund as strongly as it might have been pressed in favourable circumstances. It has therefore been necessary to draw upon the Yarrow Fund, as stated in the accounts. The Association's finances are further dealt with in the Report of the Council to the General Committee, paragraphs X–XIII.

J. C. STAMP,
General Treasurer.

Balance Sheet,

Corresponding Figures June 30, 1931. £ s. d.	LIABILITIES.		£ s. d.	£ s. d.
	To *General Fund*—			
10,942 19 1	As at July 1, 1931 As per contra . . . . (Subject to depreciation in value of Investments)			10,942 19 1
	,, *Caird Fund*—			
9,582 16 3	As at July 1, 1931 As per contra . . . . (Subject to depreciation in value of Investments)			9,582 16 3
	,, *Caird Fund Revenue Account*—			
	Balance at July 1, 1931		399 1 1	
	Less Excess of Expenditure over Income for the year as per contra		207 1 1	
399 1 1				192 0 0
	,, *Sir F. Bramwell's Gift*—			
	For inquiry into Prime Movers, 1931		86 6 2	
	Less Transferred to Sir J. Alfred Ewing under terms of the Gift		86 6 2	
84 4 7				—
	,, *Sir Charles Parsons' Gift*—			
10,000 0 0	As per contra			10,000 0 0
	,, *Sir Alfred Yarrow's Gift*—			
	As per last Account		8,707 0 0	
	Less Transferred to Income and Expenditure Account under terms of the Gift	£365 0 0		
	Less Transferred towards expenses of Centenary Meeting	2,043 5 4		
			2,408 5 4	
8,707 0 0				6,298 14 8
	,, *Life Compositions*—			
	As per last Account		1,952 2 2	
	Add received during year		135 0 0	
1,952 2 2				2,087 2 2
	,, *Toronto University Presentation Fund*—			
	As per last Account		182 18 10	
	Add Dividends		8 15 0	
			191 13 10	
	Less Awards given		8 15 0	
182 18 10				182 18 10
	,, *Lt.-Col. A. J. C. Cunningham's Bequest*—			
	For the preparation of New Tables in the Theory of Numbers.			
	As per last Account		2,904 14 9	
	Add—			
	Income Tax recovered		29 5 1	
	Dividends		103 19 2	
			3,037 19 0	
	Less Grants made		30 0 0	
2,904 14 9				3,007 19 0
44,755 16 9	Carried forward .			£42,294 10 0

June 30, 1932.

ASSETS.

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
	By *General Fund*—		
	£4,651 10s. 5d. Consolidated 2½ per cent. Stock at cost	3,942 3 3	
	£3,600 India 3 per cent. Stock at cost	3,522 2 6	
	£879 14s. 9d. Great Indian Peninsula Railway 'B' Annuity at cost	827 15 0	
	£52 12s. 7d. War Stock (Post Office Issue) at cost	54 5 2	
	£834 16s. 6d. 4½ per cent. Conversion Stock at cost	835 12 4	
	£1,400 War Stock 5 per cent. 1929/47 at cost	1,393 16 11	
	£94 7s. 4½ per cent. Conversion Stock 1940/44 at cost	62 15 0	
	£326 9s. 10d. 3½ per cent. Conversion Stock 1940/44 at cost	250 0 0	
	Cash at Bank	54 8 11	
10,942 19 1			10,942 19 1
	(*£8,274 18s. 10d.* Value of Stocks at date, £9,175 1s. 8d.)		
	,, *Caird Fund*—		
	£2,627 0s. 10d. India 3½ per cent. Stock at cost	2,400 13 3	
	£2,100 London, Midland & Scottish Railway Consolidated 4 per cent. Preference Stock at cost	2,190 4 3	
	£2,500 Canada 3½ per cent. Registered Stock 1930/50 at cost	2,397 1 6	
	£2,000 Southern Railway Consolidated 5 per cent. Preference Stock at cost	2,594 17 3	
9,582 16 3			9,582 16 3
	(*£6,404 11s. 10d.* Value at date, £5,565 18s. 4d.)		
	,, *Caird Fund Revenue Account*—		
399 1 1	Cash at Bank		192 0 0
	,, *Sir F. Bramwell's Gift*—		
	£165 12s. 10d. Self Accumulating Consolidated Stock as per last Balance Sheet	84 4 7	
	3 11 5 *Add* Accumulations to October 5, 1931	2 1 7	
	£169 4 3	86 6 2	
	Less Transferred to Sir J. Alfred Ewing as per contra	86 6 2	
84 4 7			—
	,, *Sir Charles Parsons' Gift*—		
10,000 0 0	£10,300 4½ per cent. Conversion Stock at cost		10,000 0 0
	(*£10,609.* Value at date, £10,918)		
	,, *Sir Alfred Yarrow's Gift*—		
	£8,707 5 per cent. War Loan as per last Account	8,707 0 0	
	Less Sale of £2,408 5s. 4d. Stock under terms of the Gift	2,408 5 4	
8,707 0 0	(Value at date, £6,408 19s. 4d.)		6,298 14 8
	,, *Life Compositions*—		
	£2,949 12s. 4d. Local Loans at cost	1,923 12 2	
	(*£2,064 14s. 8d.* Value at date, £2,300 14s.)		
	Cash at Bank	163 10 0	
1,952 2 2			2,087 2 2
	,, *Toronto University Presentation Fund*—		
	£175 War Stock at cost	178 11 4	
	(*£180 5s.* Value at date, £178 1s. 3d.)		
	Cash at Bank	4 7 6	
182 18 10			182 18 10
	,, *Lt.-Col. A. J. C. Cunningham's Bequest*—		
	£1,187 6s. 10d. 2½ per cent. Consolidated Stock	653 0 9	
	£300 Port of London 3½ per cent. Stock 1949/99	216 0 0	
	£100 Commonwealth of Australia 4¾ per cent. Stock	93 0 0	
	£100 New Zealand 5 per cent. Stock	103 0 0	
	£800 India 6 per cent. Stock at cost	801 12 0	
	£1,274 4s. 10d. Local Loans 3 per cent. Stock at cost	836 6 5	
	(*£2,816 17s. 6d.* Value at date, £3,050 18s. 6d.)	2,702 19 2	
	Cash at Bank	304 19 10	
2,904 14 9			3,007 19 0
44,755 16 9	Carried forward		£42,294 10 0

Balance Sheet,

Corresponding Figures June 30, 1931. £ s. d.	LIABILITIES—*continued*.		£ s. d.	£ s. d.
44,755 16 9	Brought forward			42,294 10 0
	To *Down House Endowment Fund*—			
20,000 0 0	As per contra			20,000 0 0
	,, REVENUE ACCOUNT—			
	Sundry Creditors		177 13 7	
	Do. Do. (Down House)		31 9 5	
	Bank Overdraft—			
	Down House Charges on General Fund .	£3,734 2 10		
	Less General Account	3,569 5 9		
			164 17 1	
	,, *Income and Expenditure Account*—			
	Balance at July 1, 1931	9,286 17 10		
	Less Down House Income and Expenditure Account Balance at July 1, 1931	1,882 0 6		
		7,404 17 4		
	Less Excess of Expenditure over Income for the year	387 12 11		
			7,017 4 5	
10,133 17 1				7,391 4 6
74,889 13 1[illegible]				£69,685 14 6

I have examined the foregoing Account with the Books and Vouchers and certify the Investments, and have inspected the Deeds of Down House and the Mortgage on

Approved.

ARTHUR L. BOWLEY }
W. W. WATTS } *Auditors.*

August 1932.

June 30, 1932—*continued.*

ASSETS—*continued.*

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
44,755 16 9	Brought forward		42,294 10 0
	By *Sir Buckston Browne's Gift* in memory of Darwin—Down House, Kent		Not valued.
	Do. Endowment Fund—		
	£5,500 India 4½ per cent. Stock 1958/68 at cost	5,001 17 4	
	£2,500 Australia 5 per cent. Stock 1945/75 at cost	2,468 19 0	
	£3,000 Fishguard & Rosslare Railway 3½ per cent. Guaranteed Preference Stock at cost	2,139 17 3	
	£2,500 New South Wales 5 per cent. Stock 1945/65 at cost	2,467 7 9	
	£2,500 Western Australia 5 per cent. Stock 1945/75 at cost	2,472 1 6	
	£2,500 Birkenhead Railway 4 per cent. Consolidated Stock at cost	2,013 9 9	
	£3,340 Great Western Railway 5 per cent. Stock at cost	3,436 7 5	
20,000 0 0			20,000 0 0
	(*£17,303 10s. od.* Value at date, £19,197 14*s.* o*d.*)		
	,, REVENUE ACCOUNT—		
	Investments:—		
	£2,098 1*s.* 9*d.* Consolidated 2½ per cent. Stock at cost	1,200 0 0	
	£4,338 6*s.* 2*d.* Conversion 3½ per cent. Stock at cost	3,300 0 0	
	£400 5 per cent. War Loan Inscribed Stock at cost	404 16 0	
	(*£5,358 8s. 4d.* Value at date, £5,879 17*s.* 5*d.*)	4,904 16 0	
	Second Mortgage on Isleworth House, Orpington	700 0 0	
	,, Down House Suspense Account—		
	As per last Account	938 7 0	
	Purchase of Land adjoining Down House	275 0 0	
	Stock of Catalogues at Down House	119 0 0	
	Sundry Debtors and Payments in advance	392 11 5	
	Do. (Down House)	33 17 3	
	Cash in Hand	27 12 10	
10,133 17 1			7,391 4 6
74,889 13 10			£69,685 14 6

the same to be correct. I have also verified the Balances at the Bankers and Isleworth House.

W. B. Keen,
Chartered Accountant.

Income and

FOR THE YEAR ENDED

Corresponding Figures June 30, 1931. £ s. d.	EXPENDITURE.	£ s. d.	£ s. d.
24 19 1	To Heat, Lighting and Power	20 7 5	
157 0 9	,, Stationery	211 0 8	
1 0 0	,, Rent	1 0 0	
263 11 8	,, Postages	322 17 2	
216 5 8	,, Travelling Expenses	193 1 6	
37 14 11	,, Exhibitioners	117 6 7	
278 6 1	,, General Expenses	284 11 5	
978 18 2		1,150 4 9	
1,794 7 0	,, Salaries and Wages	1,908 16 6	
75 0 0	,, Pension Contribution	75 0 0	
1,638 2 11	,, Printing, Binding, Contributors and Editorial Fees	2,650 18 3	5,784 19 6
4,486 8 1			
122 1 5	,, Zimbabwe Loan Exhibition	—	
	,, Grants to Research Committees:—		
	Palæozoic Rocks Committee	20 0 0	
	Llanmelin Committee	25 0 0	
	Transplant Experiments Committee	10 0 0	
	Kharga Oasis Committee	20 0 0	
	Sex Physiology of Parents Committee	10 0 0	
	Western Desert of Egypt Committee	100 0 0	
	Seismology Committee	150 0 0	
	Parachors of Chemical Compounds Committee	1 15 0	
	Mycorrhiza in relation to Forestry Committee	25 0 0	
	Teaching of Biology Committee	5 0 0	
	Macedonia Committee	25 0 0	
	Plymouth Laboratory Committee	50 0 0	
	Mechanical Ability Committee	32 0 0	
	Derbyshire Caves Committee	50 0 0	
	Freshwater Biological Station Committee	75 0 0	
	Human Geography of Tropical Africa Committee	20 10 9	
731 7 6	Vocational Tests Committee	8 0 0	627 5 9
5,339 17 0	Carried forward		£6,412 5 3

Expenditure Account

JUNE 30, 1932.

INCOME.

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
158 0 0	By Annual Regular Members, including £37 for 1932/3		122 0 0
1,898 5 0	,, Annual Temporary Members, including £394 for 1932/3		2,781 9 3
634 10 0	,, Annual Members with Report, including £154 10s. for 1932/3		809 9 11
138 15 0	,, Transferable Tickets, including £13 15s. for 1932/3		173 0 0
150 10 0	,, Students' Tickets, including £13 10s. for 1932/3		216 0 0
	,, Teachers' Tickets (L.C.C.)		103 5 0
15 0 0	,, Life Compositions, Amount transferred		—
1 0 0	,, Donation		—
9 18 0	,, Interest on Deposit		5 16 8
578 15 10	,, Sale of Publications		614 18 3
275 7 5	,, Advertisement Revenue		424 18 7
227 17 2	,, Income Tax recovered		256 9 11
31 13 1	,, Unexpended Balance of Grants returned		5 0 0
22 10 0	,, Liverpool Exhibitioners		22 10 0
	,, Dividends :—		
	Consols	126 11 2	
	India 3 per cent.	81 0 0	
	Great Indian Peninsula Railway 'B' Annuity	26 7 2	
	4½ per cent. Conversion Loan	32 8 5	
	Ditto Sir Charles Parsons' Gift	347 12 6	
	Local Loans	65 9 11	
	War Stock	74 5 0	
	War Stock (Series A), Sir Alfred Yarrow's Gift	391 8 6	
	3½ per cent. Conversion Loan	122 9 1	
1,340 8 5			1,267 11 9
	,, Sir Alfred Yarrow's Gift—		
	Proceeds of sale of £365 War Loan in accordance with the terms of the Gift	365 0 0	
	Less Loss on Sale	6 13 0	
361 6 1			358 7 0
27 2 6	,, Interest on Mortgage		26 5 0
5,870 18 6	Carried forward		£7,187 1 4

Income and

FOR THE YEAR ENDED

EXPENDITURE—*continued.*

Corresponding Figures June 30, 1931. £ s. d.			£ s. d.	£ s. d.
5,339 17 0	Brought forward			6,412 5 3
	To *Special Expenses of the Centenary Meeting as far as can be distinguished*—			
	,, Grants to Overseas Delegates—			
	As per last Balance Sheet	£1,500 0 0		
	Paid during year	1,540 0 0		
			3,040 0 0	
	,, Hospitality and Entertainment		271 3 4	
	,, Ditto (Secretariat)		236 14 11	
	,, Printing, Binding, Contributors' and Editorial Fees		1,319 5 10	
	,, Meeting Rooms, including Equipment, Attendants and Gratuities—			
	As per last Balance Sheet	£31 10 0		
	Paid during year	948 5 7		
			979 15 7	
	,, Travelling Allowance		100 0 0	
	,, Excursions		133 1 4	
	,, Presidential Banner		44 3 6	
	,, Badges		57 5 10	
	,, Salaries and Wages—			
	As per last Balance Sheet	£96 10 0		
	Paid during year	503 13 11		
			600 3 11	
	,, Advertisements—			
	As per last Balance Sheet	£13 7 0		
	Paid during year	41 0 0		
			54 7 0	
				6,836 1 3
531 1 6	,, Balance, being excess of Income over Expenditure for the year			—
5,870 18 6				£13,248 6 6
	To Balance brought down			1,895 12 5
	,, Down House Income and Expenditure Account—			
	Balance, being excess of Expenditure over Income for the year transferred—			
	Current Expenditure		150 13 2	
	Equipment, etc.		366 14 4	
				517 7 6
				£2,412 19 11

Caird Fund,

EXPENDITURE.

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
	To Grants paid—		
	Seismology Committee	100 0 0	
	Bronze Age Implements Committee	25 0 0	
	Mathematical Table Committee	336 8 2	
	Zoological Record Committee	50 0 0	
	Naples Table Committee	50 0 0	
415 0 0			561 8 2
34 8 7	,, Balance, being excess of Income over Expenditure for the year		—
449 8 7			£561 8 2

Expenditure Account

JUNE 30, 1932—*continued.*

INCOME—*continued.*

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
5,870 18 6	Brought forward		7,187 1 4
	By Sundry Donations, Centenary Fund—		
	As per last Balance Sheet	2,208 5 6	
	Received during year	1,907 7 3	
			4,115 12 9
	,, Subsidy from the London County Council towards cost of printing *Education in London*		50 0 0
	,, Balance, being excess of Expenditure over Income for the year carried down		1,895 12 5
5,870 18 6			£13,248 6 6
	By transfer of £2,043 5*s.* 4*d.* 5 per cent. War Loan towards expenses of Centenary Meeting from Sir A. Yarrow's Gift	2,043 5 4	
	Less Loss on Sale	17 18 4	
			2,025 7 0
	,, Balance transferred to Balance Sheet		387 12 11
			£2,412 19 11

June 30, 1932.

INCOME.

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
	By Dividends—		
	India 3½ per cent. Stock	68 19 1	
	Canada 3½ per cent. Stock	65 12 6	
	London, Midland & Scottish Railway Consolidated 4 per cent. Preference Stock	63 0 0	
	Southern Railway Consolidated 5 per cent. Preference Stock	75 0 0	
281 13 2			272 11 7
72 13 8	,, Income Tax recovered		81 15 6
95 1 9	,, Unexpended Balance of Grants returned		—
	,, Balance, being excess of Expenditure over Income for the year		207 1 1
449 8 7			£561 8 2

Down House,

EXPENDITURE.

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
788 10 0	To Wages of Staff (net)	840 10 11	
110 8 3	,, Rates, Insurance, etc.	72 4 0	
182 12 5	,, Heat, Light and Drainage	188 6 3	
31 15 7	,, Repairs and Renewals	41 1 6	
36 16 5	,, House and Garden Sundries	41 15 1	
69 14 11	,, General Expenses	68 3 9	
21 4 7	,, Printing	—	
2 3 6	,, Catalogues, Postcards, etc.	44 6 11	
			1,296 8 5
1,243 5 8			£1,296 8 5
115 5 5	To Balance brought down	150 13 2	
167 9 4	,, House and Garden Equipment, Repairs, Renewals and Alterations to Buildings, etc.	287 4 4	
7 19 0	,, Costs *re* Rates Appeal, etc.	56 18 0	
25 2 9	,, Cost of Inventory and Valuation	—	
	,, Valuation and Transport of Darwin's Library	22 12 0	
			517 7 6
315 16 6			£517 7 6

June 30, 1932.

INCOME.

Corresponding Figures June 30, 1931. £ s. d.		£ s. d.	£ s. d.
142 3 4	By Rents Receivable		137 0 0
203 11 1	,, Income Tax recovered		223 15 2
	,, Dividends—		
	4½ per cent. India Stock	182 10 8	
	Fishguard & Rosslare Railway 3½ per cent. Stock	78 15 0	
	New South Wales 5 per cent. Stock	92 3 9	
	Great Western Railway 5 per cent. Stock	125 5 0	
	Australia 5 per cent. Stock 1945/75	93 15 0	
	Western Australia 5 per cent. Stock	93 15 0	
	Birkenhead Railway 4 per cent. Stock	75 0 0	
770 14 10			741 4 5
1 0 11	,, Donations		9 19 1
10 10 1	,, Sale of Postcards, etc.		33 16 7
115 5 5	,, Balance carried down		150 13 2
1,243 5 8			£1,296 8 5
315 16 6	By Balance, being excess of Expenditure over Income for the year		517 7 6
315 16 6			£517 7 6

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN YORK, 1932.

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 (*Secretary*), Prof. P. G. H. Boswell, Dr. C. Vernon Boys, Sir F. W. Dyson, Dr. Wilfred Hall, Dr. H. Jeffreys, Sir H. Lamb, Mr. A. W. Lee, Prof. H. M. Macdonald, Prof. E. A. Milne, Mr. R. D. Oldham, Prof. H. H. Plaskett, Prof. H. C. Plummer, Prof. A. O. Rankine, Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, Mr. F. J. Scrase, Capt. H. Shaw, Sir F. E. Smith, Dr. R. Stoneley, Mr. E. Tillotson, Sir G. T. Walker. **£100** (Caird Fund grant).

Calculation of Mathematical Tables.—Prof. E. H. Neville (*Chairman*), Dr. L. J. Comrie (*Secretary*), Prof. A. Lodge (*Vice-Chairman*), Dr. J. R. Airey, Dr. R. A. Fisher, Dr. J. Henderson, Dr. J. O. Irwin, Dr. E. S. Pearson, Mr. F. Robbins, Mr. D. H. Sadler, Dr. A. J. Thompson, Dr. J. F. Tocher, Dr. J. Wishart. **£50.**

SECTIONS A, E, G.—MATHEMATICAL AND PHYSICAL SCIENCES, GEOGRAPHY, ENGINEERING.

To inquire into the position of Inland Water Survey in the British Isles and the possible organisation and control of such a survey by central authority.—Dr. Ezer Griffiths (*Convener*), Mr. E. G. Bilham, Dr. Brysson Cunningham, Vice-Admiral H. P. Douglas, Prof. C. B. Fawcett, Dr. A. Ferguson, Lt.-Col. E. Gold, Mr. W. T. Halcrow, Capt. W. N. McClean, Mr. C. Clemesha Smith, Dr. Dudley Stamp, Brig. H. S. L. Winterbotham.

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

The possibility of quantitative estimates of Sensory Events.—Dr. A. Ferguson (*Convener*), Mr. R. J. Bartlett (*Secretary*), Mr. J. Guild, Dr. R. A. Houstoun, Dr. J. O. Irwin, Dr. G. W. C. Kaye, Dr. C. S. Myers, Dr. L. F. Richardson, Dr. J. H. Shaxby, Mr. T. Smith, Major W. S. Tucker (*from Section A*); Prof. F. C. Bartlett, Dr. W. Brown, Dr. S. Dawson, Prof. J. Drever, Dr. S. J. F. Philpott (*from Section J*).

SECTION C.—GEOLOGY.

To excavate Critical Sections in the Palæozoic Rocks of England and Wales.—Prof. W. W. Watts (*Chairman*), Prof. W. G. Fearnsides (*Secretary*), Mr. W. S. Bisat, Dr. H. Bolton, Prof. W. S. Boulton, Dr. E. S. Cobbold, Prof. A. H. Cox, Mr. E. E. L. Dixon, Dr. Gertrude Elles, Prof. E. J. Garwood, Prof. H. L. Hawkins, Prof. G. Hickling, Prof. V. C. Illing, Prof. O. T. Jones, Prof. J. E. Marr, Dr. F. J. North, Dr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, Prof. A. E. Trueman, Dr. F. S. Wallis. **£20** (Contingent grant).

The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.—Prof. E. J. Garwood (*Chairman*), Prof. S. H. Reynolds

(*Secretary*), Mr. C. V. Crook, Mr. E. G. W. Elliott, Mr. J. F. Jackson, Mr. J. Ranson, Prof. W. W. Watts, Mr. R. J. Welch.

To investigate Critical Sections in the Tertiary and Cretaceous Rocks of the London Area. To tabulate and preserve records of new excavations in that area.—Prof. W. T. Gordon (*Chairman*), Dr S. W. Wooldridge (*Secretary*), Mr. H. C. Berdinner, Prof. P. G. H. Boswell, Miss M. C. Crosfield, Mr. F. Gosling, Prof. H. L. Hawkins, Prof. G. Hickling. **£15.**

The Stratigraphy and Structure of the Palæozoic Sedimentary Rocks of West Cornwall.—Mr. H. Dewey (*Chairman*), Mr. E. H. Davison (*Secretary*), Mr. H. G. Dines, Miss E. M. Lind Hendriks, Mr. S. Hall, Dr. S. W. Wooldridge.

To consider and report upon Petrographic Classification and Nomenclature.—Mr. W. Campbell Smith (*Chairman*), Dr. A. K. Wells (*Secretary*), Prof. E. B. Bailey, Prof. P. G. H. Boswell, Prof. A. Brammall, Prof. A. Holmes, Prof. A. Johannsen, Dr. W. Q. Kennedy, Prof. P. Niggli, Prof. H. H. Read, Prof. S. J. Shand, Dr. H. H. Thomas, Prof. C. E. Tilley, Dr. G. W. Tyrrell.

SECTION D.—ZOOLOGY.

Zoological Bibliography and Publication.—Prof. E. B. Poulton (*Chairman*), Dr. F. A. Bather (*Secretary*), Mr. E. Heron-Allen, Dr. W. T. Calman, Sir P. Chalmers Mitchell, Mr. W. L. Sclater.

To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth (*Chairman and Secretary*), Prof. H. Graham Cannon, Prof. H. Munro Fox, Prof. J. Stanley Gardiner. **£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 (*Chairman*), Dr. W. T. Calman (*Secretary*), Prof. E. S. Goodrich, Prof. D. M. S. Watson. **£50.**

On the Influence of the Sex Physiology of the Parents on the Sex-Ratio of the Offspring.—Prof. J. H. Orton (*Chairman*), Mrs. Bisbee (*Secretary*), Prof. Carr-Saunders, Miss E. C. Herdman. **£5.**

To consider the position of Animal Biology in the School Curriculum and matters relating thereto.—Prof. R. D. Laurie (*Chairman and Secretary*), Mr. H. W. Ballance, Mr. O. H. Latter, Prof. E. W. MacBride, Miss M. McNicol, Miss A. J. Prothero, Prof. W. M. Tattersall, Dr. E. N. Miles Thomas.

To determine the behaviour of a limited and uniform plankton population observed under natural conditions.—Dr. G. P. Bidder (*Chairman*), Mr. A. C. Gardiner (*Secretary*), Dr. J. Gray, Mr. J. T. Saunders. **£10.**

The biology of a tropical river in British Guiana and of the neighbouring districts.—Prof. J. S. Gardiner (*Chairman*), Dr. G. S. Carter and Mr. J. T. Saunders (*Secretaries*), Dr. W. T. Calman, Prof. J. Graham Kerr, Dr. C. Tate Regan. **£20.**

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. J. H. Ashworth (*Chairman and Secretary*), Prof. J. Barcroft, Prof. E. W. MacBride, Dr. M. Knight. **£50.**

SECTIONS D, K.—ZOOLOGY, BOTANY.

To try to arrange for the observation and recording of changes in the Flora and Fauna of St. Ki da since its evacuation.—Prof. J. Ritchie (*Chairman*), Prof. F. A. E. Crew (*Secretary*), Dr. A. Bowman, Prof. J. Graham Kerr, Dr. C. H. O'Donoghue, Dr. Lloyd Praeger, Prof. J. Walton.

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 (*Chairman*), Mr. J. T. Saunders (*Secretary*), Miss P. M. Jenkin, Dr. C. H. O'Donoghue (*from Section D*); Dr. W. H. Pearsall (*from Section K*). **£75.**

SECTION E.—GEOGRAPHY.

To co-operate with the Ordnance Survey in the production of a Population Density Map (or Maps) of Great Britain and to endeavour to get this published as soon as the 1931 Census is available; and, further, to examine the possibility of making similar Maps of the Empire, utilising the International Map (1 : 1,000,000) as the base.—Brig. H. S. L. Winterbotham (*Chairman*), Capt. J. G. Withycombe (*Secretary*), Mr. J. Bartholomew, Prof. F. Debenham, Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. H. King, Mr. R. H. Kinvig, Prof. A. G. Ogilvie, Prof. O. H. T. Rishbeth, Prof. P. M. Roxby, Mr. A. Stevens.

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 (*Secretary*), Prof. C. B. Fawcett, Prof. H. J. Fleure, Mr. E. B. Haddon, Mr. R. H. Kinvig, Mr. J. McFarlane, Col. N. M. MacLeod, Prof. J. L. Myres, Mr. R. U. Sayce, Rev. E. W. Smith, Brig. H. S. L. Winterbotham. **£5.**

To ascertain the place which Geography occupies in the Curricula of the Universities in the various Dominions of the Empire.—Prof. C. B. Fawcett (*Chairman*), Dr. L. Dudley Stamp (*Secretary*), Dr. W. N. Benson, Mr. L. J. Burpee, Prof. F. Debenham, Dr. C. Fenner, Prof. Griffith Taylor, Prof. J. H. Wellington.

SECTIONS E, K.—GEOGRAPHY, BOTANY.

To complete two maps of England on the 1/M. scale showing (i) the distribution of woodland (based on physical evidence) after the establishment of climatic conditions approximating to the present, and (ii) the distribution of woodland on the basis of evidence derived from early topographical writings and maps.—Sir John Russell (*Chairman*), Prof. P. M. Roxby (*Secretary*); Prof. H. J. Fleure, Mr. R. H. Kinvig, Prof. A. G. Ogilvie, Brig. H. S. L. Winterbotham, Capt. J. G. Withycombe (*from Section E*); Dr. E. J. Salisbury, Dr. T. W. Woodhead (*from Section K*). **£25.**

SECTIONS E, L.—GEOGRAPHY, EDUCATION.

To report on the present position of Geographical Teaching in Schools, and of Geography in the training of teachers; to formulate suggestions for a syllabus for the teaching of geography both to Matriculation Standard and in Advanced Courses and to report, as occasion arises, to Council through the Organising Committee of Section E upon the practical working of Regulations issued by the Board of Education (including the Scottish Education Department) affecting the position of Geography in Schools and Training Colleges.—Prof. Sir T. P. Nunn (*Chairman*), Mr. L. Brooks (*Secretary*), Mr. A. B. Archer, Mr. J. N. L. Baker, Mr. C. C. Carter, Prof. H. J. Fleure, Dr. O. J. R. Howarth, Mr. H. E. M. Icely, Mr. J. McFarlane, Rt. Hon. Sir Halford J. Mackinder, Prof. J. L. Myres, Dr. Marion Newbigin, Prof. A. G. Ogilvie, Mr. A. Stevens, Prof. C. B. Fawcett (*from Section E*); Mr. C. E. Browne, Sir R. Gregory, Mr. E. R. Thomas, Miss O. Wright, Prof. Godfrey Thomson (*from Section L*).

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Chronology of the World Crisis from 1929 onwards.—Mr. P. Ford (*Convener*), Miss Emmerson and Mr. F. W. Paish (*Secretaries*), Prof. A. L. Bowley, Prof. R. B. Forrester, Prof. H. M. Hallsworth, Prof. J. H. Jones.

SECTIONS F, G, J, L.—ECONOMIC SCIENCE AND STATISTICS, ENGINEERING, PSYCHOLOGY, EDUCATION.

Industrial Co-operation: to report on the provisions for co-ordinating and stimulating scientific work bearing on business practice, and to make recommendations.—Dr. J. A. Bowie (*Chairman*), Mr. R. J. Mackay (*Secretary*), Prof. J. G. Smith, Mr. L. Urwick (*from Section F*); Prof. W. Cramp (*from Section G*); Dr. C. S. Myers (*from Section J*); Sir Richard Gregory (*from Section L*).

SECTION G.—ENGINEERING.

Earth Pressures.—Mr. F. E. Wentworth-Sheilds (*Chairman*), Dr. J. S. Owens (*Secretary*), Prof. G. Cook, Mr. T. E. N. Fargher, Prof. A. R. Fulton, Prof. F. C. Lea, Prof. R. V. Southwell, Dr. R. E. Stradling, Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson.

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, Prof. C. L. Fortescue, Sir R. Glazebrook, Prof. A. E. Kennelly, Prof. E. W. Marchant, Sir F. E. Smith, Prof. L. R. Wilberforce.

Stresses in Overstrained Materials.—Sir Henry Fowler (*Chairman*), Dr. J. G. Docherty (*Secretary*), Prof. G. Cook, Prof. B. P. Haigh, Mr. J. S. Wilson.

SECTION H.—ANTHROPOLOGY.

To report on the Distribution of Bronze Age Implements.—Prof. J. L. Myres (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. A. Leslie Armstrong, Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. G. S. Crawford, Prof. H. J. Fleure, Dr. Cyril Fox.

To excavate Early Sites in Macedonia.—Prof. J. L. Myres (*Chairman*), Mr. S. Casson (*Secretary*), Dr. W. L. H. Duckworth, Dr. D. Randall-MacIver, Mr. M. Thompson.

To report on the Classification and Distribution of Rude Stone Monuments in the British Isles.—Mr. H. J. E. Peake (*Chairman*), Miss M. A. Murray (*Secretary*), Mr. A. L. Armstrong, Mr. H. Balfour, Prof. V. Gordon Childe, Dr. Cyril Fox, Mr. T. D. Kendrick.

To report on the probable sources of the supply of Copper used by the Sumerians. —Mr. H. J. E. Peake (*Chairman*), Prof. C. H. Desch (*Secretary*), Mr. H. Balfour, Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. Davies, Prof. H. J. Fleure, Sir Flinders Petrie, Dr. R. H. Rastall. **£25.**

To conduct Archæological and Ethnological Researches in Crete.—Prof. J. L. Myres (*Chairman*), Mr. L. Dudley Buxton (*Secretary*), Dr. W. L. H. Duckworth, Sir A. Evans, Dr. F. C. Shrubsall.

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith (*Chairman*), Prof. J. L. Myres (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Mr. G. A. Garfitt, Miss D. A. E. Garrod, Mr. Lacaille. **£5.**

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*), Dr. R. V. Favell (*Secretary*), Mr. A. Leslie Armstrong, Prof. H. J. Fleure, Miss D. A. E. Garrod, Dr. J. Wilfrid Jackson, Prof. L. S. Palmer, Mr. H. J. E. Peake. **£50.**

To investigate processes of Growth in Children, with a view to discovering Differences due to Race and Sex, and further to study Racial Differences in Women.—Sir A. Keith (*Chairman*), Prof. H. J. Fleure (*Secretary*), Mr. L. H. Dudley Buxton, Dr. A. Low, Prof. F. G. Parsons, Dr. F. C. Shrubsall.

To report on the progress of Anthropological Teaching in the present century.—Dr. A. C. Haddon (*Chairman*), Prof. J. L. Myres (*Secretary*), Prof. H. J. Fleure, Dr. R. R. Marett, Prof. C. G. Seligman.

To make a preliminary survey of some reported archæological sites in British Somaliland.—Dr. A. C. Haddon (*Chairman*), Mr. R. U. Sayce (*Secretary*), Prof. J. L. Myres.

To co-operate with Miss Caton-Thompson in her researches in prehistoric sites in the Western Desert of Egypt.—Prof. J. L. Myres (*Chairman*), Mr. H. J. E. Peake (*Secretary*), Mr. H. Balfour.

To report to the Sectional Committee on the question of re-editing 'Notes and Queries in Anthropology.'—Mrs. B. Aitken (*Chairman*), Mr. L. Dudley Buxton (*Secretary*), Miss R. M. Fleming, Prof. C. Daryll Forde, Dr. A. C. Haddon, Capt. T. A. Joyce, Prof. C. G. Seligman, Mrs. Seligman, Miss C. Wedgwood.

To report upon the steps which should be taken for the investigation and preservation of the deposits of the caves of Craven.—Prof. P. G. H. Boswell (*Chairman*), Dr. R. G. S. Hudson (*Secretary*), Mr. M. C. Burkitt, Dr. J. Wilfrid Jackson, Prof. L. S. Palmer, Dr. A. Raistrick.

SECTION I.—PHYSIOLOGY.

The supply of Oxygen at high altitudes.—Prof. J. Barcroft (*Chairman*), Dr. Raymond Greene (*Acting Secretary*), Mr. G. S. Adair, Mr. N. E. Odell, Major J. A. Sadd. **£5.**

To deal with the use of a Stereotatic Instrument.—Prof. J. Mellanby (*Chairman*), Mr. F. R. Curtis (*Secretary*).

SECTION J.—PSYCHOLOGY.

The factors involved in Mechanical Ability.—Dr. C. S. Myers (*Chairman*), Dr. G. H. Miles (*Secretary*), Prof. C. Burt, Mr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear.

To inquire into (*a*) the occupations for which a training in Psychology is necessary or desirable, (*b*) the place Psychology should occupy in the curricula for University Degrees in Arts, Science, Medicine, Education, Economics and other subjects.—Prof. F. C. Bartlett (*Chairman*), Mr. A. Rex Knight (*Secretary*), Dr. F. Aveling, Dr. W. Brown, Prof. J. Drever, Prof. B. Edgell, Mr. C. A. Mace, Prof. T. H. Pear, Dr. R. H. Thouless, Prof. C. W. Valentine, Mr. A. W. Wolters.

SECTION K.—BOTANY.

Transplant Experiments.—Sir A. W. Hill (*Chairman*), Dr. W. B. Turrill (*Secretary*), Prof. F. W. Oliver, Dr. E. J. Salisbury, Prof. A. G. Tansley. **£2 6s. 2d.** (Unexpended balance).

To consider and report on the provision made for Instruction in Botany in courses of Biology, and matters related thereto.—Prof. V. H. Blackman (*Chairman*), Dr. E. N. M. Thomas (*Secretary*), Prof. M. Drummond, Prof. F. E. Fritsch, Sir A. W. Hill, Prof. S. Maugham, Mr. J. Sager.

Fossil Plants at Fort Gray, near East London.—Dr. A. W. Rogers (*Chairman*), Prof. R. S. Adamson (*Secretary*), Prof. A. C. Seward.

To investigate the effect of conditions on the growth, structure and metabolism of Kleinia articulata.—Prof. D. Thoday (*Chairman*), Mr. N. Woodhead (*Secretary*), Dr. F. F. Blackman.

SECTION L.—EDUCATIONAL SCIENCE.

The teaching of General Science in Schools, with special reference to the teaching of Biology.—Prof. Sir T. P. Nunn (*Chairman*), Dr. Lilian J. Clarke (*Acting Chairman*), Mr. G. W. Olive (*Secretary*), Mr. C. E. Browne, Major A. G. Church, Mr. G. D. Dunkerley, Mr. S. R. Humby, Mr. E. R. B. Reynolds, Dr. E. W. Shann, Dr. E. Miles Thomas, Mr. E. R. Thomas, Mr. A. H. Whipple, Mrs. Gordon Wilson, Miss von Wyss. **£35.**

Educational and Documentary Films : To inquire into the production and distribution thereof, to consider the use and effects of films on pupils of school age and older students, and to co-operate with other bodies which are studying those problems.—Sir Richard Gregory (*Chairman*), Mr. J. L. Holland (*Secretary*), Mr. L. Brooks, Mr. A. C. Cameron, Miss E. R. Conway, Mr. G. D. Dunkerley, Mr. A. Clow Ford, Dr. C. W. Kimmins, Prof. J. L. Myres, Mr. G. W. Olive, Mr. S. Rivers-Smith, Prof. C. Spearman, Dr. H. Hamshaw Thomas (*Section K*), Dr. F. W. Edridge-Green (*Section I*). **£5.**

To consider the position of science teaching in Adult Education classes, and to suggest possible means of promoting through them closer contact between scientific achievement and social development.—Prof. J. L. Myres (*Chairman*), Mr. C. E. Browne (*Secretary*), Major A. G. Church, Dr. Lilian J. Clarke, Miss E. R. Conway, Prof. C. H. Desch, Sir Richard Gregory, Mr. S. R. Humby, Miss H. Masters, Mr. E. R. Thomas. **£10.**

SECTIONS M, E.—AGRICULTURE, GEOGRAPHY.

To co-operate with the staff of the Imperial Soil Bureau to examine the soil resources of the Empire.—Sir John Russell (*Chairman*), Mr. G. V. Jacks (*Secretary*), Dr. E. M. Crowther, Dr. W. G. Ogg, Prof. G. W. Robinson (*from Section M*) ; Prof. C. B. Fawcett, Mr. H. King, Dr. L. D. Stamp, Mr. A. Stevens, Dr. S. W. Wooldridge (*from Section E*).

CORRESPONDING SOCIETIES.

Corresponding Societies Committee.—The President of the Association (*Chairman ex-officio*), Mr. T. Sheppard (*Vice-Chairman*), Dr. C. Tierney (*Secretary*), the General Secretaries, the General Treasurer, Mr. C. O. Bartrum, Dr. F. A. Bather, Sir Richard Gregory, Mr. J. V. Pearman, Sir David Prain, Sir John Russell, Prof. W. M. Tattersall.

Committee to take cognisance of proposals relating to National Parks by the Government and other authorities and bodies concerned, and to advise the Council as to action if desirable.—Dr. Vaughan Cornish (*Chairman*), Dr. C. Tierney (*Secretary*), Prof. P. Abercrombie, Mr. T. Sheppard, Prof. W. M. Tattersall (*Corresponding Societies*), Prof. A. H. Cox (*Section C*), Sir Chalmers Mitchell (*Section D*), Dr. Harrison (*Section H*), Sir D. Prain (*Section K*).

RESOLUTIONS & RECOMMENDATIONS.

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

From Section C (Geology).

That the Committee of Section C draws the attention of the General Committee to the desirability of aerial photography of certain special topographic features in North-East Yorkshire and elsewhere, a list of which is being compiled, and suggests that the appropriate Government authority be approached.

From Sections E (Geography) and M (Agriculture).

(1) That the Council be requested to bring to the notice of the Ministry of Agriculture certain difficulties which have arisen in connection with the supplying of statistics of agricultural production to University Departments and to other accredited workers for purposes of research.

(2) That the Council be requested to invite the Ministry of Agriculture to expedite the publication of Parts I and II of Agricultural Statistics.

From Section G (Engineering).

That the British Association calls the attention of the Home Office to the objectionable and largely preventable noises caused by many motor vehicles, and suggests that the Home Office should make greater use of the powers that they possess for dealing with such nuisances.

From Section H (Anthropology).

That the Committee of Section H welcomes the present policy of the Museums Association in regard to the interchange by loan or otherwise of duplicate specimens in public museums and similar institutions, and requests the Council to make representations in this sense to the museums and other public bodies concerned.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
York, 1932.

THE PRESIDENTIAL ADDRESS

AN ENGINEER'S OUTLOOK

BY
SIR ALFRED EWING, K.C.B., F.R.S.,
PRESIDENT OF THE ASSOCIATION.

I.

Again, for the fifth time, the British Association meets in York, a city of proved hospitality and the stage of great events. York is a monument of history; its very stones are eloquent of the past. Not the least of the episodes it has witnessed was the birth of this Association. Your city, my Lord Mayor, was our cradle: we hold York in filial honour and affection. We are nomads who have strayed to the ends of the earth: we have been as far-flung as the British flag. We have enjoyed the welcome of many strange hearths. But here there is nothing unfamiliar. We take delight in coming home to a birthplace of happy memory and in recalling hopes which the past hundred years have generously fulfilled.

Last year the infant of 1831 celebrated its centenary in the vigour of manhood, with a plenitude of pomp and circumstance which demanded no less ample a setting than the metropolis of the Empire. For President we had a man of world-wide fame, who fittingly embodied the imperial aspect that is part of the glory of the British Association. We had long known General Smuts as soldier and statesman: to some it may have come as a surprise when they found him also a philosopher, a student of ideas no less than a maker of history and a leader of men. It would be an impertinence for any successor in this chair to praise General Smuts; to follow him is perforce to follow far behind. But one may congratulate the executive on the happy instinct which recognised that the occasion was unique, and so led them to an unusual—not to say a daring—choice. It was amply justified by the event. Now they have returned to the beaten track along which Presidents for the most part plod, and have made a selection for which I am glad to have no responsibility.

Of General Smuts I would say one word more. His occupancy of the chair not only added to the lustre of our rejoicings: I like to think it had a deeper significance. May we not regard it as a harbinger of the spirit of goodwill and sanity which civilisation longs for, but does not yet see? Our hundred years of science have done sadly little towards curing the nations of mutual mistrust. Surely it was a good omen that, in marking the close of one century of achievement and the opening of another, we should have had for President a citizen of the world whose life has been a lesson in subordinating the lower patriotism to the higher good, who by example no less than by precept has taught his fellows that they should beat their swords into ploughshares and not learn war any more.

Now we revisit our birthplace well aware of our maturity. We have scored our first century and begun to compile our second with the easy assurance of a Bradman or a Hobbs. At once the question arises, Is that assurance justified by the Association's continued vitality? Do we still give the community reason to support us? Or are we a survival, trading on a reputation which our present activities do little to increase? I put the question bluntly—nowadays we are all familiar with disagreeable stock-takings and shrinking values—but it need not detain us long. I am confident you will find no trace of decrepitude. It is true that the sciences included in our purview have become specialised and differentiated to a degree that would make ridiculous any claim to the qualified omniscience which was possible in our early days. It is also true that each department of science now has its own society of votaries who meet as it were in a masonic temple and converse in a jargon that has little if any meaning for the general ear. But these very facts make this Association the more useful. Notwithstanding the restrictions of specialism, science has its own broad outlook, demanding expression and explanation to laymen. And more than ever is it true—far truer than it was a hundred years ago, when we were ridiculed as a hodge-podge of philosophers and made the target of an unsympathetic Press—that laymen want to have intelligent contact with the seekings and findings of the scientific mind.

I say seekings and findings rather than conclusions, for that word has too final a ring. Here we may note a striking change in the temper of the investigator. I am old enough to remember a time when some of the spokesmen of science (never, indeed, the greatest) displayed a cocksureness that was curiously out of keeping with the spirit of to-day. Among contemporary leaders nothing is more general than the frank admission that they are groping in a half-light, tentatively grasping what at best are only half-truths. Things that to one generation seemed to be essential parts of a permanent structure are treated by the next as mere scaffolding. The quest of truth goes on endlessly, ardently, fruitfully. And yet with every gain of knowledge we realise more clearly that we can never really know. To understand, as Einstein lately said, is to draw one incomprehensible out of another incomprehensible. From time to time we discover a fresh relation between observed phenomena, but each of the things which are found to be related continues to evade our full comprehension; and that is apparently the only kind of discovery we can achieve. Our joy in the quest itself never fails; we are constantly learning that it is better to travel than to arrive.

The philosophical implications of this altered attitude are many—indeed they concern the deepest springs of thought. What I wish at the moment to point out is that the new spirit strengthens a sense of brotherhood between the scientific adept and the average man, who in his own way is also commonly a seeker after truth. He listens gladly when the specialist drops his toga and admits that in scientific matters the only dogma is that there is no dogma. Obviously too the advance of science makes an increasing claim upon the layman's notice through its technical applications. It invades his home and alters his ways; it affects almost every feature of the daily round; it brings him interests, comforts, wealth; it enormously enlarges his powers of work and play. And, further, at a time like the present, when we carry a load of social and political and economic discontents, the ordinary citizen doubtless reflects that if only we could apply the dispassionate temper of science to the difficulties of the hour we might face them with less waste of effort and greater likelihood of settlement.

These are a few of the reasons why the British Association keeps its hold on the public. It links experts with one another and with laymen, to the benefit of all. Experts gain by indulging in a short interval of comparatively lucid self-expression. They gain also by trying to understand each other, which is by no means so easy as you might suppose. To meet under these happy conditions is a stimulus to everybody. An old worker in science looks gratefully back on his attendances at the British Association not only as delightful human events but as red-letter days in his own development, as milestones in the unceasing march of his subject, and as helps in the hard task of keeping himself more or less in step.

It is recorded that York was chosen for our birthplace because in the Yorkshire Philosophical Society the infant would secure intelligent dry-nursing at the hands of a large body of friendly amateurs. In a letter to the Secretary of that Society, Sir David Brewster described the purpose of the proposed Association in the following words :[1]

> 'The principal objects would be to make the cultivators of science acquainted with each other, to stimulate one another to new exertions, to bring the objects of science more before the public eye, and to take measures for advancing its interests and accelerating its progress.'

There, in a nutshell, is what the Association set out to do, what it may fairly claim to have done, and what it still does. If you want an illustration, you had it last year when a great audience sat for hours, with every sign of sustained attention, while the Evolution of the Universe was discussed by British and foreign specialists of acknowledged authority, immense learning, and conspicuous variety of opinion.

At the end of that symposium the debate was admirably summed up by Sir Oliver Lodge, the Nestor of physics, who in every sense has filled a big place in our gatherings for more than fifty years. He has taught us much : would that he could teach his secret of perpetual youth ! In a recent volume of reminiscences[2] he tells delightfully of the meetings he has frequented and the friendships to which they have led. If he is thankful for them, so are we for him. Not a few of us have found inspiration in the fountain of his knowledge, in the spontaneity and aptness of his spoken word, in the width of his sympathy and understanding, and have learnt to love him for his large humanity.

My own first contact with these meetings antedates even that of Sir Oliver. Sixty-five years ago it chanced that the Association in its peripatetic course came, for the first time, to my native town and I was taken, a boy of twelve, by my mother to the Section of Mechanical Science, having already announced my intention of becoming an engineer. To the pundits of Section G we must have seemed an odd pair, the douce minister's wife and the shy little boy in his kilt. It was by my own wish, of course, that I was taken, and my mother counted no labour lost that might develop intelligence in her family of sons. The boy could not understand much of what he heard ; it was something, however, to see the leonine head of the sectional president, Macquorn Rankine, over whose engineering text-books he was later to spend many assiduous hours. There is no boundary to a mother's dreams, but in their wildest excursion they can scarcely then have pictured what is happening in this hall to-night.

[1] *The British Association : A Retrospect, 1831–1931,* by O. J. R. Howarth, p. 14.

[2] *Advancing Science, being Personal Reminiscences of the British Association in the Nineteenth Century,* by Sir Oliver Lodge.

Here let me make a confession which may also serve as an apology. I have the unwelcome distinction of being the oldest President the Association has ever suffered. In its primitive years the average age of Presidents scarcely exceeded fifty: one of them, aged only twenty-nine, afterwards founded the Cavendish Laboratory, and so did a service to science which it would be impossible to overvalue. As time went on the choice fell on older men, and now the electors have taken what one hopes may be regarded as an extreme step. But, as it happens, this is not the first time I have read the President's Address. At the Edinburgh meeting of 1921 the President, Sir Edward Thorpe, was prostrated by illness and asked me to act as his mouthpiece. The small service so rendered brought an unexpected reward. Some newspaper report must have confused the platform substitute with the real President, for a well-known novelist sent me a copy of one of her romances which was no doubt meant as a tribute to Sir Edward. It was called *The Mighty Atom*—an arresting title. Perhaps that is why I did not read beyond the title-page. Without close examination it was put by a more orderly hand than mine on a shelf that already held works on like subjects by authors such as J. J. Thomson and Rutherford and Bohr. *The Mighty Atom* was said to be one of the best sellers of its day: in that respect, if in no other, it found congenial company when it was joined on the same shelf by a series of volumes from the fascinating pens of Eddington and Jeans. These, however, I need not tell you I have read and reread, to my entire pleasure and partial understanding.

II.

If 'The Mighty Atom' was an arresting phrase, it was also an apt one. For we now know the atom to be indeed mighty in senses that were little suspected by the begetters of atomic theory. It has been mighty in sweeping away ideas that were found inadequate, in demanding fresh concepts, in presenting a new world for conjecture and experiment and inference, in fusing chemistry and physics into a single science. It is found to be mighty in the complexity of its structure and the variety of radiations it may give out when excited to activity. It has unravelled for us the bewildering tangle of spectroscopic lines. And, most surprising of all, the atom, however seemingly inert, is mighty in being a magazine of energy which, for the most part, it locks safely away. This is fortunate, for if the secret were discovered of letting loose the atomic store we should invite dissolution at the hands of any fool or knave. And it is also fortunate that in the furnace of the sun, at temperatures far higher than those of our hottest terrestrial infernos, the stored energy of the atom is drawn upon, as we believe, and has been drawn upon for ages, to keep up that blessed radiation which makes man's life possible and is the source of all his power.

In the middle nineties there set in an astonishing renaissance of physical science which has centred in the study of the atom and extends by inevitable logic to the stars. In quick succession came three great discoveries: the X-rays by Röntgen in 1895, radioactivity by Becquerel in 1896, and the electron by J. J. Thomson in 1897. Sensational, puzzling, upsetting, these events inspired every physicist to new activities of thought and equipped every laboratory with no less novel methods of research. A flood of further discovery followed, the flow of which continues unabated. Within the last few months notable items have been announced that well deserve our attention. It may not be inappropriate if I try for a few minutes to touch—however lightly—on one or two aspects of this subject, as it is seen through the eyes of an engineer.

Thanks mainly to J. J. Thomson, Rutherford and Bohr, we now recognise the atom of any substance to be a highly complex structure, built up, so to speak, of two sorts of blocks or brickbats—the electrons, which are indivisible units of negative electricity, and the protons, which are indivisible units of positive electricity. It is strangely simple to be taken back, as it were, to the nursery floor and the childish game, and given just two sorts of blocks, exactly alike in each sort, and exactly the same number of each sort, with which to build the universe of material things. The blocks are unbreakable: we cannot produce them or destroy them or change them. In respect of electrical quality the two kinds are equal and opposite, but they contribute very unequally to the atom's mass, each proton (for some reason not yet understood) contributing about 1,840 times more than each electron. Every substance is made up of blocks of the same two sorts. If you compare different substances you find that the diversity of their chemical and other properties arises solely from differences in the number and arrangement of the blocks which compose their atoms. Any atom, in its normal or electrically neutral state, must contain an equal number of protons and electrons. All the protons in any atom are gathered close together at the centre, along with some of the electrons, forming a compact, dense portion which is called the nucleus. Although the nucleus accounts for nearly the whole of the atom's mass, it occupies no more than a very minute fraction of the atom's volume. Those of the electrons which are within the nucleus doubtless serve to bind the protons together; the other electrons constitute, as it were, a voluminous crinoline, or rather a series of crinolines, extending relatively far away from the centre and giving the whole atom an exceedingly open structure. Within that open structure upheavals may be caused by outside agents in various ways. One or more of the electrons in the crinoline may be temporarily removed (as, for instance, by the action of heat or by the incidence of energetic radiation), and the atom is then said to be ionised : for a time the balance between positive and negative is upset. But the missing electron returns to its place, or another comes instead, and when this happens a definite amount of radiation is given out, much as energy is given out when a weight falls from one to another landing of a staircase. We may speak of the landings as energy levels. The radiation which issues when an electron falls from one energy level to another constitutes what is called a photon.[3] It has two aspects, behaving in one like a particle and in the other like a group of waves, and at present we have to accept both though we cannot fully reconcile them. The photon carries a definite quantity of energy and is characterised by a definite frequency of vibration. Its energy depends on the two levels between which the electron falls, and this determines the frequency of the vibration which the photon conveys, for the frequency is equal to the energy divided by that mysterious constant of nature, the Quantum of Action discovered by Planck. In any element all the atoms have the same set of energy levels : these contribute to the emission spectrum and account for its groups of spectral lines. In heavy atoms there are many energy levels, and consequently very many lines appear in their spectra.

I will not weary you with details that are now fairly familiar. What we have to realise is that all matter consists of the two kinds of electricity, protons and electrons, held apart we do not know how. To the early experimentalists who electrified rods of resin or glass by rubbing them, electricity seemed no more than a curious attribute of matter : now we regard it as matter's very essence—the ultimate stuff out of which every atom is built. If you ask, What is electricity ? there is no answer, save that it is a thing which exists in units of two sorts, positive and negative, with a strong attraction for each other, and that in any atom you find them somehow held apart against that attraction, with a consequent storing of potential energy. They are prevented from coalescing, although the difference of potential between them is nearly a thousand million volts. Why they do not flash together is a mystery—one of the many mysteries which physicists have still to solve.

Engineers are accustomed to the idea of storing energy in a condenser by charging the opposed plates to a potential of a few

[3] We owe the name 'photon' to Prof. G. N. Lewis of Berkeley, California, who proposed it in a letter published in *Nature* of December 18, 1926.

scores or hundreds or thousands of volts. That is done by transferring some of the crinoline electrons from one to the other plate : it involves only a minute supplementary separation, which disappears when the condenser is discharged. In every atom we have a permanent separation of electricities ; the protons and electrons look at one another, so to speak, across an immensely greater dielectric gulf which no laboratory operation ever causes them to bridge. That is why every atom is a magazine of energy, the quantity of which (mc^2) is proportional to the atom's mass.

Any of the usual operations of the electrical engineer, such as charging and discharging a condenser or a storage battery, or driving a dynamo and conducting electricity from it to a distant station where it can actuate a motor or heat the filaments of lamps to incandescence, may be described as the setting up and the breaking down of a comparatively small extra difference of potential between the opposed electricities in some of the atoms of the engineering plant. In every process of industrial electricity, on whatever scale, what happens is a temporary enlargement of the potential difference which always exists between electrons and protons, and then a return to what may be called nature's *status quo*. But those supplementary differences of potential which the engineer first superimposes and then allows to disappear are exceedingly small, even at their greatest, in comparison with the gigantic difference which the normal condition of the atom itself involves.

A notable event of the year is the strong evidence which Dr. Chadwick of the Cavendish Laboratory has found for the existence of what is called the neutron—a type of particle in which an electron and a proton are associated in particularly close juxtaposition. There is a like close association between electrons and protons in the nucleus of any heavy element, but it had not previously been discovered in a single isolated pair. Twelve years ago Lord Rutherford conjectured the existence of such a particle and described the properties it should possess. Its excessive smallness and density, together with its lack of an external electric field, give it a unique power of penetrating matter. It is too slim to be confined under pressure in any vessel : it will simply slip through the walls. The normal hydrogen atom has the same two constituents, one proton and one electron, but in nothing like the same intimacy of association, for the hydrogen atom wears its electron as a bulky crinoline which confers on it an immensely greater volume. The neutron, on the other hand, may be said to have taken the crinoline off, folded it up and put it in its pocket. Not to be too fanciful, we may at least describe the partners as clasping one another so tightly that the electron has ceased to be a fender ; none the less as a unit of negative electricity it still serves to give electrical balance to the pair. Though so close together the two constituents of the neutron remain separate and distinct, parted by nearly as many million volts as in a hydrogen atom. In this hitherto unknown particle, whose existence the experiments of Dr. Chadwick seem to have definitely proved, we have a new physical entity of extraordinary interest and a powerful tool for further research.

Lord Rutherford was the first to discover and name the nucleus. It is the inner sanctuary of the atom, the repository of secrets many of which have yet to be disclosed, almost unapproachable, not only because of its smallness but because of the electric field in which it is encased. Recognising the nucleus to be a richly charged strong-room, Rutherford has spared no effort to break it open. He has submitted it to a furious bombardment, using as missiles the alpha particles which radioactive substances project. These particles, each consisting of four protons and two electrons compactly built together, have the necessary velocity and energy to penetrate to the atom's heart. Rutherford had perforce to fire into the brown : he could not aim his gun, nor even tell when it would go off : the chances of a hit were no more than one in many millions. But hits were in fact obtained—hits so effective that they chipped off protons and caused the missile to be absorbed, thus realising the dream of the alchemist by making one element change into another. That was a dozen or more years ago : since then his attack has lost none of its severity. It has been taken up under his guidance by a school of workers and many further secrets of the nucleus have been revealed.

Quite recently two of his disciples have gone one better, as disciples sometimes do, to the joy of their lords. Dr. Cockcroft and Dr. Walton have used missiles of their own making instead of those that come spontaneously and intermittently from substances such as radium or thorium. By beautiful devices they have applied their knowledge of electrical engineering and their mastery of electrical technique to project single protons into the nucleus of lithium, using a steady potential of several hundred thousand volts to give the projectile sufficient penetrating power. An atom of lithium has (usually) seven protons and four electrons in its nucleus ; the other three electrons constitute the crinoline. Here again it was a case of firing into the brown : out of millions of shots a few reached their billet. When the projected proton forces an entry into the lithium nucleus it creates a domestic disturbance of the liveliest kind. For with the seven protons already in occupation it makes an eighth ; the group then splits into two sets of four, each taking two of the electrons, and they fly violently apart with an energy drawn from the atomic magazine. The result is that two helium atoms are formed. This is a notable achievement, the first artificial splitting of the atom by a laboratory process in which there is no recourse to the violent projectiles which radioactive substances provide. It has been followed up by successfully applying the same method to break up the atoms of other elements.

It is a satisfaction to learn that in all the encounters and emissions and absorptions that are studied among atoms and photons and the parts of atoms there is, so far as we yet know, strict compliance with the accepted principles of conservation in respect of momentum and energy and mass, though matter (in the ordinary sense) is liable to transformation into energy and energy into matter. When radiation is emitted some matter disappears, for the atom that emits it loses a little of its mass ; when radiation is absorbed a like quantity of matter comes into being.

But the engineer finds himself obliged to admit that no mechanical model of the atom can be expected to give an adequate picture of that strange new world. Our mechanical ideas are derived from the study of gross matter, which is made up of vast aggregates of atoms, and any model must share the limitations this implies. It is futile to explain the constitution of the atom in terms applicable to gross matter, just as it would be futile to study the psychology of an individual by observing only the movements of crowds. So we must expect to find within the atom and among its parts qualities and actions different in kind from those we know, and paradoxes which without a wider vision we cannot interpret. Such a paradox indeed confronts us at the present time, when we try to harmonise the wave aspect and the particle aspect of the photon, of the electron, and indeed of matter itself. These things are still a mystery—a riddle which some day we may learn to read. Meanwhile we do well to remember that any attempt to portray the structure of the atom in the language of ordinary experience is to give undue significance to symbols and analogies that are more or less invalid. Qualifying phrases like ' so to speak ' or ' as it were ' cannot be escaped. They are confessions that the image is inevitably a distortion of the reality it is intended to suggest.

III.

Let us now glance back to the early days of the Association, and trace a little—a very little—of what it has done for the advancement of science, both pure and applied. The two inevitably march together. Between discovery and invention there is, in effect if not always in form, a close partnership with a constant interchange of advantage. No discovery, however abstract, is safe from being turned to practical account ; on the other hand, few if any applications fail to react in stimulating discovery and providing the experimentalist with more effective weapons of attack.

From the first the Association took cognisance of engineering as one of the subjects it was created to advance. One of its earliest acts, and a very wise one, was to invite reports on the state of science: these were called for in many different fields and were written by the best available experts. In the first batch of such reports were two that dealt with engineering, one on the Strength of Materials and the other on Hydraulics. As it happened they were of very unequal merit; but they are alike in this, that they demonstrate how conspicuous was the lack of science on the part of early British engineers.

The engineers of those days were big professional figures. They had covered the country with a network of roads and bridges and canals; they had drained the fens; they had built harbours and lighthouses. By multiplying factories, by extending the uses of coal and iron, they were laying the foundations of that commercial supremacy which, so long as it lasted, we took for granted as a sort of national right. They had taught the world how to light towns by gas, and were beginning to drive ships by steam. Above all, they had shown that a new era of locomotion was about to set in. A railway connecting Liverpool with Manchester had been opened: its success was proved, and schemes were projected that would soon utilise labour on a large scale for a host of tunnels and cuttings and embankments, and so relieve the scourge of unemployment which—as we also know—follows the scourge of war. The engineering pioneers were sagacious men who put their faith in experience; they knew little of theory and cared less. Instinct and personality carried them through difficulties of a kind that science might have helped them to solve or to avoid. They had the sense to profit by their own mistakes.

It is significant that in 1832, when the British Association called for a report on the present state of our knowledge of Hydraulics as a branch of engineering, the terms of reference included this curious phrase: 'Stating whether it appears from the writings of Dutch, Italian and other authors that any general principles are established in this subject.'

The report was written by George Rennie, a son of the greater Rennie who left us a monument of his genius—I wish I could say an imperishable monument—in Waterloo Bridge. After giving a good summary of the work of foreign theorists the reporter remarks:

> 'It only remains for us to notice the scanty contributions of our own countrymen. While France and Germany were rapidly advancing upon the traces of Italy, England remained an inactive spectator of their progress.'

It is clear that there was much need for the scientific leaven which the new Association could, and did, provide.

Another of the early concerns of the Association was with the performance of steam engines. At the date of our foundation more than fifty years had passed since the inventions of Watt provided an engine fit to serve as a general means of producing power. Its earliest application, and still at that date its most common one, was in the pumping of mines. Engineers took a professional and even sporting interest in what they called its 'duty,' meaning the amount of water pumped through a given height for each bushel of coal consumed. Nevertheless it is a remarkable fact that neither they nor the physicists of that period had any notion that the process involved a conversion of heat into mechanical work. It is difficult for us now to imagine a world of physics and engineering where the idea had not yet dawned that there was such a thing as energy, capable of Protean transformations, but in all of them conserving its total amount. Enlightenment was soon to come, and our meeting-rooms furnished the scene. In 1843 Joule brought before one of the sections his first determination of the mechanical equivalent of heat. He spoke with the modesty natural—in those days—to a man of twenty-four. His paper was received in chilly silence. Two years later, after further experiments, he reappeared; but again no notice was taken of the heresies of a youthful amateur. Nothing daunted, he prepared a fuller case for the Oxford meeting of 1847, perhaps remembering that Oxford is the home of lost causes. In a narrative written many years later, Joule has told how the Chairman suggested that as the business of the Section pressed he should not read the paper, but merely give a brief account of his experiments:

> 'This [he says] I endeavoured to do, and discussion not being invited, the communication would have passed without comment if a young man had not risen in the Section and by his intelligent observations created a lively interest in the new theory. The young man was William Thomson.'

But Thomson, though deeply interested, was not at first convinced. Nearly four years more were to pass before he satisfied himself that the doctrines of Joule did not clash with the teachings of Carnot, of which he was then an enthusiastic proselyte. At length he became a convert; he saw, as we should now say, that the First Law of Thermodynamics was in fact consistent with the Second. Then indeed he accepted the principles of Joule in their entirety and was eager in their support. Quickly he proceeded to apply them to every part of the physical domain. Along with Clausius and Rankine he formulated the principles which govern the whole art of producing power by the agency of heat. The steam turbine of Parsons, the gas engines of Otto and Dugald Clerk, the oil engines of Daimler and Diesel, with all their social consequences in making swift travel easy by road and possible by air, are among the practical results. On the same thermodynamic foundation was built the converse art of mechanically producing cold, which we employ in ever-increasing measure for the import and storage of our food. Joint experiments undertaken by Joule and Thomson led to a further discovery which later enabled the process of refrigeration to be carried very near to the limit of coldness which Thomson himself established as the absolute zero. In the hands of Linde and Claude the 'Joule-Thomson effect' as a means of producing extreme cold has created new industries through the liquefaction of air and the separation of its constituents by methods of fractional distillation. However cold, however near the absolute zero, was the Association's first reception of Joule, we may claim that in effecting a conjunction between him and Thomson it made amends. Their meeting in 1847 ushered in a new era both of scientific theory and of engineering practice.

Of the Association's many other services there is little time to speak. When the telegraph developed in the middle of last century and spread itself across the Atlantic, largely under the guidance of that same William Thomson (whom later we knew as Lord Kelvin), there were no accepted units in which electrical quantities could be measured and specified. The scientific world was as badly off then for a standard of electricity as the commercial world is now for a standard of value. The need of electrical standards was urgently felt, by none more than Thomson himself. He stirred the Association to act: a strong committee was set up, and in time its work served as a basis of international agreement. There is no danger that any country will wish to 'go off' the standards thus established. To settle them was an incalculable boon to science no less than to technics. It paved the way for the revolution of the eighteen-eighties, when electricity passed, almost suddenly, from being no more than the servant of the telegraph to be master of a great domain. It was then that the electric light and the electric transmission of power gave it a vastly extended application, and the fundamental discoveries of Faraday, the centenary of which we lately celebrated, came into the kingdom for which they had waited nearly fifty years.

Another notable achievement of the Association was to promote the establishment of a National Physical Laboratory. Informal talks at our meetings in the nineties led to the appointment of a committee which moved the Government of the day to take action. The Laboratory was constituted, and Sir Richard Glazebrook was appointed its first head. What it has become in his hands and the hands of his successor, Sir Joseph Petavel, does not need to be told. From small beginnings it has grown to be an influential factor in the world's scientific progress, and a legitimate subject of national pride.

Another by-product of quite a different sort is the memorial to Charles Darwin which we hold as trustee of the nation and of all nations. At our meeting in 1927 the President, Sir Arthur Keith, spoke in his address of the house where Darwin lived and worked, pointing out how admirably it would serve as a monument of the great naturalist. No sooner was the suggestion published than a donor came forward whose devotion to the memory of Darwin expressed itself in a noble gift. Sir Buckston Browne not only bought and endowed Down House, but arranged with pious care that the house and its grounds should exhibit, so far as was possible, the exact environment of Darwin's life. The pilgrims who now visit this shrine in their thousands see Darwin's study as it was when the master thought and wrote, and can reconstruct the habit of his days. There could not be a more appropriate memorial. Its custody by the Association involves obligations which are by no means small, and we may claim that they are worthily fulfilled.

One may safely say that there is no department of scientific endeavour our meetings have not aided, no important step in the procession of discovery they have not chronicled. It was at our meeting of 1856 that Bessemer first announced his process of making a new material—what we now call mild steel—by blowing air through melted pig iron. Produced in that way, or by the later method of the regenerative furnace and the open hearth, it soon revolutionised the construction of railways, bridges, boilers, ships, and machinery of all sorts, and it now supplies the architect with skeletons which he clothes with brick and stone and concrete. It was at the Oxford meeting of 1894 that Lodge demonstrated a primitive form of wireless telegraph based on the experiments of Hertz, a precursor of the devices that were brought into use a little later through the practical skill and indefatigable enterprise of Marconi. At the same meeting there was an epoch-making announcement by the late Lord Rayleigh. His patient weighings of the residual gas which was found after depriving air of all its oxygen led him to the discovery of argon. That was a surprise of the first magnitude; it was the herald, one may say, of the new physics. Next year his colleague Ramsay presented other members of the family of inert gases. It is curious to recall the indifference and scepticism with which these really great discoveries were received. Some of the chemists of that day seem to have had no use for inert gases. But the stones which the builders were at first disposed to refuse are become head-stones of the corner. In the architecture of the elements they fill places that are distinctive and all-important; they mark the systematic sequences of the periodic law. In a metaphor appropriate to atomic physics we may describe them as coy ladies with a particular symmetry in their crinoline of electrons, unresponsive to advances which other atoms are ready to make or to receive. Inert though they be, they have found industrial uses. Helium fills airships; argon fills incandescent lamps; and neon, so modest a constituent of the atmosphere that you might think it born to blush unseen, has lately taken to blushing deliberately and even ostentatiously in the shop-signs of every city street. In the field of pure science it was neon, outside the radioactive elements, that first introduced us to isotopes. And helium has a greater glory as the key to radioactive transformations and historian of the rocks. Disciples of evolution should be grateful to helium for delivering them from the cramping limits of geological time which an earlier physics had mistakenly imposed.

My own recollection covers many surprises that are become commonplaces to-day: the dynamo, the electric motor, the transformer, the rectifier, the storage battery, the incandescent lamp, the phonograph, the telephone, the internal combustion engine, aircraft, the steam turbine, the special steels and alloys which metallurgists invent for every particular need, wireless telegraphy, the thermionic valve as receiver, as amplifier, as generator of electric waves. To that last we owe the miracle of broadcasting. Who, a generation ago, would have imagined that a few yards of stretched wire outside the window and a magic box upon the sill should conjure from adjacent space the strains of Beethoven or Bach, the exhortations of many platforms, the pessimism natural to those who forecast the weather, and the optimism of orators who have newly dined?

> 'Sounds and sweet airs, that give delight and hurt not.
> Sometimes a thousand twangling instruments . . .
> And sometime voices . . . that, when I waked,
> I cried to dream again.'

I don't know any product of engineering more efficient than that magic box. It needs no attention; it is always ready for service; and when you tire of it you have only to switch it off. A blessing on it for that! Heard melodies may be sweet, but those unheard are often sweeter. Do you ever reflect, when you pick and choose among the multitude of airs and voices, or shut out all from your solitude of thought, that they are still there, physically present, individual, distinct, crowding yet not interfering, besetting you though you do not perceive them, silent until you determine that one or another shall catch your ear? Go where you will, to the ocean or the wilderness or the Pole, you cannot escape that vast company of attendants; they come to you, unheard, unseen, from every quarter of the globe with a swiftness no other messengers approach. Is any fairy tale so strange as that reality? In all the wizardry of science surely there is nothing more wonderful than this.

IV.

Among the inventions which have revolutionised the habits of modern man some were developed by steps that were mainly empirical. Others, especially those that are most recent, have had a very different history: science has been their incubator and their forcing-house. In the advance of any invention there is bound to be an element of trial and error, but when the scientific method is consistently applied the proportion of error is small and progress is swift. We see this exemplified in the development of mechanical flight, where one difficulty after another has been vanquished by aid of well-directed theory and well-related experiment. Or consider that immensely important modern art, the art of communication by telegraph and telephone, by wire and 'wireless.' There the efforts of scientific engineers were dominant at every stage, and it was through their guidance that the art quickly achieved its world-wide triumphs. It is true that in the story of long-distance radio-telegraphy there was a striking episode where the courage of the practical inventor forestalled the discovery of a recondite scientific fact. It happens that the wireless waves from a radio-station, instead of shooting out straight into space as such rays might be expected to do, become bent in the upper regions of the atmosphere, taking a surprising and convenient curvature which enables them to travel round the surface of the globe. An unlooked-for kindness on the part of Nature has provided what we now call the Heaviside layer by which she works this happy trick. The strange fact that the rays could somehow bend was recognised and applied by Marconi before anybody had a rational explanation to suggest. Speaking broadly, however, it was scientific nursing of the infant art, and scientific culture throughout its period of growth, that brought it to the splendid manhood which now blesses mankind.

I think we may regard the whole art of electrical communication as an unqualified blessing, which even the folly of nations cannot pervert: in that regard it differs conspicuously from some other inventions. Before it came into use the sections of civilised man were far more separate than they will ever be again. There could be scant sympathy or understanding, little chance of effective co-operation among communities scattered over the earth. A calamity might fall on one and be already old before others knew of it to offer help. Now we have all the world made practically instant in its interchange of thought. Through this physical linkage, which annihilates both space and time, there is opened a possibility of quick discussion, common resolution, simultaneous action. Can you imagine any practical gift of science more indispensable as a step towards establishing the sense of international brotherhood which we now consciously lack and wistfully desire? Should that aspiration ever become more than a dream we shall indeed have cause to bless the creators of electrical communication, to praise them and magnify them for ever.

In the present-day thinkers' attitude towards what is called mechanical progress we are conscious of a changed spirit. Admiration is tempered by criticism; complacency has given way to doubt; doubt is passing into alarm. There is a sense of perplexity and frustration, as in one who has gone a long way and finds he has taken the wrong turning. To go back is impossible: how shall he proceed? Where will he find himself if he follows this path or that? An old exponent of applied mechanics may be forgiven if he expresses something of the disillusion with which, now standing aside, he watches the sweeping pageant of discovery and invention in which he used to take unbounded delight. It is impossible not to ask, Whither does this tremendous procession tend? What, after all, is its goal? What its probable influence upon the future of the human race?

The pageant itself is a modern affair. A century ago it had barely taken form and had acquired none of the momentum which rather awes us to-day. The Industrial Revolution, as everybody knows, was of British origin; for a time our island remained the factory of the world. But soon, as was inevitable, the change of habit spread, and now every country, even China, is become more or less mechanised. The cornucopia of the engineer has been shaken over all the earth, scattering everywhere an endowment of previously unpossessed and unimagined capacities and powers. Beyond question many of these gifts are benefits to man, making life fuller, wider, healthier, richer in comforts and interests and in such happiness as material things can promote. But we are acutely aware that the engineer's gifts have been and may be grievously abused. In some there is potential tragedy as well as present burden. Man was ethically unprepared for so great a bounty. In the slow evolution of morals he is still unfit for the tremendous responsibility it entails. The command of Nature has been put into his hands before he knows how to command himself.

I need not dwell on consequent dangers which now press themselves insistently on our attention. We are learning that in the affairs of nations, as of individuals, there must, for the sake of amity, be some sacrifice of freedom. Accepted predilections as to national sovereignty have to be abandoned if the world is to keep the peace and allow civilisation to survive. Geologists tell us that in the story of evolution they can trace the records of extinct species which perished through the very amplitude and efficiency of their personal apparatus for attack and defence. This carries a lesson for consideration at Geneva. But there is another aspect of the mechanisation of life which is perhaps less familiar, on which I venture in conclusion a very few words.

More and more does mechanical production take the place of human effort, not only in manufactures but in all our tasks, even the primitive task of tilling the ground. So man finds this, that while he is enriched with a multitude of possessions and possibilities beyond his dreams, he is in great measure deprived of one inestimable blessing, the necessity of toil. We invent the machinery of mass-production, and for the sake of cheapening the unit we develop output on a gigantic scale. Almost automatically the machine delivers a stream of articles in the creation of which the workman has had little part. He has lost the joy of craftsmanship, the old satisfaction in something accomplished through the conscientious exercise of care and skill. In many cases unemployment is thrust upon him, an unemployment that is more saddening than any drudgery. And the world finds itself glutted with competitive commodities, produced in a quantity too great to be absorbed, though every nation strives to secure at least a home market by erecting tariff walls.

Let me quote in this connection two passages from a single issue of *The Times*.[4] In different ways they illustrate the tyranny of the machine. One is this:

> 'The new Ford works built upon a corner of Essex . . . will soon be able to produce motor-cars at the rate of two a minute.'

The other comes from Moscow. It also relates to the mass-production of motor-cars, and indicates how Russia is reaching out towards a similar perfection under the austere stimulus of the Five Years' Plan:

> 'The Commissar lays down dates for the delivery of specified quantities by each factory and invests twenty-one special directors with extraordinary powers to increase production, threatening each director with personal punishment if deliveries are belated.'

We must admit that there is a sinister side even to the peaceful activities of those who in good faith and with the best intentions

[4] *The Times*, June 25, 1932.

make it their business to adapt the resources of Nature to the use and convenience of man.

Where shall we look for a remedy? I cannot tell. Some may envisage a distant Utopia in which there will be perfect adjustment of labour and the fruits of labour, a fair spreading of employment and of wages and of all the commodities that machines produce. Even so the question will remain, How is man to spend the leisure he has won by handing over nearly all his burden to an untiring mechanical slave? Dare he hope for such spiritual betterment as will qualify him to use it well? God grant he may strive for that and attain it. It is only by seeking he will find. I cannot think that man is destined to atrophy and cease through cultivating what after all is one of his most God-like faculties, the creative ingenuity of the engineer.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

SOME ASPECTS OF APPLIED GEOPHYSICS

ADDRESS BY

PROF. A. O. RANKINE, O.B.E., D.Sc.,

PRESIDENT OF THE SECTION.

It will be in accordance with the desire of this Section, I am sure, that I should take this opportunity of placing on record our appreciation of the work of Dr. E. H. Griffiths, who died since our last meeting. Dr. Griffiths was President of this Section when the Association last met in this city in 1906. Subsequently he was President of Section L, and, still later, he rendered great service to the Association as General Treasurer for a period of eight years. His contributions to knowledge in the field of accurate thermal measurements are of fundamental importance, although they are liable to be overshadowed by the more recent and more spectacular discoveries in atomic physics. It is natural enough, but still in some ways regrettable, that physicists of the younger generation turn to the new and attractive branches of physics, and avoid so comparatively dull a subject as heat. Thus the disappearance of men like Griffiths and Callendar, who so often worked in close association, leaves this important part of experimental physics greatly in need of new workers of equal initiative and skill.

One other reference is, I think, called for before passing to the subject of my address. We are now commencing the second century of our existence as an association for the advancement of science. It could scarcely have fallen out more appropriately that this year is specially marked by the important new discoveries in the Cavendish Laboratory—interpreted as the production of *neutrons*, about which we shall hear more during our proceedings, and as the transformation of the elements by artificial means. Whether or not these interpretations may require future modification, there can be no doubt as to the fundamental nature of the phenomena observed. It seems certain, too, that we can look forward confidently to further remarkable developments, which, we may hope, will form the subject of a presidential address in this Section. But it is, as yet, too early to take stock of this, and related, recent work, and there are others much more qualified than I to undertake the task in due course. Accordingly I have chosen a subject with which I am more familiar, and which, although not new, seems to be worthy of consideration at the present time.

Perhaps some apology, or at least explanation, is necessary for the choice of a subject for which I have not even been able to find a satisfactory title. Applied geophysics may clearly be taken to include certain aspects of meteorology or oceanography or, indeed, any branch of knowledge in which physics is applied, in the service of mankind, to the elucidation of the properties of the earth. I propose to deal with what is in fact only a limited field of work. Put briefly, it covers the application of physical methods to the examination, without digging or boring, of what lies beneath the surface of the earth at relatively shallow depths of less than a few thousand feet. The application is more particularly directed to the discovery of deposits of economic importance, such as minerals or oil, or the structural formations with which they are likely to be associated.

Truly this is a subject as different as it could very well be from those flights of theoretical physics—relativity, quantum theory, wave mechanics and the like—which those of us with slower minds and more pressing other occupations try so desperately to follow. In our admiration and, perhaps, envy of the apparent ease with which the pioneers in these new fields make progress, we are inclined, wrongly, I think, to allow it to be assumed that modern physics and atomic physics are one and the same thing. It should not be overlooked that physics is making rapid strides forward also in other directions. Much that is new in the precision of measurement, in the choice of methods, and in the invention and design of physical tools for the attack on old problems hitherto unsolved, has become in recent years added to our knowledge. This is true with regard to the particular branch of physics we are now to consider. Its fundamental basis is not new. It involves no appeal to, let us say, wave mechanics ; the old gravitational theory of Newton and the electromagnetic theory of Maxwell serve well enough our purposes. Yet its successful application continues to demand the highest experimental skill that training in physics can provide, and initiative ability equal to that more frequently directed in less practical channels.

My subject is also a border-line one, and, perhaps for that reason, has not received as much attention as it deserves, at any rate in this country. Its practice involves the co-operation of geologists with physicists, except in those rare examples of the same person being expert in both branches of knowledge. This co-operation is desirable for many reasons, and essential for others. The geologist, if I may say so, is more practically-minded than the physicist. He puts a higher monetary value upon his work, and he is bolder in the expenditure of money upon exploratory investigations. His experience in the field accustoms him to the rigours of work out of doors as compared with the calm of a laboratory, and he is more ready to attack problems at first sight unlikely to be soluble. He has a keener eye, too, regarding the economic results of his field work. As illustrating these points I can do no better than relate the fact that it was a famous geologist, the late Prof. de Böckh, who suggested to the equally famous physicist, Baron von Eötvös (whose work we shall consider more fully later), that the Eötvös torsion balance should be used to locate and delineate buried salt domes—geological features with which oil is frequently associated. Prof. de Böckh once told me that at first Eötvös was horrified at the idea. He regarded the use of his instrument for such an economic purpose as debasing science, and it was only with great difficulty that he was eventually persuaded to initiate what has now become a common and successful practice in various parts of the world.

I may perhaps mention, too, that when I first became interested about five years ago in applied geophysics, I was very doubtful of its use. Could conditions underground, I asked myself, ever be so simple and free from complications that physical observations on the surface would point unequivocally to the solution ? The answer to this question is, generally speaking, in the negative ; but here the geologist comes in again. He carries out his preliminary survey by his own methods, and is often able to indicate both the limited region where a geophysical survey seems desirable, and in a general way the kind of formation which is to be sought, thus enabling a suitable choice of method to be made. He provides, in fact, the *selection rules* for the geophysicist, in much the same way as the quantum theorist does for the spectroscopist, as regards both where to look and what to expect to find. It is true that sometimes a *forbidden* result persists in obtruding itself inconveniently upon the geological interpretation, just as a *forbidden* spectral line may refuse to be extinguished. But usually the solution of a problem has to depend upon the combined result of geological and physical evidence, and is only approximate at that. Still, the co-operative effort is undoubtedly more likely to lead nearer to the truth than either singly, and physics and geology must accordingly work hand in hand.

Geophysical Prospecting.

Before going on to consider the theoretical basis and the practical methods employed, we may well inquire what justification there is for carrying out geophysical surveys of the kind to be described. Why go to the expense of supplementing a geological investigation by systematic measurements of a physical character ? Geophysical surveying is costly, either in the price of the necessary instruments, or in running expenses, or in both. A high quality gravity torsion balance, for example, costs £1,000, and it may be noted that nearly two hundred of these instruments were at one time in use on the oil-fields in America. The portable seismometers required for an alternative method of attack are also expensive, and the running costs in seismic work rapidly mount up, owing to the requirement of, possibly, a hundred tons of high explosive during a survey. And it is necessary to reckon, besides, the substantial salaries and wages bill of the geophysical staff, often working in fields remote from civilisation, and requiring all the special accessories of camp life.

The answer to the question proposed is that everything depends on relative cost. If the servant in the parable had happened to forget where he had buried his talent, geophysical assistance for its recovery would not have been a sound economic proposition. But if the prize is of great value—millions of tons of mineral oil, for instance—extensive application of suitable geophysical methods may become both justifiable and advisable. Each problem has to be considered from this point of view, on the basis of the experience gradually accumulating from previous surveys. But it is not my purpose to discuss this interesting economic subject, except to say that there are well-established cases where geophysical methods properly applied have, at relatively low cost, either led to the discovery of important mineral deposits previously unknown, or have facilitated the precise location of such deposits, thus reducing abortive digging or drilling to a minimum.

It is mainly the physical basis of the work that I wish to review. And here I should point out that this limitation will exclude 'divining,' whether for water or any other underground feature. Innumerable claims of successful use have been made for the divining-rod and similar indicators, but the *modus operandi* has never been explained, and none have been established on an acceptable physical basis. This is not to say that all the claims are necessarily false, and I do not wish to use this occasion to express scepticism. For I have discovered, to my surprise, that the use of the hazel twig for water-divining finds credence among scientific friends, the honesty of whose beliefs is above suspicion; consequently I am less ready to be dogmatic on the subject. Nevertheless, I am glad to escape from this highly controversial ground by defining in a sufficiently exclusive manner what is a geophysical method, and what a geophysical instrument, in relation to the search for minerals. The basis of every geophysical method is the differentiation, usually abrupt, of some physical property as between rocks. The four principal methods—gravitational, magnetic, seismic and electrical—depend, in fact, upon differences, in the various media underlying the earth's surface, of density, of magnetic susceptibility, of velocity of elastic wave propagation, and of electrical conductivity respectively. Associated with these variations of physical properties, either naturally or through stimulation by artificial means, there are produced, at or near the earth's surface, calculable physical effects which may be capable of measurement by suitable apparatus. Such apparatus is a geophysical instrument, in the sense in which the term will be used. Divining-rods do not belong to this category; nor, on present evidence, do those apparently more elaborate instruments which are sometimes found advertised and illustrated in such unexpected organs of publicity as the popular story magazines. Whatever the outward form depicted may suggest, and whatever the validity of the remarkable claims to infallibility in the text, these instruments cannot be regarded as geophysical instruments until the mode of action is revealed, and proved to be dependent on known physical laws. In short, there must be something physical to measure, and the instrument must be able to measure it.

Considering the simplicity and obvious nature of the physical concepts involved, it is not surprising that frequent suggestions have been made over a long period of years to put the matter to practical test. As early as the seventeenth century, indeed, the magnetic method was successfully employed to locate deposits of magnetite and other highly ferruginous ore-bodies, by observing how the earth's magnetic field was distorted locally by their magnetisation. And the beginnings of the electrical methods appear to date back to 1830. But substantial progress was not made until comparatively recent years, and practical geophysical prospecting—that is, systematic surveys with instrumental equipment specially designed and adequate for the purpose—can be described as a post-war development. It is of this that I wish to speak ; and, in this work which has suffered from inadequate publication, and the very nature of which implies collaboration, I shall not attempt to assign credit in any precise manner. Except in one case. I single out Eötvös as the somewhat reluctant pioneer of geophysical prospecting as it is known to-day. His fundamental work on gravitation has made practicable what is still the best-established and most precise geophysical method available.

The Gravitational Method.

I do not think that Eötvös has yet received in this country the full recognition which his work deserves. Possibly this is because the early accounts appeared in rather inaccessible journals ; or, possibly, there were real doubts concerning the validity of his claims. I remember, as a student, hearing vaguely about his experiments—and his name, without anyone knowing how to pronounce it. In the same lectures we learnt much fuller details of Boys' classic measurement of the constant of gravitation, without realising how remarkably similar in essential form the Eötvös and Boys instruments were. But the fact is that when Boys was inventing and making the quartz fibres for his torsion balance to weigh the earth, Eötvös had already tackled successfully the difficult task of making robust and portable for field work another torsion balance of not greatly inferior sensitivity. And while Boys was busy with his measurements in a constant-temperature cellar, Eötvös was completing the protection of his portable instrument against the temperature variations inevitable in the rigours of the field. A few years later he made notably successful gravitational surveys on the frozen surface of Lake Balaton, and on the Great Hungarian Plain ; but it was not until Shaw and Lancaster-Jones [1] had demonstrated in 1923 that an Eötvös balance, acquired for the Science Museum before the war, behaved according to specification, that the remarkable nature of Eötvös' achievement began to be appreciated here in this country. Truly Eötvös could claim in 1896,[2] following eight years' work, and only a year after the publication of Boys' paper, that the extreme sensitivity of the methods he had invented for measuring the space variation of gravitational fields had enabled him to attack problems hitherto deemed to be unassailable.

Even now I do not think it is well enough understood how small were the effects which Eötvös measured under the unfavourable conditions of field work. At the present day very fine measurement is common enough, usually by methods of electrical amplification which have become available ; but it may be well to place on record again what Eötvös did forty years ago without such aids. We can illustrate this in a very striking way. The earth's gravitational field, even apart from local irregularities, is not uniform, or, rather, spherically symmetrical. Owing mainly to

[1] *Proc. Phys. Soc.*, vol. 35, pp. 151, 204.

[2] *Annalen der Physik*, vol. 59, p. 354. 'Die äusserst empfindlichen Methoden, die ich besonders zur Messung der räumlichen Variationen dieser Kräfte ersonnen habe, machten es möglich, mich solchen Aufgaben zuzuwenden, die bislang für unangreifbar gehalten werden durften.'

the earth's rotation, the apparent value of the gravitational intensity increases in passing from equator to pole. The total change is about 5 cm./sec.^{2}, and the maximum rate of horizontal variation is at latitude 45°. In this region the change of g for a step of one metre northwards is 8×10^{-7} cm./sec.^{2}, or, approximately, only one thousand millionth of the gravitational acceleration. This the Eötvös torsion balance, even in its early forms,[3] was capable of indicating definitely, being several times as large as the limit to which the instrument would respond. And the measurement could be made with the instrument occupying a single position in a space of less than a square metre, simply by making observations with the apparatus as a whole in a number of different azimuths. When we compare this with what is possible in the measurement of gravity by ordinary pendulum methods, we see how great a step Eötvös made. By timing a standard portable pendulum, with all the precautions and corrections usually employed, variations of g of, perhaps, one part in a million can be detected. Eötvös, in effect, multiplied by a thousand the accuracy of measurement of terrestrial gravity variations.

This remarkable sensitivity was secured by deliberately excluding gravity itself from exercising any control in the instrument, which was constructed so as to respond only to *variations* of the gravitational field. The same is true with regard to Boys' apparatus, where the small forces of gravitational attraction between lead and gold spheres are balanced, not against any component of terrestrial gravity, but against the elastic torsion in the suspending fibre of quartz. The principle in both was, of course, not new; and we ought accordingly to spare some of the credit for the Rev. John Michell, who, towards the end of the eighteenth century, proposed and began to construct the first apparatus of the torsion balance type. He died before being able to carry out his plans, but his apparatus, with certain modifications and improvements, became the instrument with which Cavendish made the first laboratory measurement of the constant of gravitation.

Eötvös adopted the same principle in his torsion balance. By the use of suitable suspending wires he obtained the necessary sensitivity, and he secured protection against the spurious influences of air convection by proper design of the enclosure. He also extended the functions of the apparatus by arranging in an appropriate manner the distribution of the masses in the suspended beam. It would take too long to describe the instrument, and at the same time do justice to those used in other branches of geophysical surveying. It must suffice here to indicate that the Eötvös torsion balance provides means of measuring, normally by observations of the changes of torsion accompanying changes of azimuth of the instrument as a whole, two properties of the local gravitational field, each having magnitude and direction. The magnitude of the first, for which a satisfactory name has not yet been devised—the 'horizontale

[3] There have been many newer forms designed and constructed by various inventors since this date. For example, photographic and automatic recording has been successfully introduced, and there have been improvements in the details of construction. These modifications cannot be discussed here. It is worthy of note that, among modern instruments, those produced by Süss of Budapest, the firm which made the earliest models, are still in the first rank.

Richtkraft' according to Eötvös—is the product $g(c_1 - c_2)$, where c_1 and c_2 are the greatest and least curvatures of the local 'level' or equipotential gravitational surface; its direction is horizontal and in the vertical plane of least downward curvature. The suspension in the instrument responds to this curvature difference in so far as the mass-distribution in the beam partakes of the nature of a Coulomb beam—i.e. in its simplest form two equal heavy masses at the ends of a light horizontal rod. Such a beam would have no tendency to turn horizontally if the level surface were truly spherical; but otherwise it would, if free to do so, set itself along the direction of least downward curvature.

The other departure from gravitational uniformity which the balance measures is the *gravity gradient*, or the rate of change of the vertical gravitational intensity with horizontal distance in the direction in which the change is greatest. It is a vector, and both its magnitude and direction can be obtained from the instrumental observations. The response in this case is due to the unsymmetrical vertical distribution of the masses in the beam, the effective mass on one side of the suspending wire being lower than that on the other. This causes the beam to tend to set with the lower mass pointing in the direction of the gravity gradient, and there is torsion in the suspension if the beam occupies any other azimuth.

It will be seen, I think, without further elaboration, that in any given location of the instrument there are, in effect, two differential 'fields' acting simultaneously upon it. Its reaction to them provides the means of measuring the particular gravitational distortions which they represent. This part of the work is pure physical measurement of a straightforward character, and attaining, as I have indicated, a surprising degree of precision. It is in the interpretation of the results that the real difficulties arise. The problem is to ascertain to what extent the gravitational irregularities measured are due to density differences in the buried structure, and to assign to the latter a position and shape consistent with the observations. In country where the surface is otherwise than virtually horizontal it is necessary to survey its irregularities, and make calculated allowances for their contribution to the total measured gravitational distortion. This topographical effect may indeed sometimes be so large in comparison with that of hidden structure as to render gravitational surveying ineffective. The earth's rotational effect, of course, has always to be eliminated, but this presents no difficulty. What remains after these corrections constitutes the data for geophysical interpretation; and this is the stage where the geologist's 'selection rules' have to be applied. As in all geophysical methods, interpretation is necessarily indirect. Underground structures, agreeable to the geologist's experience, have to be taken as hypotheses, and tested by calculation and comparison with the data provided by surface observations.

The most important example of successful application of gravity surveying is in the detection of salt domes, and in the determination of their depth and extent. The first survey of this kind, in 1918, provides a striking illustration of the way in which geological knowledge has generally to be used in combination with the physical measurements, in order to secure the proper interpretation. Much to the surprise of the observers, the gravity gradients found in the neighbourhood of the salt dome pointed *towards* it, whereas the relatively low density of salt, in comparison with that of the earth in which it was embedded, led to the expectation of a *minimum* of gravity directly above the dome. The explanation of the paradox lay in the recognition of the possibility of the existence of a cap rock, or shell of relatively high density anhydrite, covering the salt in the dome. Close to the dome this nearer material was the predominant factor, and produced a gravitational attraction; it was only at greater distances, where the great bulk of the deeper salt more than compensated for its depth, that apparent gravitational repulsion was actually observed.

I have, rather regretfully, to leave at this stage this part of my subject. My recent practical experience with torsion balances has aroused in me the greatest admiration for the work of the original inventor and his successors, and for the skill and precision with which most of these remarkable instruments have been constructed by the makers. It comes as something of a shock, even though we do not doubt the universal law of gravitation, to see for the first time a small mass of gold being attracted by a neighbouring lead sphere a few inches in diameter. With a torsion balance at our disposal the same becomes commonplace, and is indicative of the great power of these instruments for geophysical purposes. Accumulated evidence from the field confirms this view. There is convincing proof that extensive underground features, such as the salt domes mentioned, limestone anticlines and synclines, rock faults, and deposits of hæmatite or of brown coal, produce, if not too deeply buried or masked by complicating irregularities, gravitational disturbances large enough to lead to their delineation by means of the torsion balance.

The Seismic Method.

The seismic method of prospecting began to be used about 1919, chiefly owing to the initiative of Mintrop. To some degree it has replaced the gravitational method, on account of the greater speed with which it enables a given area to be surveyed—a most important economic criterion, of course. But there are other important reasons why, under certain conditions, it must be preferred. If, for example, the topography of the country is too irregular for the corresponding corrections to be applied reliably to torsion balance observations, gravity surveying is excluded; and seismic work, which is not so sensitive to surface conditions, may still prove of value. Again, the structure to be determined may itself settle the choice of method. For instance, if the problem were to determine the depth of a horizontal interface of discontinuity between two strata of very great extent, the torsion balance would not find anything to measure; the seismic method, on the contrary, would be confronted, as we shall see, with its most direct and simplest task. But while admitting these undoubted advantages, and recognising the many notable successes of seismic surveying under suitable conditions, it is necessary to state that this method does not yet rest on so sure a theoretical foundation as the law of gravitation; nor do the portable seismographs employed give records so unambiguous as the readings of the torsion balance.

The basis of the seismic method is the same as that underlying the investigations of the propagation of earthquake shocks in relation to the determination of the structure of the earth's crust. The difference is only one of degree. Artificial and controlled explosions replace the sporadic natural shocks, and, although the detonation of perhaps a ton of gelignite may be spectacular and dangerous enough, it is trivial compared with the natural disturbances occurring, even in England. The distances involved are also correspondingly small. But in so far as there is a theory of natural earthquake propagation, it serves also for the seismic method of geophysical prospecting. In trying to determine the depth of an underground stratum the most direct method of attack would be to measure, if possible, the time of travel of a particular disturbance from the surface to the interface and back to the surface after reflection. A knowledge of the velocity of propagation in the upper medium only would then give the depth required. This method has been used with great success in determining the depth of the ocean by means of the Admiralty echo-sounding machine. But it fails in application to the solid earth, for the reason that the attenuation of vibrations with distance is far greater in the earth than in the sea; consequently much larger initial disturbances have to be used—in fact, violent explosions. Even if—as ought always to be done for the sake of efficiency—the explosion is arranged so that the surface of the ground is not broken, thus eliminating danger to observers, the delicate seismographs cannot as yet be properly protected against the direct effect. They would thus be so greatly disturbed as to mask completely the onset of the small reflected disturbance arriving shortly after. This effect, indeed, persists to a less but still important degree even when the seismograph is removed to quite large distances from the explosion. It is true that some important results have been obtained by employing this so-called reflection method, but the reading of the records is a matter of considerable uncertainty, owing to the difficulty of identifying the time of onset of the reflected disturbance in the midst of the effect of that propagated directly. For, in the first place, we have no means of knowing the precise form of the initial motion arising from the explosion, or the manner in which the form changes during propagation. And, secondly, none of the portable seismographs at present available record with complete accuracy the disturbances which reach them: all, to a greater or less degree, display resonance at certain frequencies, and thus treat preferentially corresponding components of the motion to which they are subjected. This uncertainty has led to the more general adoption of a method, properly called the diffraction method, although the adjective 'refraction' is sometimes incorrectly used. Its great advantage is that it enables the inevitably feeble disturbances, which have penetrated to and through the lower medium, to reach the seismograph, under certain conditions, *in advance* of the much greater direct wave. Consequently the times of arrival of these indirect, or diffracted, disturbances are recorded unmistakably upon the seismogram, however much the instrument may be agitated later on.

The theoretical basis of this method has been worked out in a partial manner only. Let us take in illustration the simplest possible case, namely, that of two horizontal strata in which the velocities of propagation of longitudinal disturbances are v_1 in the upper and v_2 in the lower stratum. The condition that v_2 is greater than v_1 is essential to the method. From the point of view of *plane* wave propagation the limiting ray-path would be from the upper surface to the interface, incidence upon which would be at the critical angle θ, given by $\sin \theta = v_1/v_2$, then horizontally in the lower medium just grazing the interface, with final emergence, also at the critical angle, into the upper medium to reach the surface again. The first and last parts of the path would be at the velocity v_1; the intermediate part would be at the higher velocity v_2. Assuming, for the moment, that this represents the path of a real and finite disturbance, it is easy to see that while, at short ranges, the direct disturbance travelling close to the upper surface will reach the seismograph first, at sufficiently great distances the reverse will be true. The indirect disturbance, having in part of its path the advantage of the higher velocity in the lower medium, overtakes the direct one which travels all the time in the upper medium with the lesser speed. It spurts, as it were, and is thus able to cover a longer total distance in the same, or even less, time: And if we can measure the instants of arrival of the *initial* disturbance at various distances from the source, including ranges great enough for the indirect disturbance to arrive first, we have at our disposal means of calculating, by very simple geometry, the depth of the interface.

But the indirect path described, if the corresponding waves are plane, is of no practical interest, because no energy is associated with it; the conditions clearly imply total internal reflection. Yet the fact remains that disturbances *do* reach distant points at times consistent with the course indicated. Their appearance in the records of near earthquakes, where the sphericity of the layers of the earth's crust is insufficient to account for the magnitude of the effects observed, led Jeffreys [4] to investigate the problem as one of diffraction. He showed on this basis that a small, but finite, disturbance of the nature and apparent speed actually observed was to be expected. The argument, it is true, was limited to the case of two fluids separated by a horizontal interface; and, strictly, the application to the solid media of the earth's crust still lacks adequate theoretical justification. But there is no doubt that experimentally, both in regard to natural earthquakes and the seismic prospecting method, the assumption of similar paths of propagation depending on diffraction has led in many cases to reasonably certain determination of sub-surface discontinuities. Moreover, in the solid material of rocks there is more scope for the judicious application of the diffraction principle, since transverse as well as longitudinal disturbances are propagated, and changes from one type to the other may occur at each interface.

The principles of the method can be readily applied to structures less simple than a single horizontal interface; and the observations obtained in the field, plotted on time-distance graphs, enable such features as the slopes and curvatures of strata, and the depths of more than one successive bed to be recognised under favourable conditions. For success the principal requirement is a large velocity-ratio as between the rocks

[4] *Proc. Camb. Phil. Soc.*, vol. 23, p. 472 (1926).

constituting the various beds. Salt domes under alluvial deposits, for example, are in this respect suitable structures, and the location of many such domes was the first achievement of the seismic method. It has also been employed with valuable results in determining the underground contours of limestone anticlines and deep-seated granitic basements at depths of several thousand feet. We may notice that the method is rarely, if ever, able to reveal directly the presence of the mineral actually sought. It does not find oil as such, for example, but it may discover those rock structures with which there is a high probability of oil being associated. For the essential knowledge of such associations applied geophysics depends on geology.

Concerning the portable seismographs and time recorders which are the tools of the method, I must here be content with remarking that many ingenious instruments have been made available latterly in this country as well as abroad. Most of them record the displacements of the earth's surface at the place where the instrument is located ; a few record the velocity, as in the Galitzin seismograph. There are claims too, rather shrouded in secrecy, of the successful use of accelerometers. I mention this because it seems to me that this is the direction we ought to pursue in future developments. The diffracted disturbance, calculated by Jeffreys, begins with zero displacement and zero velocity, but its initial acceleration is finite. Consequently such disturbances may be expected to display much sharper and precisely determinable onsets in the record if this is of acceleration instead of either displacement or velocity. Greater accuracy of timing would thus be secured, leading to more precision in the results ; probably, also, smaller and less expensive explosive charges would be required. The application of piezo-electricity [5] obviously suggests itself.

The Magnetic Method.

We pass now to the magnetic method. In actual practice it is the simplest and least costly. It consists of measuring, with suitable portable magnetometers, local variations of components of the earth's magnetic field, usually the vertical and horizontal intensities. The instruments which have been designed for the purpose enable observations to be made quickly, so that a large number of stations can be occupied, and a wide area covered, in the course of a single day. Under suitable conditions, therefore, much information regarding underground structure may be obtained by means of a survey lasting only a relatively short time and involving comparatively little expense. But it should be pointed out that this apparent economy has sometimes led to the method being employed on problems for which it is at present unsuitable, and to claims being made as to its performance which are doubtful. It is necessary to bear in mind that the basis of magnetic surveying is the differentiation of rocks in respect of magnetic susceptibility, and the consequent discontinuities of

[5] Prince Galitzin in 1915 described an apparatus depending on piezo-electricity for the direct measurement of accelerations, and subsequent investigators have used the method also ; but seismographs of this type do not seem to have come into common use, at any rate as portable instruments.

magnetisation under the influence of the earth's general magnetic field. For the field distortion thereby produced at the earth's surface to be marked it is necessary for the responsible rock structure to have a large susceptibility ; this implies that only highly ferruginous rocks will be easy to find. No difficulty, for example, presented itself in the case of the great magnetic anomaly at Koursk, where two elongated deposits of magnetite, totalling 20 billion tons, and several hundred feet deep, produce, over a region of many square miles, prodigiously large variations [6] of all the terrestrial magnetic elements. For this survey the magnetic method was eminently suitable, and comparatively insensitive instruments served. Ore-bodies of similar magnetic material, but of much smaller dimensions, give rise to anomalies less marked but still unmistakable. Thus deposits of ilmenite and pyrrhotite, as well as magnetite, if not too deeply buried in relation to their size, can be both detected and located with considerable precision by simple magnetic measurements.

I do not mean to imply that the magnetic method of surveying is limited to the detection of ore-bodies of this kind. Igneous rocks generally, and particularly basalt, may contain considerable quantities of iron, and consequently possess an effective magnetic susceptibility much larger than non-ferrous materials. There is abundant evidence that structures of such rocks have been determined, under favourable conditions, by the use of magnetic variometers. Moreover, in recent years these instruments have been much improved in sensitivity, so that, at any rate nominally, they are capable of measuring variations of about 5γ only in the vertical or horizontal force. This development is bringing within the field of applicability of the magnetic method even sedimentary formations only slightly ferruginous, if due care is taken to make corrections which are unnecessary where the anomalies are great. But I should, nevertheless, reject the claims, which have sometimes been made, to have used present-day instruments to locate salt domes by reason of the diamagnetism of rock salt. In fact, the conclusion seems inevitable that the susceptibilities, whether positive or negative, of materials not within the ferro-magnetic class are too small to be responsible for field distortions at present measurable with portable instruments. Variation in the iron content of rocks has been the origin of the anomalies so far observed.

If we are to hope to bring within the scope of the magnetic method non-ferruginous underground formations, we must improve greatly the sensitivity of the instruments, and at the same time exclude the operation of certain disturbing factors. It is little use rendering apparatus more sensitive if this involves enhancing also corrections of an uncertain character. The chief difficulty with the variometers at present available is the application of the corrections for diurnal variation of the earth's field and for temperature changes. A certain degree of sensitivity having been achieved by balancing the control of the normal earth's field against

[6] The vertical anomaly has a maximum of about 2 gauss; the horizontal field has both positive and negative values ranging over about 1·3 gauss, and the declination, accordingly, varies from 0° to ± 180°. These effects are larger than could be attributed to the magnetisation of the magnetite under the influence of the earth's present field. The deposit has strong permanent magnetism derived in a way not known.

a control suitably imposed by gravity, by elastic torsion, or by an artificial magnet, the daily variations of the earth's field, amounting to as much as 35γ, make themselves manifest. Temperature changes also, by causing variations of dimensions, elasticity or magnetic moment, disturb the balance, and thus affect the observations to an extent corresponding to 15γ per degree centigrade. Moreover, where, as is most usually the case, the method of mounting the indicating magnet is on knife edges, friction adds uncertainty of the order of 5γ. If we could escape the necessity of applying the corrections which these important effects involve, we should feel much safer in attaching significance to anomalies only a few times larger than the limit of measurement of the apparatus.

A year ago I thought I saw the way to do this, and brought the proposed method to the notice of this Section. It was to make use of the essential principle which gives to the Eötvös gravity balance its extraordinary sensitivity, namely, to measure the space-variation only of the forces in question. I found later that Eötvös himself had worked on these lines, and actually constructed an instrument partially fulfilling the conditions; although it is not clear that he realised the full significance of complete success. I have to confess that unexpected practical difficulties of construction have so far prevented realisation, but I have not given up hope that a magnetic instrument can be constructed to operate in the same way as the proved gravity instrument. Accordingly it may be worth while to indicate what a device of this kind might be expected to achieve. Also, if I present the difficulties, perhaps someone more able than myself may show how to surmount them.

The chief virtue of such a magnetic torsion balance is that it would discriminate between *time-variation* and *space-variation* of the earth's magnetic field. The variation with time of a magnetic field remaining spatially uniform would not affect it; it would respond only to a sufficient distortion in space. (Even if this distinction of space and time is repugnant to relativity, it is practically of real importance.) Calculation shows that with the magnets and suspending wires now available we could anticipate an instrument which would be just about sensitive enough to respond, in the average magnetic latitude, to the non-uniformity [7] of the earth's main field. The additional lack of uniformity arising from diurnal variations, or even magnetic storms, is by comparison small, because the amplitude of the variations is only a small fraction of the total field, and they are very widespread in character; consequently they would fail to disturb the instrument appreciably. We should therefore be able to attribute the distortion observed solely to local magnetic features, apart from a nearly negligible correction for general earth's magnetism. The effect of changes of temperature also would be comparatively small, for

[7] I.e. the non-uniformity implied by the change in the resultant intensity from about 0·64 gauss vertically at the magnetic poles to about 0·32 gauss horizontally at the magnetic equator.

Unlike the gravitational 'horizontale Richtkraft' of Eötvös, its magnetic equivalent turns out to be zero everywhere on the surface of a uniformly magnetised earth. But the analogue of the gravity gradient, i.e. the northerly gradient of the earth's vertical intensity, is zero at the magnetic poles only; it has its maximum value, about $1 \cdot 5 \times 10^{-9}$ gauss/cm., at the magnetic equator.

they would be proportional to the variation of field intensity over the limited space occupied by the suspended system, instead of to the full intensity at the station. In the gravity torsion balance they are, in fact, negligible, and they could be made equally so here.

In order to realise in a magnetic torsion balance the full advantages of the corresponding gravity instrument, we must make the magnet system in the suspension completely astatic, so that, in a precisely uniform field, no couple acts upon it. It is here that the practical difficulties of construction present themselves. The polar nature of magnetism, as contrasted with gravitation, added to the fact that the earth's magnetic field is not everywhere nearly vertical, demands a precision of construction which may be unattainable. For example, to reduce to negligible proportions the directive action of a horizontal magnetic intensity of 0·18 gauss upon a suspension of the Coulomb balance type, we should require two magnets equal, and remaining equal, in moment to within one part in a hundred million, and with their magnetic axes aligned in opposite directions with an accuracy of one-hundredth of a second of arc. The conditions applying to an instrument[8] for measuring only the horizontal gradient of vertical intensity are not, however, so severe and unpromising, and it is in this direction that there appears to me to lie hope of practical realisation. One magnet only is required, suspended with its magnetic axis nearly vertical from one end of a torsion balance beam, and suitably counterbalanced by a non-magnetic load at the other end. This is, indeed, a modification of the form used by Eötvös, which he operated with partial but not complete success. The outstanding difficulties to be overcome relate to the elimination of the effects of torsion in the fibre used to suspend the magnet from the beam arm. If this can be done we shall have, as indicated earlier, means of extending greatly the scope of the magnetic method of surveying.

Electrical Methods.

I have left until last reference to electrical methods, not because they are of less importance, but because I am less familiar with them, and could not speak with any of the authority which comes from practical experience. Accordingly I shall use this opportunity of calling special attention to the work of the Imperial Geophysical Experimental Survey[9] which operated in Australia from 1928 to 1930. This survey, under the leadership of Mr. Broughton Edge, whose extensive experience of electrical surveying is well known, was concerned chiefly with electrical investigations. Until its work began, although it required no great insight to recognise that the basis of electrical surveying was the differences of the electrical conductivity of underground bodies, and that the procedure was to measure

[8] The equivalent of the gravity gradiometer, a modification of the Eötvös torsion balance, due to Shaw and Lancaster-Jones. See *Mining Magazine*, May 1929.

[9] The survey was instituted as a result of the suggestion of the Geophysical Sub-Committee of the Committee of Civil Research, and was carried out under the joint auspices of the British Empire Marketing Board and the Australian Commonwealth Government. The report, 'The Principles and Practice of Geophysical Prospecting,' was published in 1931 (Cambridge University Press).

direct or alternating current distribution in the earth's surface, or the implied electromagnetic effects just above the surface, the details of the methods employed were shrouded in mystery.[10] The report of the survey has lifted the veil, and the aims of the Committee of Civil Research, in suggesting this systematic research in the field, have been to a large extent realised. We find the various methods fully described, some of them having been devised and applied for the first time during the survey. The difficulties and limitations, as well as the successes, are made plain, and the conditions determining the choice of the most suitable methods for particular problems are indicated clearly. It is, I think, no exaggeration to say that the report is the most comprehensive and authoritative treatment available of the subject of electrical surveying.

The Future of Geophysical Surveying.

Much, however, remains to be done in all branches of geophysical surveying, in order to put it on a more secure basis and to determine more certainly the scope of its applications. It must be confessed that until quite recently practically all the work was being done by German investigators, both in the construction and improvements of instruments, and in their use in the field. But some interest has now been awakened in this country, and considerable progress has been made in enabling us to take an increasingly active part in the investigations. It would be a pity to let this interest and activity die—yet that is the danger. Unfortunately, in scientific undertakings, whether national or commercial, we have not yet adopted one of the fundamental principles of the family, when the call is everywhere, as now, for economy. Not the full-grown and robust, but the newly-born and undeveloped, first feels the pinch. And, if the infant has a particularly large appetite, or needs special and expensive nourishment, proper provision is more than ever likely to be withheld. In such a situation geophysical surveying finds itself just now. By its nature the work is necessarily costly. Except as regards some aspects of the construction and improvements of instruments it cannot be confined to a laboratory ; and, with the same limitation, it can rarely be an individual effort. Effective research in the field implies adequate scientific personnel, transport, labour and materials, in addition to the instrumental equipment. If we are to make substantial progress in this direction the expense must be faced.

I recognise that it would be foolish, as well as useless, to press now for the initiation of any costly schemes. But it is permissible to hope and

[10] The Report of the Sub-Committee of the Committee of Civil Research on Geophysical Surveying (H.M. Stationery Office, 1927) contains this passage : ' In particular, the electrical method has throughout been treated, by the companies employing it, as a jealously-guarded secret trade process. In the result, little information is available to the general scientific world regarding the methods employed . . . the apparatus required, the field operations, or the interpretation of results. We believe that . . . a full disclosure of the scientific facts would tend, more than anything else, to stimulate the natural development of this method of geophysical surveying, by placing it on a scientific footing, similar to that of the gravimetric method.'

believe that the subject will not be completely neglected in these difficult times. We can occupy the lean years in making ourselves more familiar with what is already known, and in conducting new investigations on a modest scale, as, indeed, is being done at South Kensington by the Imperial College with the assistance of the Department of Scientific and Industrial Research. Then, when the fat years come, and the mining industries again call for the help of geophysicists, we shall be found, at least, not wholly unprepared.

SECTION B.—CHEMISTRY.

SOME ASPECTS OF STEREOCHEMISTRY

ADDRESS BY

DR. W. H. MILLS, F.R.S.,

PRESIDENT OF THE SECTION.

It is many years since the opening address to this Section was devoted to the subject of Stereochemistry. I think, therefore, that it might be useful at this present time to consider some of the problems connected with molecular configuration and review them in the light of present knowledge.

Looking back on the history of stereochemistry we can distinguish a succession of well-marked phases in its development.

There was the initial phase, Pasteur's discovery of *lævo* tartaric acid, his consequent recognition that every optically active substance must have its antipode, and his establishment of the doctrine of molecular dissymmetry.

The theory of van 't Hoff and Le Bel of the relation between molecular dissymmetry and structure in carbon compounds marked the beginning of a second phase. It originated soon after the structure theory had developed sufficiently to provide an adequate basis for it. In the form in which it was presented by van 't Hoff—the theory of the tetrahedral distribution of the valencies of the carbon atom—it provided a framework into which we have been able to fit practically all that we know of the stereochemistry of carbon. For the ensuing quarter of a century stereochemical progress was largely made up of applications of the theory of the asymmetric carbon atom, and the conception still retains its usefulness.

A new stage was marked by Pope's discovery that the valencies of other elements besides carbon had sufficient configurational stability to give rise to mirror-image isomerism, and a further advance was attained when Werner brought within the scope of stereochemical investigation those complex compounds of the transitional elements which at that time seemed to lie outside the domain of the ordinary laws of valency.

By the optical resolution of compounds of this class he established the theory of co-ordination and at the same time demonstrated the association of the co-ordination number 6 with octahedral configuration.

The rule of the asymmetric carbon atom had provided so simple and reliable a guide to indicate when molecular dissymmetry was to be expected in carbon compounds, and the number of stereomers corresponding with a given molecular structure could be so simply determined with its aid that a certain tendency had arisen among organic chemists to think too much in terms of asymmetric atoms and lose sight of the more fundamental principles on which the conception was based. A stage of some importance in the development of stereochemistry was therefore marked by the synthesis, by Perkin and Pope, and the subsequent resolution of methyl*cyclo*hexylideneacetic acid, for this was the first representative to be synthesised of a type of compounds, bearing a certain configurational relationship to allene, in which it is clearly more natural to consider the dissymmetry of the molecule as a whole than to refer it to the presence of an asymmetric atom.

The present period is one that has been marked by particularly notable advances. On the one hand, progress in molecular physics and in crystallography has given us a knowledge of atomic dimensions and of the configuration of simple molecules and ions which, as far as we can see, could never have been obtained by the methods of classical stereochemistry. It is the progress thus attained which chiefly distinguishes the present period from those that have gone before.

During this same period the more purely chemical methods of investigation of molecular configuration have also been yielding results of great interest, some of them in directions in which advances had been quite unanticipated.

We have only to recall the discovery of molecular dissymmetry in the diphenyl series dependent on the restriction of rotation about a single bond, the discovery of optically active sulphinic esters and sulphoxides, and of optically active salts of nitroparaffins, the determination of the true configuration of aldoximes and ketoximes and the demonstration of the non-planar strainless character of six- and higher-membered alicyclic rings to see how far from being exhausted is the usefulness of the methods of classical stereochemistry.

The electronic theory of valency, which was one of the first-fruits of the application of the new knowledge of atomic structure to chemical problems, has greatly increased the clearness of our ideas of the various types of chemical combination, and the octet rule in particular has enabled us to gain a fuller understanding of the constitution of many atomic groupings.

The octet theory has not only led to a greatly increased clearness in our views of the nature of valency. We have only to supplement it by a simple three-dimensional interpretation and it serves also to indicate the relative directions of the valencies in space.

If we consider the general results of the stereochemical investigation of compounds in which we have to infer that a central atom is associated with an octet of electrons corresponding with the electron group of highest principal quantum number in the succeeding inert gas, we find it clearly indicated that there is something in the arrangement of this octet which is related to a tetrahedral configuration.

If this octet really does correspond with that of the inert gas, it is what we might expect if the orbits of the electrons constituting the inert gas octet might in certain circumstances be related to a tetrahedral system of axes.

The tridimensional extension of the octet theory can be simply represented, of course in a purely diagrammatic manner, by placing the four pairs of dots, by which the four pairs of electrons of the octet are indicated, at the four angles of a tetrahedron concentric with the atom under consideration. The diagram will then indicate that another atom linked by a given pair of electrons will be situated on the axis through the corresponding angle of the tetrahedron.

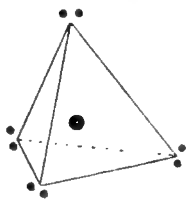


FIG. 1.

There is little doubt that atoms are deformable, and we have clear evidence that valencies can be deflected. We can therefore only expect the tetrahedron to be a regular tetrahedron when the central atom is linked to four other atoms and these are all alike. The tetrahedral octet will therefore only indicate the general character of the configuration of the compounds represented with its aid ; it cannot be expected to predict accurate values of intervalency angles. Subject to this limitation there is, as far as I am aware, no established fact relating to the stereochemistry of compounds formed in accordance with the octet rule which is at variance with the indications of this tridimensional diagram.

Where in such compounds we have to infer the presence of two-electron links only, then we find invariably that a four-co-ordinate atom has a tetrahedral configuration, a three-co-ordinate atom a pyramidal, and a two-co-ordinate atom an angular configuration. This is illustrated by the configurations of methane, ammonia and water.

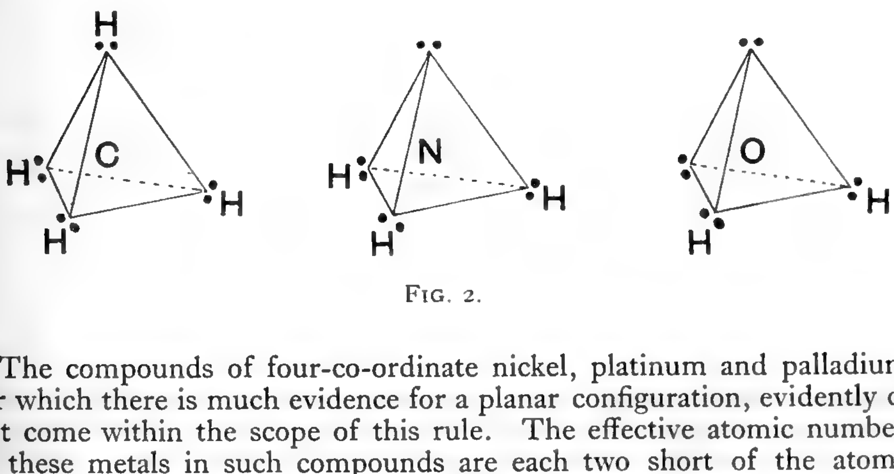
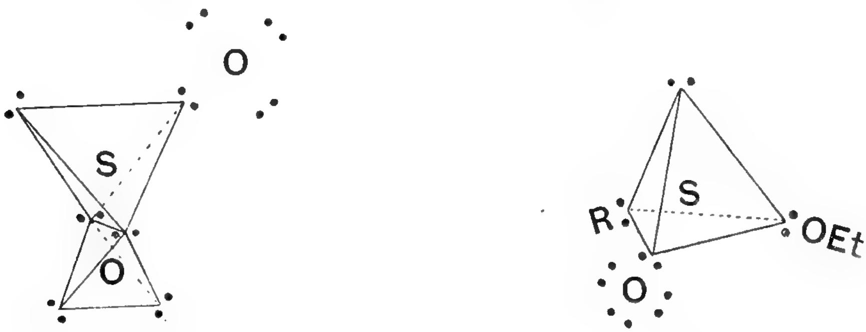


FIG. 2.

The compounds of four-co-ordinate nickel, platinum and palladium, for which there is much evidence for a planar configuration, evidently do not come within the scope of this rule. The effective atomic numbers of these metals in such compounds are each two short of the atomic numbers of the succeeding inert gas. The three-co-ordinate compounds of the elements of the third group of the periodic table likewise lie outside the scope of the rule. An effective atomic number corresponding with the succeeding inert gas is, however, clearly not a necessary condition for a tetrahedral octet, as is shown, for example, by the tetrahedral configuration of the permanganate ion.

Where the presence of four-electron links is to be inferred, the rule similarly correctly indicates the configuration. Thus carbon dioxide, according to the rule, should be a linear compound, and its infra-red spectrum and zero di-pole moment indicate that it has in fact this configuration.

The value of the stereochemical indications given by the octet rule is well illustrated by a comparison of some of the compounds of sulphur with compounds to which, until comparatively recently, chemists were in the habit of attributing similar constitutions. Thus, application of the rule shows at once that sulphur dioxide will not correspond in configuration with carbon dioxide. In sulphur dioxide one oxygen atom, according to



Sulphur dioxide. Sulphinic Ester.

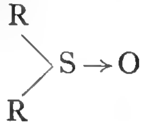
FIG. 3.

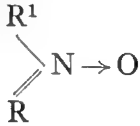
the octet rule, must be bound by a four-electron link, the other by a two-electron link to the sulphur. The tridimensional octet indicates that sulphur dioxide must then have an angular configuration with an angle between the lines joining the sulphur and the oxygen centres which, if the tetrahedron were regular, would be $125 \cdot 5^\circ$; and, as is well known, the large molecular di-pole moment and the indications of the infra-red spectrum of sulphur dioxide show that its configuration must in fact be angular. Again, the analogy of the sulphite ion in configuration to the chlorate ion, both of which according to the results of X-ray examination are pyramidal structures, and its difference from the planar carbonate ion is very clearly shown and on the basis of the octet rule could easily have been predicted.

I believe the highly interesting discovery by Phillips, some seven or eight years ago, of the molecular dissymmetry of the sulphinic esters came as a complete surprise to chemists, for the common practice had been to assign to these compounds a constitution analogous to that attributed to the carboxylic esters. In a similar way the sulphoxides were generally given formulæ corresponding with those of the ketones until Kenyon and Phillips showed that sulphoxides of appropriate constitution could be resolved into optical antimers.

Had the confidence then existed in the octet theory and its stereochemical implication that we have since acquired, the pyramidal configuration of the three-co-ordinate sulphur in these compounds could have been most easily predicted.

A comparison of the sulphoxides with the N-ethers of the oximes is possibly not without interest, since it shows that the presence of a





co-ordinate (or semipolar) link is not in itself sufficient to produce a pyramidal configuration. In the oxime ether the nitrogen atom and the three atoms directly attached to it are evidently co-planar.

Very considerable interest attaches to the possibility of the existence of compounds of tri-co-valent carbon of pyramidal configuration. The triaryl alkyl compounds of the alkali-metals in all probability contain

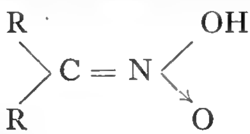
R

the anion R : C̈ : If this is so, this ion must certainly be pyramidal, and

R

hence molecularly dissymmetric when the three aryl radicals are different, but it is not possible at present to predict how stable the antimeric configurations would be. However, questions of considerably greater theoretical importance centre about another type of compounds in which there seems reason to infer the presence of a pyramidal tri-co-valent carbon atom of marked configurational stability.

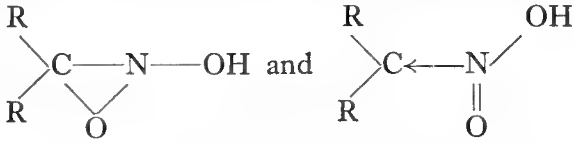
When Hantzsch discovered the *aci*-form of phenylnitromethane he appeared to have obtained exceedingly strong evidence of the correctness of Michael's formula for the sodium salts of the nitroparaffins. There seemed little doubt that the *aci*-form of a secondary nitroparaffin had the constitution which in modern symbols we should represent as :



In a compound of this structure the $> C = N <$ group and the four atoms directly attached to it would evidently lie in one plane. The remarkable discovery by R. Kuhn and Albrecht that optically active methylethylnitromethane retained its activity when converted into its sodium salt showed therefore that the Michael formula could not possibly be right.

With Mr. H. Cole I have recently obtained confirmation of Kuhn and Albrecht's discovery. We have been able to prove that the *aci*-form of phenylcyanonitromethane is molecularly dissymmetric, since we find that the compound can be resolved with alkaloids in the ordinary way. When the brucine salt is converted into the sodium salt a strongly optically active solution is obtained. The activity of the sodium salt seems to be quite stable at the ordinary temperature, but disappears on the addition of excess of mineral acid.

In the present state of knowledge there would appear to be only two possible formulæ for the *aci*-form of a nitroparaffin which would account for the non-planar configuration of the anion thus established. These are:



As Kuhn points out, there are very grave objections to the former of these, the cyclic formula. The nitro-bodies themselves are non-reactive; their *aci*-forms are highly reactive. As regards their general chemical behaviour, the relation between the two forms corresponds very closely with that between keto- and enol-desmotropes. The saturated cyclic formula for the *aci*-form is in entire disaccordance with the high chemical reactivity of the compound. The alternative formula with the tri-co-valent carbon atom seems, on the other hand, to be in harmony with the chemical behaviour of the *aci*-modification, as well as in agreement with its experimentally established non-planar configuration. It would seem therefore that, for the present at any rate, we are bound to accept the second formula in spite of the highly unusual feature which it presents of the tri-co-valent carbon atom.

The configuration of the anion is clearly indicated by the tri-dimensional octet formula (Fig. 4). The distribution of the ionic charge

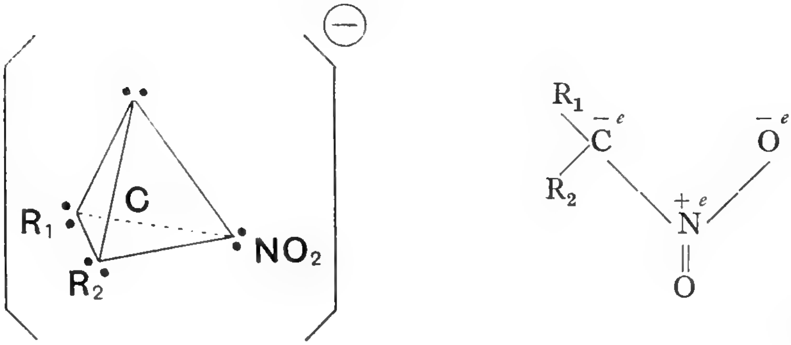


FIG. 4.

is a question of considerable interest. If we were to assume equal sharing of the electrons in each of the valency links by which the nitrogen atom is bound to the three atoms attached to it, our formula would indicate the presence of charges of $-e$ on the carbon and the singly linked oxygen atom and one of $+e$ on the nitrogen atom, $-e$ being the electronic charge. We know, however, that there will not be equal sharing, and the inequality will result in diminishing the negative charges on the carbon and the singly linked oxygen. Part of the negative electricity thus removed will be transferred to the doubly linked oxygen atom, and part will go to diminish the positive charge on the nitrogen. We do not know what amounts will thus be transferred. It would seem probable, however, when we consider the di-pole moment associated with the carbon-oxygen link, that the resultant negative charge of the carbon atom would be more considerably diminished than that of the singly linked oxygen atom.

There is an important point which this formula does not make clear. The anion can combine with the hydrogen ion either to form the *aci*-modification or to regenerate the true nitro-body, and these processes take place with extraordinarily different velocities.

The former change is part of an ionic equilibrium and will occur with the great rapidity characteristic of ionic reactions ; the latter takes place so slowly that its course, in favourable cases, can easily be observed. It would thus appear that, in the encounters of the nitro-ion with hydrogen ions, a considerable proportion of the encounters on the nitro group result in combination (since the acidic hydrogen in crystalline phenyl *iso*-nitromethane, for example, is presumably co-valently linked), whilst an exceedingly minute proportion of the encounters on the negatively charged carbon atom are effective.

It would, therefore, seem that combination of the hydrogen ion with the tri-co-valent carbon atom can only take place under very special conditions which rarely occur. It is thus probable that it is only when this carbon atom is suitably activated that it is capable of combining with a hydrogen ion.

One of the most striking features of the stereochemistry of the pyramidal tri-co-valent atoms is the great variation in configurational stability exhibited by compounds of the different atoms. We may contrast, for example, the permanence of the optical activity of dissymmetric sulphonium ions with the configurational lability of the tertiary amines, which has hitherto prevented the demonstration of their pyramidal configuration by the methods of classical stereochemistry, though it is clearly shown by the considerable molecular di-pole moments which they possess.

There are certain evident principles which must affect the stability of the molecular configuration determined by the relative valency directions of a central atom.

It is clear that increase in the atomic radius of the central atom should diminish configurational stability. It is probably in consequence of this that it is so much easier to obtain quaternary ammonium ions in an optically active state than the corresponding phosphonium and arsonium compresses.

Again, we should expect that compounds in which the normal valency only of the central atom is employed would show greater configurational stability than co-ordination compounds, for the reason that in the latter the nuclear charge of the central atom is relatively less in comparison with the number of electrons it has to control. We may attribute to this cause the optical lability of the compounds of four-co-ordinate beryllium, which contrasts strongly with the configurational stability of the compounds of tetravalent carbon.

It may be noted as a matter of observation that six-co-ordination compounds, which are, as far as is known, universally of octahedral configuration, are more stable configurationally than tetrahedral four-co-ordination compounds. If the movements involved in optical inversion in the two types are considered, it is clear that this is what we should expect.

Finally, it would be anticipated that a compound would have a greater configurational stability if the central atom had a resultant positive charge than if its resultant charge was negative, since the field controlling the octet would be stronger in the former case. Perhaps the difference between the tertiary amines and the sulphonium compounds is partly to be accounted for in this way.

In the tertiary amines we may infer from the di-pole moment—and the length—of the single carbon-to-nitrogen link that the external electrostatic effect of the nitrogen atom and its associated electrons is equivalent approximately to that of a negative charge of $0{\cdot}3e$ at its centre, while the three directly attached carbon atoms have resultant positive charges of about $0{\cdot}1e$.

In the corresponding sulphonium ions we have similarly to infer the existence of positive charges of about $0{\cdot}65e$ on the sulphur atom and $0{\cdot}12e$ on each of the attached carbon atoms. Thus, whilst there is a positive charge on the sulphur in the sulphonium compounds, there is a negative charge on the nitrogen in the amines, and the former should increase and the latter diminish the stability of the associated octet.

On the other hand, if the constitution attributed by Kuhn to the salts of the nitroparaffins is correct—and, as we have seen, there is good reason to think that it is—then in these compounds we have very considerable configurational stability of a tri-co-valent atom associated with the presence of a negative charge.

In view of this it is improbable that the difference in optical stability between the amines and the sulphonium ions can be wholly attributed to a difference in sign of the resultant charge on the central atom, though doubtless this has a contributory effect.

It is interesting to look back on some of the principal difficulties which were encountered in interpreting stereochemical phenomena on the basis of the older conceptions of valency, and to review them from our present standpoint.

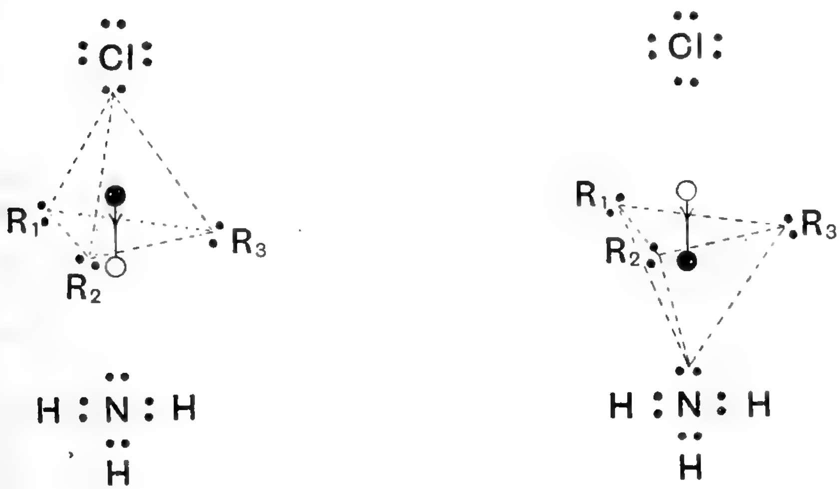
Probably the most conspicuous example of these is afforded by the problem of the Walden inversion, which Emil Fischer described in 1907 as being, 'since the fundamental investigations of Pasteur, the most surprising observation which had been made in the field of optically active compounds.'

The difficulty of bringing the experimental observations on this inversion within the scope of any fixed set of rules is well recognised. I think, however, that if we review the evidence at present available, it might be interpreted as indicating generally that there is at any rate one type of reaction which, taking place at an asymmetric carbon atom, is normally accompanied by an inversion of configuration. This type of reaction is one that might be described as an ionic interchange, and includes such changes as the replacement of halogens by hydroxyl by means of aqueous alkalies, or of the arylsulphoxy-group by the acetoxy-group by means of alkali metal acetates.

Closely allied to reactions of this type—and also apparently normally associated with an inversion of configuration—are the interactions of halogen compounds with ammonia, leading to the formation of a substituted ammonium ion and a halogen ion.

Reactions of these types can be represented with extreme simplicity with the aid of the tetrahedral octet, and it is then seen that they would naturally be accompanied by an inversion of configuration.

Let us take as an example of such an interchange of radicals at an asymmetric carbon atom the reaction commonly referred to as the 'replacement of chlorine by the amino-group' by means of ammonia.



Before reaction. After reaction.

FIG. 5.

In representing this reaction the experimental facts to which we have to give expression are: (i) the asymmetric carbon atom unites with a molecule of ammonia, forming a substituted ammonium ion; (ii) the configuration is inverted; (iii) a chlorine ion is set free.

In order to represent these three facts with the tetrahedral octet we have simply to move the nucleus of the carbon atom away from the chlorine and towards the ammonia (suitably situated) through a distance of half the height of the tetrahedron. It is a movement analogous to that which we have to assume for the nitrogen nucleus in the amines to account for the inversion of configuration which these compounds so readily undergo. When the essential features of the change can be thus so simply and naturally represented, it is difficult to resist the belief that the representation corresponds closely with the reality.

Thermodynamically considered, the reason for the change is to be found in the loss of free energy by which it must be attended, and this is the same whether the process results in an inversion of configuration or not.

From this point of view the necessity for the change is independent of the particular mechanism by which it may be effected, but different mechanisms will bring it about with different velocities.

There would seem an evident possibility, in these ionic interchanges, of the hydroxyl or other anion (or the ammonia) interacting at one of the other three faces of the tetrahedron, in which case no inversion of configuration would ensue. The di-pole moment, which must be associated with the link between the carbon atom and the radical which is going to be eliminated as an anion, will, however, have a directive effect on the attacking anion (or the polar ammonia molecule), and this will cause the probability of approach to be greatest on the opposite face of the tetrahedron, especially when the other substituents are relatively indifferent. Elimination of the ionisable group will also be facilitated most when the movement of the nucleus is directly away from it. Thus it would appear that the mechanism effecting the change with the greatest velocity would be that which produces an inversion of configuration.

In these ionic interchanges the reaction-mechanism is sufficiently clear to enable us to discuss their stereochemical aspect. Reactions such as those of phosphorus pentachloride or thionyl chloride on hydroxylic substances, or even of moist silver oxide on halogen compounds, are evidently more complex, and their mechanism seems at present too imperfectly known to justify speculation on the configurational changes by which they may or may not be accompanied.

A phenomenon which was generally regarded, though not with very good reason, as closely related to the Walden inversion was that of *trans*-addition at a double bond. The two phenomena had, however, this in common, that both showed the inadequacy of the old conception of the solid carbon atom with fixed valency poles. The two solid tetrahedra attached edge to edge and opening on one angle to allow of the attachment of the two addenda gave too crude a picture.

The ethylenic link is now regarded rather as a unit, formed from two pairs of electrons of opposite spins, and possessing torsional rigidity. When combination with, for example, a chlorine molecule occurs, two electrons of opposite spins are taken to share in binding the two chlorine atoms, leaving two, also of opposite spins, to form the single link by which the two carbon atoms remain united.

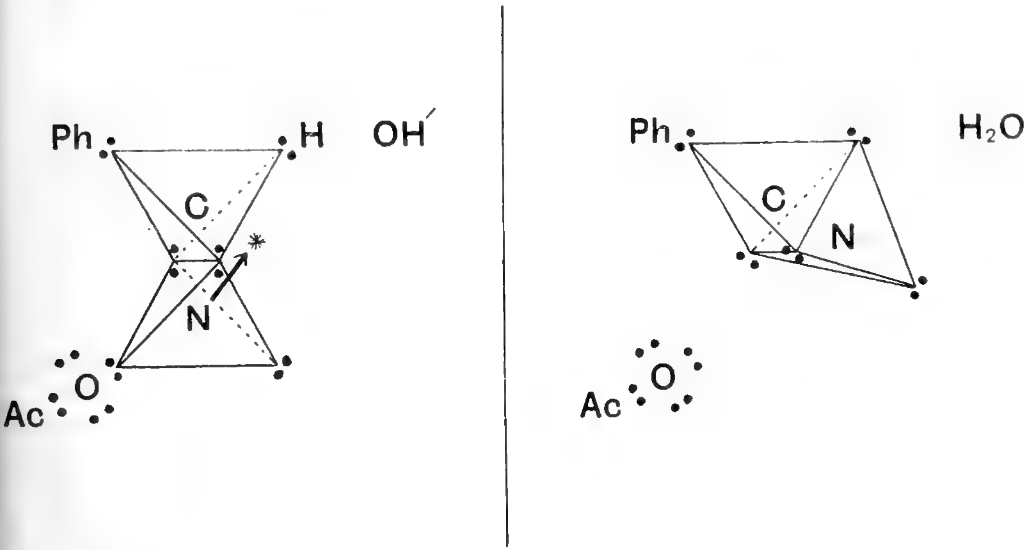
Experiment shows that this process can take place so as to lead either to *cis*- or to *trans*-addition, and, since these may occur concurrently, we may conclude that, so far as the readjustment of the link is concerned, there is no great difference in the facility with which the two types of change take place.

The result appears to be determined partly by the energy relations between the possible products, and, since chlorine shows a greater tendency to *cis*-addition than bromine, it is probable that simple mechanical factors, such as the distance between the centres of the two atoms to be added, have an important effect. It is easy to see that an increase in this distance might favour *trans*-addition.

Closely related to the phenomenon of *trans*-addition is that of *trans*-elimination. It has long been recognised that in ethylene derivatives the *trans*-elimination of radicals takes place as a rule more readily than *cis*-elimination, and more recently evidence has accumulated that this is also the case with the aldoximes and their derivatives.

The assumption which was formerly made that, in a pair of stereo-isomeric aldoximes, the isomer which was the less easily dehydrated had the hydrogen and hydroxyl on opposite sides of the CN group is almost certainly wrong.

Of the different methods of converting β-benzaldoximes into the corresponding benzonitriles, that which proceeds most smoothly, and is probably least obscure in its mechanism, consists in the conversion of the oxime into its acetyl derivative and the treatment of this with aqueous sodium carbonate.



Before reaction. After reaction.

FIG. 6.

The elimination of acetic acid from the oxime acetate is a reaction which can be very clearly represented with the aid of the tetrahedral octet, and with this method of representation it is indicated plainly that *trans*-elimination should take place more readily than *cis*-elimination.

When the acetyl derivative of the β-oxime is treated with sodium carbonate the products are water, benzonitrile, and the acet-ion. The components of benzonitrile and of the acet-ion are already present in the acetyl derivative, and since both are indifferent towards sodium carbonate solution their liberation must take place as a secondary consequence of some direct action of the solution on the molecule of the acetyl derivative. This is clearly the removal of a proton by union with a hydroxyl ion from the alkaline solution to form water. The elimination of acetic acid thus consists of a chain of three events, each dependent on the next. The first is the removal of the proton. The second is the movement of the nitrogen nucleus to bring it into alignment with the phenyl-carbon valency. The third, which is the immediate consequence of the second, is the liberation of the acet-ion.

The determining factor which causes the unequal readiness of *cis*- and *trans*-elimination is the linear configuration of benzonitrile. The centres of the carbon and nitrogen atoms of the cyanogen group and of the carbon atom of the phenyl group to which it is attached lie in a straight line. The formation of benzonitrile therefore entails the movement of the nitrogen nucleus in the direction shown.

In the derivative of the β-oxime, represented in the diagram, this movement is directly away from the acetoxy-group and consequently results in the liberation of this as the acet-ion. The successive events in the chain are correlated, and they proceed readily.

In the corresponding derivative of the α-oxime, the movement of the nitrogen nucleus entails no similar withdrawal from the acetoxy-group. There is no corresponding opportunity for the latter to escape as the acet-ion, and the chain of events does not take place.

In the β-oxime derivative the possibility of the complete withdrawal of the proton is conditioned by the rapid breakdown of the resultant negative ion into benzonitrile and acet-ion. The α-oxime acetate would yield a negative ion which would possess no corresponding tendency to split off an acet-ion. In accordance with its lack of acidity the α-acetate could not, therefore, give up a proton to the alkaline solution.

The greater facility of *trans*-elimination in the ethylene series is evidently capable of an analogous explanation.

Not only were the configurations formerly assigned to the aldoximes based on a false assumption, but we now know from the work of Meisenheimer that those attributed to the stereo-isomeric ketoximes have also to be interchanged. In the Beckmann transformation the radicals which migrate do not lie on the same side, but on opposite sides, of the CN group.

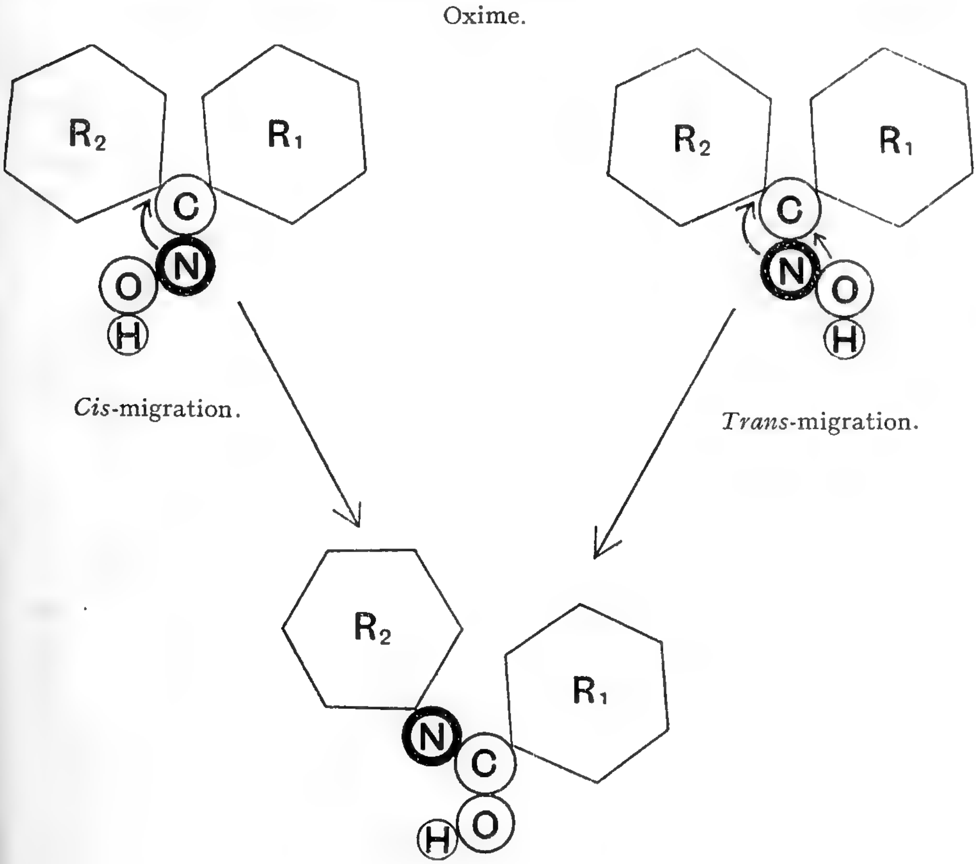
It is usual to think of the migration of the groups. But if we imagine the change occurring in an isolated molecule and remember that moment of momentum must be conserved, it is clear that most of the movement by which the relative displacement is brought about would be executed by the nitrogen atom. We therefore get a truer picture of the change by regarding the groups as relatively stationary and directing our attention on the movement of the nitrogen atom.

Inspection of the diagrams which indicate the alternative movements of the nitrogen atom corresponding with *cis*- and *trans*-migration, shows at once how much more probable the latter is.

The Beckmann change is brought about by energetic reagents, but if we view the phenomenon broadly, disregarding intermediate stages and looking at the final result, it is clear that the principal source of the energy difference between the oxime and the anilide is the replacement of the weak oxygen-to-nitrogen link in the former by the strong oxygen-to-carbon link in the latter compound.

We may accordingly see, as the driving force which brings about the change, the affinity of the oxygen for the central carbon atom. It may therefore be concluded that the first step in the process of actual transformation is probably the attachment of the oxygen atom (or its representative in an intermediate product) to this carbon atom. If this is so, then the consequent displacement of the nitrogen atom must inevitably occur in a direction away from the oxygen atom, that is, in the direction that leads to *trans*-migration.

In any case, the passage of the nitrogen atom across the line of closest



Anilide (enolic form).

FIG. 7.

approach of the oxygen atom to the central carbon atom, which is required for *cis*-migration, must seem exceedingly unlikely.

This more concrete way of looking at the Beckmann transformation enables us to see, I think, very clearly that the *cis*-interchange of groups, instead of being an assumption that could be taken for granted, was in fact a highly improbable hypothesis. It indicates that the natural course for the migration of groups to pursue is that which leads to a *trans*-interchange.

I now pass to the consideration of a question which has been of deep interest to all who have reflected on stereochemical problems, the optical activity of living matter. It was a subject to which Pasteur devoted much thought, and he was disposed to seek the origin of the optical activity of the products of vegetable life in cosmic causes.

'The universe,' he said, 'is a dissymmetrical whole. I am inclined to think that life, as manifested to us, must be a function of the dissymmetry of the universe or of the consequences that result from it. The universe is dissymmetrical; for, if the solar system were placed before a mirror, the image of the bodies that compose it moving with their several motions could not be superposed on the reality. Even the movement of solar light is dissymmetrical. A luminous ray never falls without constant change of direction on the leaf in which vegetable life is bringing about the creation of organic matter. Terrestrial magnetism, the opposition which exists between the north and south poles in a magnet, that offered us by the two electricities positive and negative, are but resultants from dissymmetrical actions and movements.'

Pasteur tried to obtain experimental confirmation of these views. At Strasburg he had powerful magnets constructed with the object of introducing dissymmetric influences during the formation of crystals. At Lille again, in 1854, he had a clockwork arrangement made by means of which he intended, with the aid of a heliostat and reflector, to cause a plant to germinate and grow under conditions in which the natural apparent movement of the sun from east to west was reversed.

Since the discovery by Cotton in 1896 that alkaline solutions of copper tartrate have unequal coefficients of absorption for dextro- and lævo-circularly polarised light, the action of circularly polarised light appeared to be the most promising method of obtaining molecularly dissymmetric compounds in an optically active state without the use of other optically active substances. Since, further, circularly polarised light must occur in nature—as, for example, by reflexion of the plane polarised part of the light of the sky at the surface of the sea—the unequal destruction which it must effect of the dextro- and lævo-forms of dissymmetric compounds, acting for immense periods of time, has been regarded by some as the most probable cause of the optical activity of the compounds contained in living matter, especially as Byk has shown that, in consequence of the rotation of the plane of polarisation of the light by the earth's magnetism, there must be a preponderance of one of the two forms in the total amount of circularly polarised light thus produced.

These considerations have been brought into prominence by the marked success which has recently been attained by Werner Kuhn and Knopf in activating the dimethylamide of α-azidopropionic acid by means of circularly polarised light. Kuhn has discussed the biological significance of this achievement, and he gives reasons to show that the possibility of the optical activity of living matter having been brought about through the long-continued action of circularly polarised light can by no means be rejected.

When one considers, however, the minuteness of the proportion of the total illumination received by an organism under natural conditions that can be circularly polarised, and the difficulty that has been experienced in demonstrating the optically activating effect of this form of light, even under the favourable conditions of the laboratory, it is impossible not to feel a certain scepticism of an explanation based on the action of circularly polarised light thus produced.

It is true that circularly polarised light of greater intensity might be produced by naturally occurring doubly-refracting minerals; but its production in this manner would be necessarily so highly localised and so evenly distributed between the dextro- and lævo-forms that it is difficult to believe that initially optically inactive living matter could be rendered optically active through the agency of circularly polarised light produced in this way.

It would, therefore, seem not out of place to seek for other possible causes of the dissymmetry of living matter, and it may be profitable to inquire whether the property of growth which is characteristic of living matter may not necessarily lead to its dissymmetry.

We know that many components of living matter are substances of great molecular complexity, and the more complex the substance the more likely it is to be molecularly dissymmetric, and, as a matter of fact, a large proportion of the compounds which occur in living organisms are optically active.

Again, many of the reactions which go on in living matter, and on which vital activity depends, are thus reactions between molecularly dissymmetric compounds.

Now when a reaction takes place between two molecularly dissymmetric compounds, there is always more or less difference between the velocities of reaction of a given antimer of the one compound with the two antimeric forms of the other. Thus, as was shown by Marckwald and McKenzie, lævo-menthol reacts more rapidly with dextro-mandelic acid than it does with lævo-mandelic acid.

It is easy to see why this should be. Chemical interaction between organic compounds necessitates the apposition of the two reacting groups in a particular manner, and when each of the reacting groups possesses a complex environment it is evident that there must be a difference in the readiness with which a dissymmetric molecule can be thus apposed to the dextro- and lævo-forms of a co-reactant molecule.

We can express this by saying that reactions between molecularly dissymmetric compounds are *stereo-specific*, and it is fairly obvious that, in general, the more complex the compounds the more highly stereo-specific reactions between them are likely to be.

It is therefore probable that many of the reactions on which vital processes depend are highly stereo-specific. Of isolated reactions that can be studied *in vitro*, it would seem that those most nearly related to the reactions of living matter are reactions involving enzymes, and it is well known how highly stereo-specific these may be.

Now in living matter, every dissymmetric component is present in one only of its two antimeric configurations, and it appears that the configurations of these components are so correlated that each dissymmetric molecule encounters only that antimer of its dissymmetric co-reactants with which it interacts the more rapidly. It is evident that living matter thus constituted must be greatly more efficient than a hypothetical form of living matter in which every dissymmetric component was present in equal quantities of both its antimeric forms.

This can perhaps be made clearer by consideration of some reaction which we might regard as a simplified model of a biological process. Let us consider the hydrolysis of dextro-sucrose by invertase, at not too great concentrations, so that the velocity of hydrolysis is approximately proportional to the concentrations both of substrate and of enzyme, and compare the initial rate of inversion with what it would be if we employed instead inactive materials at the same total concentrations—*dl*-sucrose and inactive invertase. From the known specificity of the action of invertase we may safely assume that ordinary invertase would activate dextro-sucrose only and that its mirror image would activate lævo-sucrose only.

Then it is clear that in the first experiment every sucrose molecule that encountered invertase would be susceptible of activation by it, whereas in the second only half the encounters would be potentially effective and the reaction would proceed at only half the rate at which it takes place in the optically active mixture.

Great caution is obviously necessary in applying the law of mass action to biological processes, since adsorptions on enzymes and on active surfaces have to be taken into account ; if in our model we had sufficiently increased the sugar concentrations, so that the enzyme was working at its maximum capacity, there would have been little or no difference between the rates of hydrolysis in the active and the inactive mixtures.

If, however, we are justified in assuming that in living matter concentrations of this order are not approached, and that diminutions in concentration of a molecular species would be accompanied by an approximately proportionate fall in the velocity of the reaction or reactions in which it was concerned, then the inactivation of living matter by the instantaneous replacement of half of each of its optically active components by their enantiomorphs would suddenly diminish the rates of all the stereo-specific reactions proceeding in it to rates approximating more or less, in the case of reactions of bimolecular type, to one-half of their former magnitudes.

Thus, in a general way, it is clear that if we are right in assuming that the reactions of living matter include reactions of a stereo-specific type, then living matter must gain very greatly in efficiency through the optical activity of its dissymmetric components.

Let us now consider the optical activity of living matter in connection with the phenomenon of growth.

In the growth of, for example, a vegetable organism of a primitive undifferentiated type we observe the existing tissue building up, with the aid of absorbed radiant energy, tissue of the same nature as itself from the materials of its inorganic environment.

We have an association of chemical compounds which is capable of synthesising from simple inorganic materials each of the organic materials of which it is itself composed, and the rates of production of these are controlled, so that each is produced at a rate which, on the average, is proportional to the amount of it present in the tissue.

We have particularly to note that, though the new tissue is built up from symmetrical inorganic materials, each of its dissymmetric components is produced in one only of its two optically active forms, and this form is the same as that present in the tissue by which it has been produced.

We must therefore conclude that the chemical reactions concerned in growth, or at any rate those concerned in the production of the primary dissymmetric tissue components, are completely stereo-specific. The mechanism concerned in the synthesis of, for example, glucose from carbon dioxide and water produces dextro-glucose only without, apparently, a trace of its enantiomorph.

Let us now endeavour to imagine what the effect on the process of growth would be if all the dissymmetric components of the growing tissue were instantaneously racemised. On account of the stereo-specific character of the mechanisms of growth we should then have two practically independent mechanisms working side by side. We should have the original mechanism producing dissymmetric compounds of the configurations which occur in nature, *d*-glucose, *d*-cellulose, *d*-tartaric acid, *l*-leucine, and so on. We may arbitrarily call this the *d*-system. The concentrations of all its dissymmetric components would be reduced by this racemisation to half their original values. Working alongside this, and in practical independence, we should have the enantiomorphous *l*-system producing antimers of the dissymmetric compounds found in nature.

The velocities of the different synthethic processes would be variously affected by this change. The velocity of the fundamental process of carbohydrate photosynthesis, the formation of the symmetrical compound formaldehyde from symmetrical carbon dioxide and water, would remain unchanged. This process is independent of mirror-image isomerism; there is thus no need for assimilation pigments to be optically active, and chlorophyll is in fact described as being optically inactive. Again the condensation of formaldehyde to glucose, in which a dissymmetric polymerisation-catalyst must necessarily be involved, since normally the *d*-form of glucose is alone produced, would take place initially with unaltered velocity on account of the symmetry of formaldehyde. Immediately after the change the inactive tissue would go on producing *dl*-glucose at the same rate at which the optically active tissue had been producing *d*-glucose.

As soon, however, as we come to consider the further transformation of the first formed optically active products, the relative inefficiency of the optically inactive tissue becomes apparent.

If, for example, the glucose in the tissue undergoes a transformation involving interaction with another dissymmetric substance, such as a polymerisation under the influence of a dissymmetric catalyst, then, as we have already seen with our model, the inversion of sucrose, the process should proceed less rapidly in the inactive than in the active tissue to a degree dependent on the order of the reaction involved, provided always that the concentrations are below those at which the catalyst becomes saturated.

It would be out of place to attempt to pursue this in detail. I wish merely to emphasise the conclusion that if the reactions of living matter are as stereo-specific as the optical activity of the products indicates that they are, and if, further, a diminution in the concentration of a reactant in a biochemical process produces a comparable diminution in the reaction velocity, as the study of enzyme actions indicates may be the case as long as certain limits of concentration are not exceeded, then the synthesis of the components of new tissue will proceed more rapidly in living matter constituted, as we now find it, with all its dissymmetric components present in correlated optically active forms, than it would in living matter otherwise identical but optically inactive.

Let us now consider the growth of a tissue which is not completely optically inactive, that is, a tissue in which the *d*- and *l*-systems are not present in equal quantities.

Let us suppose, for example, that there is twice as much of the *d*-system as of the *l*-system.

It is clear, if the arguments which I have put forward are valid, that in the process of growth of a tissue thus constituted, the *d*-system will increase at a relatively greater rate than the *l*-system.

The complex dissymmetric components of the new tissue will be built up from the simple symmetrical food-materials by chains of synthetic reactions and the rates of formation of the end-products will be controlled by the velocity of the slowest link in the chains. If we consider a case in which, as must frequently happen, this slowest link is an interaction involving two dissymmetric molecules, and if we suppose that the application of the law of mass action is so little obscured by adsorption phenomena that we may with sufficient approximation assume that, as in a simple bimolecular reaction, the reaction velocity is proportional to the second power of the concentration, then the rate of formation of the *d*-component will be four times that of its enantiomorph. If this applied to every dissymmetric constituent of the new growth, then, whereas there was twice as much of the *d*- as of the *l*-system in the old tissue, there would be four times as much of the *d*- as of the *l*-system in the new growth.

It will be clear that, even though the reactions of living matter may be less completely stereo-specific than I have, for simplicity, assumed, and though the velocities of the bi- and poly-molecular reactions in question may increase more slowly with the concentration than according to the second power, yet as long as they increase more rapidly than according to the first power of the concentration any excess of one system over the other in the old tissue will become greater in the new growth.

In a subject as complicated as this, and where precise knowledge is so lacking, it is not possible to give an exact proof, but I hope I may have succeeded in indicating that there is an *a priori* probability that an optically inactive growing tissue would be, as regards its optical inactivity, in a state of unstable equilibrium. If there were the slightest departure in either direction from exact equality of the *d*- and *l*-components of the tissue, this would increase with growth continually, according to a compound interest law until, eventually, the system originally in slight defect was completely swamped by its enantiomorph.

From this point of view the optical activity of living matter is an inevitable consequence of its property of growth.

The question how an original bias could have arisen provokes an inquiry into the probable degree of variation from exact equality to be expected in the numbers of *d*- and *l*-molecules when a given number of molecules of a dissymmetric compound are produced under undirected conditions.

It is very well known that the most probable distribution of *d*- and *l*-molecules is that in which the numbers of the two kinds are exactly equal. The probability of the occurrence of this exact distribution, where the numbers are large, is, however, very small, and is greatly exceeded by the sum of the probabilities of the other distributions. An exactly equal distribution will practically never occur, and it is of interest to know the average degree of inequality to be expected for a given number of molecules.

This is easily calculated for a relatively small number, for example, 100,000. Plotting the probabilities of obtaining given numbers of *d*-molecules, as ordinates, against the numbers, as abscissæ, a symmetrical curve is obtained—

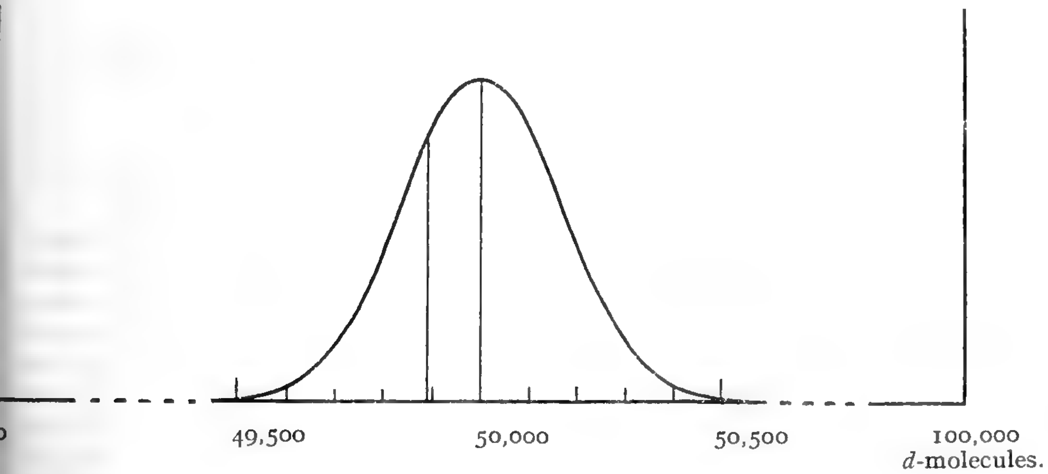


FIG. 8.

which just becomes distinguishable from the base-line at about 49,500 and rises to a maximum at, of course, 50,000 *d*-molecules. The ordinate of 49,894 divides the half-area into two equal portions. If, therefore, a number of groups of 100,000 molecules of a dissymmetric compound are produced under conditions under which the probability of formation of *d*- and *l*-molecules is equal, half the groups will contain an excess of more than 212 molecules of one enantiomorph or the other. We may regard this proportion of 0·21 per cent. as expressing the degree of statistical dissymmetry (which we may call *k*) to be expected when 100,000 dissymmetric molecules are produced under unbiassed conditions.

As we take larger and larger numbers of molecules the average difference between the numbers of *d*- and *l*-molecules produced becomes, of course, absolutely greater, but relatively less.

I am indebted to Mr. L. A. Pars for calculating the very simple relation which exists between the average degree of dissymmetry k and the number of molecules n, when n is large. It is

$$k = 0{\cdot}6743/\sqrt{n}$$

Thus the average degree of dissymmetry sinks to 0·067 per cent. for one million and to 0·021 per cent. for ten million molecules. In other words, when ten million dissymmetric molecules are produced under conditions which favour neither enantiomorph, there is an even chance that the product will contain an excess of more than 0·021 per cent. of one enantiomorph or the other. It is practically impossible for the product to be absolutely optically inactive. It is more probable than not that it will possess a very small but nevertheless a finite optical activity, exceeding 0·021 per cent. of that of the optically pure substance.

Of course, ten million molecules represents a quantity of matter which is exceedingly minute in comparison with the quantities that chemists are accustomed to handle. To gain a concrete notion of the magnitudes involved, we may imagine a catalytically active compound of a molecular weight of 35,000, and, with regard to the well-established biological potency of very small quantities of many substances, we may suppose that it exerts a marked influence on the metabolism of living matter when present at a concentration of 0·1 per cent. Ten million molecules of this substance would then be contained in a sphere of protoplasm of three hundredths of a millimetre, or 30 μ in diameter.

This is at least a thousand times as large (in bulk) as the smallest forms of vegetable life. A number of green algæ and some of the smallest blue-green algæ are only 3 μ in their larger diameter.

In microscopic forms of life it appears, therefore, by no means impossible that the number of molecules of one vitally dominant dissymmetric catalyst contained in an organism might be sufficiently low to ensure the probability of the presence of a small but finite relative excess of one of the enantiomorphous forms, when that quantity of the compound was produced under symmetrical conditions.

If we could assume, therefore, that the first portion of living matter which arose on this planet was of microscopic dimensions, we might account on the basis of the laws of probability for the existence of a minute initial bias towards one optical system or the other; and this would then, if the principles which I have endeavoured to explain are justified, eventually lead to the complete optical activity of the molecularly dissymmetric components of all living matter. The development of the organic kingdom from a single germ would provide a simple explanation of the configurational relationship which appears to exist between the optically active components of the most diverse forms of life, as is illustrated by the occurrence in nature of glucose in its dextro-rotatory form only. The mystery of living matter seems to lie in its power of growth. Given this, the optical activity of its components appears to follow as a necessary consequence of the law of mass action and the stereo-specificity of interactions between dissymmetric compounds.

SECTION C.—GEOLOGY.

THE CONTACTS OF GEOLOGY: THE ICE AGE AND EARLY MAN IN BRITAIN

ADDRESS BY

PROF. P. G. H. BOSWELL, D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

Geology in its Modern Aspects.

One of the most attractive features of geology is the number of its contacts with other sciences and with the industrial arts. In this respect students of our science may account themselves fortunate or otherwise, according to their point of view and degree of maturity. We need only call to mind the recent progress in sciences with which geology makes contact to realise that the geologist is required, by the very breadth of his interests, to keep acquainted with such important advances in knowledge; nor is it accounted to him for virtue to keep to a path of narrow specialisation, unmindful of the limitations which they must necessarily impose.

Geology is primarily an observational science. Only to a limited extent at present are its data amenable to mathematical treatment. None the less, its 'laws' are based on foundations which, established firmly as many of them were nearly a hundred years ago, have survived the searching tests of a century's observations, and have been strengthened in no small measure by the fulfilment of divers predictions. Discoveries that revolutionise the very basis of thought must, from the nature of our subject, be few and far between, and it is therefore unnecessary to discuss the fact that geologists have not for many decades aroused the scientific world by sensational announcements. The development of our science from close observations of innumerable field-phenomena and from cautiously drawn inferences, has been guided by the principle that 'the present is the key to the past.' But this is not to say that startling and fascinating hypotheses have been lacking. I need only cite those of Continental Drift and the Nappe Theory of Mountain-building. It has rather made for strength in our science that these flights of imagination have been looked at askance, after the traditional manner of British geologists; and some attractive hypotheses have not emerged unscathed after careful study in the cold light of accumulated facts.

Trends in geological thought during the past century have often been the subject of presidential addresses. My immediate predecessor in this chair appropriately compared the geological problems of 1831 with those in the succeeding three quarter-centuries. On an earlier occasion Prof. W. J. Sollas, in his characteristically felicitous and convincing manner, reminded us of Huxley's exposition of how first Hutton and then Lyell rescued our science from the stultifying catastrophism of the Noachian flood tradition by founding the Uniformitarian school, whose touchstone was the principle just mentioned, the interpretation of the past by reference to causes now in operation. Huxley further demonstrated how this swing of the pendulum was damped, and (as Prof. Sollas later pointed out) the most striking advance in geological thought engendered, through the publication of *The Origin of Species*, by which Evolutional Uniformitarianism became our watchword. The new conception of the evolution of life on the earth was accompanied, as every great forward movement must be, by theories and hypotheses thrown out far in advance of the army of accumulated facts. Some of these outposts had to be abandoned; others were able to dig themselves in. A long period of consolidation in the battle for enlightenment was inevitable. The onus of testing and proving the general truth of evolution and of describing the nature of evolutionary changes has naturally fallen on the geologist. Such a task, involving laborious stratigraphical and palæontological studies, was one after his own heart, for he was enabled while pursuing it to follow other geological interests. But it was not a task that could be hurried, since it included the full investigation of stratigraphical successions at home and abroad. Indeed, the present detailed studies of the rocks and fossils of small divisions of the geological record had inevitably to become a leading feature in our publications; and, while they bear witness to the fact that the necessary labour is far from finished, they unfortunately tend to repel the student of other sciences. Further, during the last fifty years there has come to us the realisation that not only life, but environment and crustal movement have been undergoing steady changes in character throughout geological history; and we cannot disregard the obvious connection between them. To Eduard Suess we owe the first exposition, in his *Das Antlitz der Erde*, of tectonic geology on a regional scale, a branch of the science which has grown apace. In this study, geologists abroad (whose lines are cast in more favourable places) have taken a relatively greater part than those in Britain. As a branch of science that collates and co-ordinates a huge mass of facts, not always clearly related, but from which we may look forward to illuminating generalisations, regional and tectonic geology must be recognised as a striking feature of our science to-day.

While realising, however, that detailed stratigraphical investigation and field-mapping, with its great British tradition behind it, must remain an essential, we should not lose sight of the fact that geology is also an experimental science. Sir John Flett, in his address to the section at Edinburgh in 1921, reminded us that the earliest synthetic work on the chemistry of igneous magmas and rocks was accomplished by James Hall, who actually melted and recrystallised rocks in the laboratory and investigated the conditions of temperature and pressure that resulted in the recrystallisation of limestone. During the past century, a long line of experimenters has followed Hall's footsteps, but the elaborate equipment now required for physico-chemical investigations in petrology has been a deterrent to work in our impoverished Universities. The wonderful record of achievement of the Geophysical Laboratory in Washington, however, shows what can be done; and we may hope that a revival of activities in this direction will before long be witnessed in this country. As in every science, not less than in some branches of geology, the results obtained and the facts recorded are a measure of the success of the technique employed. The wide range and varied interests of geology now demand a body of investigators thoroughly trained and conversant with the methods of cognate sciences. How can we ensure the supply of such trained geologists, and how are they to acquire the necessary technique?

Geology in Schools and Universities.

Students are still attracted to geology by a pure love of the subject, just as they were in the old days of the great amateurs. Were it not for this, the restriction of science in schools to subjects other than geology would long ago have emptied our university class-rooms. It might be urged that geology offered definite opportunities for an attractive career, but this is a fact of which pre-university students and their mentors are even now only vaguely aware. And we should not forget that the value of geology as a cultural subject has frequently been emphasised. For the breadth of view it engenders and the enthusiasm it inspires, it should find a place in the curriculum of every university student (as it used to in the Royal College of Science and still does in at least one American university).

I may here quote the authority of the Prime Minister, who recently expressed the view that 'if any one of the sciences were selected as the key to all the other sciences—as that which in its subject-matter and its history, the history of its evolution, enforces the true scientific method—geology might be selected as that science. For it touches all the fundamental sciences; it teaches the young how things become, how age merges into age, how species merge into species, how generation merges into generation, institution into institution—in short, how to approach that problem of a working and progressive society by making them acquainted with the processes of earth structure and of life lived on that structure.'

Again, Professor H. E. Armstrong, in one of the wholesome scourgings that he is wont to deliver to the scientific community at not infrequent intervals, rightly declares that the broad culture advocated by Huxley full fifty years ago has not yet come to us. From his own experience, he urges the feasibility and desirability of the study of geology in schools, and would regard it as the only possible foundation of a true geography. I can testify that as a school-subject geology makes an admirable and popular hobby, but it might be inadvisable further to overload an already heavy curriculum by adding it as a regular course of study. As an essential part of his training, we may regard it as highly desirable that the future student of geology should have a working knowledge of elementary chemistry, physics, mathematics and biology. The absence of geology from the school curriculum is not necessarily serious, so long as the formal work imposes no handicap on students who wish to go forward with the subject at the university. In most institutions, however, such a handicap does exist in the form of concessions granted for pre-university training to a University Intermediate standard in subjects such as chemistry, physics, and mathematics, whereby the length or intensity of the university course in those subjects is reduced.

If, however, geology could be introduced more widely into schools (as it has been in some) as part of a general course in elementary science—a revival and extension of Huxley's Physiography—it could with advantage be supplemented by field-excursions, and related to the activities of school societies and museums.

Assuming this general training in elementary science, with possibly an introduction to our subject, we may next ask how its further study is related to the advance of knowledge in other sciences.

The Contacts of Geology.

Geology makes contact with astronomy at an early stage in the history of our planet, when the astronomer hands over the new-born earth for the consideration of the geologist. We accept his assurance that its birth was an extremely unusual, if not almost unique, event, in that it was procreated in the mere approach of solar parents and suffered gestation in a hypothetical tidal disruption. By a process of condensation and sweating, its constituent matter, not differing from that of the other heavenly bodies, became arranged in the concentric shells that allowed life to develop on the surface, and provided there the means for its maintenance.

The earth's history has been that of a pulsating globe, its crust subject both to disturbances that have originated below the surface, and to modifications that have arisen from the interplay of the successive spherical shells known as the lithosphere, hydrosphere, and atmosphere. This interplay is the result of such manifestations of energy as the gravitative action of the sun and moon and radiation from the sun; indeed, the movements of the atmosphere and the action of the tides represent for the geologist the music of the spheres. When and how life arose on the earth is a problem scarcely nearer solution to-day than it was at the first meeting of the British Association, but it is clear that not until Man had evolved as a civilised being did life play more than a minor part in influencing physical environment. In the earlier, as in the later, history of our planet, the problems of geology were of a physico-chemical character, serving to emphasise the contact of geology with its sister sciences of chemistry and physics. Our appreciation of this relationship has developed in recent years with the advances in geochemistry and geophysics. From a desire to further such knowledge have arisen investigations concerned with the stability-relations of elements, of simple chemical compounds, and of minerals generally; with the influence of temperature and pressure on the solid, liquid, and gaseous materials involved in the constitution of the earth; and with the transmission of wave-motion through these materials. By these studies we have come to comprehend, at least in part, the delicacy of equilibrium that exists in rock matter, whether viewed from the standpoints of the constitution of the atom, of phase-rule relationships or of the buoyancy (isostasy) of areas of the earth's crust as a whole. Incidentally, although this is a side-issue of purely scientific investigations, we find at every turn that the door has been opened to important industrial applications of the facts so gathered, and geology in consequence continues to play its rôle as one of the most valuable instruments in the service of Man.

Germane in this connection are the recent and active developments in our knowledge of the formation and emplacement of the deposits of useful metals and non-metals. These advances have resulted from the realisation that the problems involve the application of physical and chemical laws, and that ores, veinstones, and salts ultimately have a genetic connection with sub-crustal magmas. In those cases where superficial deposits conceal from the geologist possible mineral wealth existing at depth, he is now able to call to his aid the methods of applied geophysics—gravitational, magnetic, electric, radio-active, and seismic.

The advances in the technique of geophysical prospecting in recent years are so outstanding as to justify our pausing for a moment to refer to them. Not only is precision given to estimates of the extent and depth of ore-bodies of large dimensions, and of irregular alluvial ore deposits covered by overburden, but the location of the water-table underground, as well as the distinction between fresh and saline waters, and the demarcation of salt-deposits and of the cavities occupied by brine, can also be effected. Estimation of the depth of buried topographic features, and the determination of thickness of overlying deposits such as Glacial Drift (of great importance in establishing foundations), or of detritus like that formed by tropical weathering, can now be made with considerable success. The position of old mine-workings, bad ground, and flooded areas can be determined with safety and at less expense than by the older method of exploration, which might at any moment result in loss of life. It should be emphasised, however, that geophysical prospecting supplements and gives precision to the ordinary geological methods of investigation—it cannot replace them.

As distinct from their formation, the concentration of sparsely disseminated elements and compounds into workable masses is due to chemical and physical processes ; similarly, the action of plants and animals results in the concentration of energy in such fuel-products as the various coals, oil-shales and petroleum. Exactly in what manner deposits of the latter type formed and accumulated in commercial quantities is by no means clear, nor for that matter is it always evident in the case of metallic ores (as was manifest from the discussions in this Section at the Centenary Meeting). But we may hope for further enlightenment from experimental and synthetic work at present in progress, especially when it guides and is guided by further field-investigations.

Time was when the establishment of the truth of organic evolution and the concomitant inquiry into the manner in which the minute changes in organisms arose was all-sufficient for the majority of thinkers. But Eduard Suess, with a wider and deeper grasp of the essentials of earth-history, approached more nearly to a philosophic conception, when he wrote in an oft-quoted passage of ' those great physical changes in comparison with which the changes in the organic world only appear as phenomena of the second order, as simple consequences.' To determine fully the profound influence exercised by those rhythmic or cataclysmic earth-movements on the evolution of life is, however, only to carry the inquiry a stage farther back. The *vera causa* still remains obscure. Latterly we have witnessed efforts to explain both mountain-building movements and the more widespread interchange of areas of land and sea as the effects of convection currents in the earth's interior, resulting from changes of density due to temperature and pressure or to mineral rearrangement in the subcrustal materials : 'oft the teeming earth Is with a kind of colic pinch'd and vex'd.'

Thus we arrive once more at the necessity for an understanding of the problems of physico-chemical relationships. Whether sub-crustal volume-changes in minerals and rocks originate as the result of a legacy from solar parentage in the form of the earth's internal heat, or of the running-down of the radio-active clock, is still a matter for discussion ; but there is little doubt that the effects of the atmosphere and hydrosphere on the crust, in eroding a load of rock in one place and imposing newly-formed sediment in another, have played their part in determining the location of crustal disturbances.

Many of the other contacts of geology are so obvious and familiar that I need only refer to them briefly. Such, for example, are illustrated by the intimate relationships of botany and zoology to palæobotany and palæozoology. Again, it is unnecessary to emphasise that the study of either living organisms or fossil remains cannot be effective if divorced from one another. Nor need one amplify the statement that the proof of the reality of evolution rests with the geologist.

In the case of geography, the connection may be through the physical or the humanistic sides. Physical geography, for example, is but physical geology re-named and, as a *sine qua non* of preliminary geographical studies, its essential basis is field-work. It can only be taught effectively, therefore, by the geologist. The influence on the development of mankind of the major crustal features of the earth and of scenic types is profound, as also is that of the solid and superficial rocks and of the various mineral resources contained in them. To mention only one example, the partition of Hungary, like the restoration of Alsace, suggests that if a geological map did not hang on the wall at the Versailles Congress, its implications were in the minds of those present.

In the application of geological principles to the problems of civil engineering we have a contact which has become increasingly close during the last half-century. Indeed, it is scarcely an exaggeration to say that no great engineering undertaking that involves an interference with the materials and loading of the earth's crust is now promoted without geological advice. Loss of life and money, as well as the possibility of subsequent litigation, is thereby reduced to a minimum. Canal-cutting, tunnelling, road and railway construction, drainage, coast-erosion, mitigation of earthquake-effects, harbour-engineering, sanitation, and impounding of water-supplies for either power purposes or direct utilisation all require a detailed knowledge of the geology of the locality if they are to be successfully prosecuted. The recovery of underground water by means of wells, boreholes, and adits has long been dependent on the advice of the geologist, and it is no less his function to take into careful consideration in this and other connections the location of cemeteries, the methods of disposal of sewage, and the prevention of the pollution of rivers.

Apart from the problems involved in the proper location of means of communication and of heavy structures, the provision of raw materials used in constructional work falls largely within the geologist's province. Natural road-stones and building-stones are still in great demand, although they were at one time more widely used than now. At the present day the geologist is called upon to provide the raw materials for the making of concrete, artificial stone, bricks, and cement. Concrete and the various artificial stones which are now being extensively manufactured find their analogues in the rocks, and the improvement in their quality, as in that of cement, is both a geological and geochemical problem. Questions of the deterioration or improvement with time of natural and artificial stone, cement, bricks, and mortar are paralleled by the decay or induration of rocks, a field of inquiry but little explored.

I must ask indulgence for thus labouring the obvious, but it is appropriate from time to time to review, as my predecessors in this chair have done, the services demanded from geology by the ever-increasing needs of the community. It is not without relief that I turn to a contact where geology is able to help in the spirit of pure investigation, that of the relationship of Early Man to well-established geological phenomena. Here we may well fail to see any practical applications or utilitarian reward, but the discussion is none the less interesting for all that.

The Ice Age and Early Man in Britain.

When the British Association last met in York (in 1906), G. W. Lamplugh, then President of Section C, expounded the view that, with the evidence then available, he could find no proof of interglacial epochs in Britain, but only of a period of continuous glaciation during which ' the margins of the ice-lobes underwent extensive oscillations.' The case which he presented so skilfully and with such an extensive knowledge of field-phenomena and literature was difficult to answer. Further data and increased knowledge of the history of Man in Britain have caused most, if not all, of us to adopt the multiglacial theory. It will be my task to summarise the evidence that has produced this change of view from monoglacialism.

The recent fortunate discoveries of skeletal remains of primitive Man in China, Java, Palestine, and East and South Africa, remarkable as they are, should not cause us to lose sight of the fact that the steady advance of archæological knowledge in this country during the past two or three decades has been no less startling. Only some fifty years ago, Skertchley's advocacy of the great antiquity of Man in the Fen country was received with scepticism. At the present day it is recognised on all hands that the rise of Man was not a post-glacial phenomenon; on the contrary, we are now certain that Man was as characteristic a mammal of glacial and interglacial times as the mammoth and straight-tusked elephant. The tendency to regard present-day geographical conditions as having been inaugurated after the passing of the Ice Age is still seen in the practice of referring the terraces of existing rivers to post-glacial times. When, therefore, a river-terrace is described as post-glacial because it is proved to be of later date than the local boulder clay, we should remember that this use of the term post-glacial has only a local significance and is therefore loosely applied. The very extent of the broad and elevated areas of ancient river-gravels is evidence of conditions capable of giving rise to rivers of great volume. If such conditions were due to a very heavy rainfall, they would be accompanied by an exceptionally luxuriant flora ; but of this we have no evidence. More probably, therefore, the volume of water arose from melting ice.

It is because the work of the last twenty years has so greatly resolved the difficulty of co-ordinating the evidence of Man's activities with that of the advance and retreat of the glaciers, that I have elected in this address to review our state of knowledge of the subject. This is not to say that the difficulties have all been overcome, but the reception accorded to an attempt which I made recently at scavenging among the confused deposits and literature of East Anglian geology and prehistory encourages me to make another effort. It can but afford an incentive to vigorous discussion and the consequent establishment of relationships at present obscure.

As has frequently happened in British stratigraphical history, the situation of our country has provided exceptionally valuable imformation for use in correlation. Special conditions resulted from the position of the greater part of the British Isles as an area just beyond the margin of successive glaciations ; in addition, a remarkable variety of human industries has been found. Our cultural evidence cannot vie with that of the caves of France and northern Spain, with their richness in painting and sculpture, but we may claim that the prehistoric remains in Britain have more illuminating contacts than those abroad.

As is well known, an elevation of the British area of little more than 100 feet would be sufficient to re-establish land-connection with the Continent by way of the east and south-east of England. We have good evidence in support of the view that in late Pliocene times such a connection existed, and that the area now occupied by the North Sea was land drained by a large forerunner of the present River Rhine, of which the Thames and other rivers of the east of England were merely tributaries. The ' warm ' and southern fresh-water shell, *Corbicula fluminalis*, now living in the Nile, Euphrates, and other southern rivers, had already established itself in streams that fed the late Pliocene representative of the North Sea. Under the climatic oscillations which followed during the Glacial Epoch, it appears to have retreated southwards before the ice-advance and only to have returned to our area in Acheulian interglacial times.

Wherever the cradle of Man may have been, Asia or Africa, the evidence of prehistoric stations shows that the waves of his successive migrations advanced north-westwards across Europe. The British Isles were his *Ultima Thule*, along the road to which he sought his prey. His advance was determined by the extent to which the country was ice-free, for we find that successive human industries extend farther northwards and north-westwards as the ice retreated, although the re-advances of the glaciers and flooding of the country temporarily drove the new invader back.

If the time-succession of human industries recognised by our archæological colleagues holds good (and in general it is becoming more firmly established every year), we should expect the sequence pre-Chellian, Chellian, Acheulian (Clactonian-Levalloisian), Mousterian, Aurignacian, Solutrian, Magdalenian, Tardenoisian, and Neolithic, when traced north-westwards across England, to display the phenomena known to geologists as overlap. The newer deposits and human waves would extend farther than the older, as the area was opened up to them by the retreat of the ice.

This is found to be broadly the case. I propose, therefore, to examine the evidence for the contact of Early Man with stratigraphical horizons in the east of England, then to endeavour to trace the history of events across the Pennines to the Irish Sea, and thence to return by way of the Severn Valley and the Thames.

The praiseworthy labours, extending over a long period of years, of the officers of the Geological Survey, and the work of numerous other investigators, have served to show that, in the main, the topographic features of Britain at the beginning of the Ice Age were similar to those of to-day. Many of our important river-valleys, long thought to be post-glacial, are now known to have been pre-glacial. They have been modified in detail, it is true, and their terraces have in many cases been proved to be of inter-glacial and late-glacial age. On the other hand, glaciers have here and there acted as dams and, by forming glacier-lakes and overflow channels, have caused permanent modification of river-courses ; such effects can, of course, be recognised without difficulty.

The distinction formerly drawn between River-Drift Man (Early Palæolithic) and Cave Man (Late Palæolithic) belongs almost to the dark ages of the science. We recognise now that human occupation-sites were largely determined by environment and topographic features. If no caves were available, late Palæolithic Man was as ready as his forbears to establish camps on open sites. River-Drift Man could not inhabit caves in Britain for the very good reason that caves almost exclusively occurred in areas protected by contemporary ice or snow.

Our attempts at correlation may suitably begin in the east of England, where the succession of Late Pliocene and glacial deposits is most complete.

East Anglia.

The oldest deposit of undoubted glacial origin in Britain is found as remnants which have escaped denudation in the east of Norfolk (where it is known as the Norwich Brickearth), in Yorkshire (the Basement Clay), and in Durham (the Scandinavian Drift). No remains of Man have been found in it, and its age is inferred by reference to beds above and below. Nevertheless, in the Crag deposits which underlie the Norwich Brickearth and are referred to the later Pliocene, the late W. G. Clarke, Mr. J. Reid Moir and Mr. J. E. Sainty have discovered worked flints which are accepted by most archæologists as artefacts. The Crag deposits consist of marine shelly sands and loams, with 'stone-beds' at the base of their several divisions; and it is in the stone-beds that the worked flints known as rostro-carinates and also large flakes are found. If the flints were worked by Man the industry would appear to be pre-Chellian.

The next horizon containing supposedly-worked flints is the gravel bed which often forms the base of the Cromer Forest-bed. If it is agreed that the deposit of coarse flints on the foreshore between Cromer and East Runton is the undisturbed local base of the Forest-bed, and if the flaking of the flints is regarded as Man's handiwork, we here have evidence of another pre-Chellian industry, of which flakes and not rostro-carinates are typical forms. The accompanying fauna, including *Elephas antiquus* (the straight-tusked elephant), *Hippopotamus amphibius*, *Rhinoceros etruscus*, and *R. leptorhinus*, contains ancient elements in addition to forms associated with Chellian Man on the Continent. Above the gravels of the Cromer Forest-bed are black laminated clays containing peat with occasional scattered flint fragments, usually small, and displaying a characteristic black shiny lustre. No flints of undoubted human manufacture have been found *in situ* in this bed, but from time to time implements have been discovered on the foreshore and in one instance in the Cromer Till. From their appearance and patina, it has been assumed that they came from the black clays. They comprise 'Chellian' hand-axes and flakes, but, as will presently be seen, they must either belong to an earlier industry than that generally included in the Chellian, or the Chellian industry must straddle a major glaciation, that of the Norwich Brickearth; it may even straddle two glaciations.

The progress of climatic cooling, indicated by the mollusca of the various Crag deposits, is continued in the two succeeding deposits, the Leda-myalis Bed and the impersistent and rarely-exposed Arctic Freshwater Bed, in neither of which have remains of Man yet been found. These beds, however, have some significance for the archæologist, for they suggest an elevation of the sea-floor and the production of an extensive land-surface in East Anglia. What beings peopled that land-surface we do not know. As parts of it persisted for long ages, while other parts were covered by glacial deposits and again exposed by denudation, it is impossible at the moment to refer to their relative position in the geological time-scale any materials that may have been subsequently picked up from this surface.

At the end of the episode of the Arctic Freshwater Bed and the Leda-myalis Bed a striking change of physical conditions is inferred, for the next deposit is the Norwich Brickearth already mentioned. This consists of clayey sands in which pebbles and boulders of chalk, flint, and crystalline rocks are scattered sporadically. No rocks identifiable as of exclusively British provenance have been found in it, but numerous types peculiar to Norway have been recognised. Of late years opinion has been veering to the view that it has originated from the melting of an ice-sheet in water, but whether this water was brackish or salt is not known. Undoubtedly the ice-sheet had not only delivered into East Anglia boulders transported from Scandinavia, but had also incorporated much material from the bed of the North Sea, including fragments of shells.

The striking feature of the Norwich Brickearth, as we see it to-day, is its oxidised and sometimes decalcified character ; it presents an eroded appearance, and its surface is often hummocky and weathered. One indication of its antiquity is the fact that the river-systems of eastern Norfolk have been carved through it. The deposits of the next glacial episode (the Great Chalky Boulder Clay) occur *within* the valleys and wrap over their slopes, so that an important and probably long period must have intervened between the two glaciations. During this period elevation occurred, extensive valley-erosion took place, and the brickearth was weathered and denuded. At certain localities near Yarmouth sands were deposited (' Mid-glacial ' sands) which overlie the Norwich Brickearth and contain a cold molluscan fauna, formerly regarded as derived, but now generally believed to be indigenous. The evidence thus goes to show that the interval, although protracted, was scarcely warm ; nevertheless, the amelioration of climate was sufficient to ensure that the North Sea ice retreated completely from the land-area of Britain, giving place to sheets of shallow water, sufficiently saline to support a marine fauna. At a later stage, the elevation of the area (presumably consequent upon the removal of the ice-load) resulted in the excavation or re-excavation of the valley-systems of eastern Suffolk and Norfolk just referred to.

While these physical changes were in operation Man was possibly not absent from the scene. Although we find no undisputed evidence of his remains in the sands and gravels, we should remember that he is not an aquatic animal. In certain of the so-called ' Mid-Glacial Sands and Gravels ' Mr. Reid Moir has found what he claims to be early points and edged-worked scrapers of Acheulian type. The flaking of these flints is not accepted as human by all archæologists, and there is the additional stratigraphical difficulty that the sands and gravels of different parts of East Anglia (formerly mapped together as ' Mid-Glacial ') include deposits which lie both above and below the Great Chalky Boulder Clay. Similar sands and gravels occur also below and even within the Norwich Brickearth, and have up to the present proved difficult to distinguish from one another.

When the ice-sheets re-advanced over East Anglia they brought with them rock-debris of a very different character from that which built up the Norwich Brickearth. While the matrix of the Brickearth suggests that the bottom-deposits of the North Sea, including probably the unconsolidated sands and clays of the Eocene and Pliocene, were largely incorporated, the boulder clay of the re-advance is constituted almost entirely of material from well-known British outcrops. These include igneous rocks from the north of England, the Cheviots, and Scotland, Upper Palæozoic limestones and sandstones, and various examples from the Triassic, Jurassic and Cretaceous Systems. Notably, the Oxford and Kimmeridge Clays of the Fen area and the Chalk provided the bulk of the constituents. A minor quantity of Scandinavian rocks, incorporated in Cambridgeshire and Hertfordshire, represents the remnants of the ploughing-up of the Scandinavian Drift, of which otherwise no traces are left in these areas. No implements of undoubted human origin have been found in the Great Chalky Boulder Clay, but Mr. Reid Moir has from time to time announced discoveries of Mousterian flakes and points. Even if the flaking on these flints is accepted, I feel that the provenance of many is questionable, for the deposits in which they were found may have been a second (Upper) Chalky Boulder Clay, to be referred to later as the Upper Chalky Drift.

Long ago Clement Reid and James Geikie stated their belief that the far-famed Cromer Till of the coast of Norfolk passed laterally into the Great Chalky Boulder Clay. In Geikie's view the Cromer Till and Contorted Drift were the product of his second glaciation, the Weybourn Crag representing his first glaciation of the east of England. I have elsewhere summarised the stratigraphical evidence bearing on this point and need only say here that the Weybourn Crag does not itself appear to me to yield evidence of more than the gradual refrigeration of climate in late Pliocene times. In its lithological characters the Cromer Till is essentially different from the Norwich Brickearth. It contains numerous erratics of British type, but Scandinavian erratics also occur here and there. To explain the archæological difficulties, I should be inclined to regard the Cromer Till and Great Chalky Boulder Clay as contemporaneous, but Dr. J. D. Solomon prefers to follow Harmer in grouping the Cromer Till with the Norwich Brickearth.

The general lithology of the deposit and the sporadic occurrence of the erratics suggest that the Till melted out in water, possibly when the ice-margin was slowly retreating from the area. Mr. Solomon adduces good evidence in support of the view that Clement Reid's subdivisions of the Cromer Till, the First and Second Tills of the Mundesley area, separated by sands and loams, represent an oscillation during the glaciation, when a temporary retreat of the ice permitted the deposition of sands and loams in a lake-like area of water.

F. W. Harmer followed James Geikie in grouping with the Cromer Till the Contorted Drift, which overlies and incorporates portions of the Till. He also correlated both of them with the Norwich Brickearth, and with the highly Chalky Drift of Sheringham and Weybourn, holding firmly to the opinion that the Cromer Ridge was the terminal moraine of the North Sea (Scandinavian) ice-sheet, of which the Norwich Brick-earth was the *moraine profonde*. But the topography of the Cromer Moraine is youthful and almost unmodified by erosion, as many observers have noted. The correlation of the Cromer Moraine with the Norwich Brickearth cannot be maintained on the geological evidence, and it breaks down entirely when the archæological succession is taken into account.

The marly or chalky drift of the Weybourn area was regarded by H. B. Woodward and the Geological Survey as part of the Great Chalky Boulder Clay, contemporaneous with that exposed, for example, at Cawston, which contains erratics of Neocomian Sandstone, Red Chalk, and tabular Lincolnshire flint. This Chalky-Neocomian Boulder Clay is a facies of the Great Chalky Boulder Clay and is clearly the lateral equivalent of the Chalky-Jurassic Boulder Clay. As indicated on Harmer's maps, it lies side by side with it in Lincolnshire, Norfolk and Cambridgeshire, and was regarded by him as reflecting the different outcrops along the strike of which the Great Eastern Glacier travelled.

No Chalky-Neocomian Drift has been encountered in the area of the Cromer Moraine; indeed, from Weybourn eastwards, it is not seen again until it appears, interdigitating with the Chalky-Jurassic Boulder Clay, at Scratby, near Ormesby, north of Yarmouth. The line of demarcation between the two facies of boulder clay, having passed south of Norwich, sweeps north-eastwards and then northwards. The absence of the Chalky Boulder Clay in the Cromer district suggests that the ice had rounded some obstacle which prevented its direct passage over northern Norfolk. There was no high ground to form such an obstacle, for the Cromer Moraine was not then in existence. One is therefore tempted to infer that the ice which produced the Cromer Till, and which, on the evidence of its erratics, had passed down the east coast of England to the Norfolk coast, lay in the way.

Before leaving the problem of the Cromer Till and Contorted Drift, I must make reference to the implements found in association with these deposits. Unfortunately, finds of Chellian implements have been very few and the provenance of all but one is a matter of inference. As I have discussed the evidence in detail elsewhere, and given references to the appropriate literature, I will here only repeat the general conclusions. If the workmanship of the hand-axes in question be accepted as Chellian, and if the implements came from undisturbed Cromer Till, then the probability is that they were picked up from the surface (perhaps a land-surface) of the Cromer Forest-bed or other Pliocene deposits, or of the Norwich Brickearth, by the oncoming Cromer Till ice. In that event the Chellian industry of Cromer would be of pre-Chalky Boulder Clay age and would be separated from the Acheulian by the glaciation which produced that Boulder Clay. The intimate association of the Chellian and Acheulian implements in many river-gravels and the gradualness of the change in the technique of flaking are not necessarily arguments against an intervening glaciation; further, when Chellian and Acheulian implements are found together elsewhere, the former are commonly much more abraded and scratched than the latter. Indeed, the fact that the majority of the Chellian implements found throughout England are as a rule rolled and usually occur in the oldest implement-bearing gravels suggests that they may have been derived from a land-surface at a time when a marked change of conditions resulted in torrential floods. Evidence supporting this view is found in the Whitlingham deposits, to be described later.

In the Cromer district Acheulian flakes and axes have been found in gravels lying above the Contorted Drift (the so-called river-gravels at West Runton and the Cannon-Shot gravels of the Ridge). These implements are probably derived, but if they are unrolled and *in situ*, as has been claimed, the underlying Contorted Drift into which the gravels are eroded must be pre-Acheulian, that is, the disturbances are probably due to the ice-sheet which produced the Great Chalky Boulder Clay.

The deposits which succeed the Great Chalky Boulder Clay (using that term to include the Chalky-Jurassic Boulder Clay and the Chalky-Neocomian Boulder Clay) yield the most satisfactory evidence known to us of a widespread climatic change. The ice retreated from practically the whole, if not the whole, of East Anglia, leaving here and there trails and fans of sands and gravel and occasional lake-like areas, often several square miles in extent, in which laminated clays and loams were deposited. Some of these basins, like that at Hoxne, were connected with the existing river-systems, others lay high on the boulder clay plateau ; all seem to have become gradually silted up with sediment which, from its petrographical character, is evidently the finer washed-out matrix of the Great Chalky Boulder Clay. The deposits are laminated, but no true varves have been found. In the present connection, however, the main point of interest lies in their fossil-contents, which include leaves, pollen, land and fresh-water shells, bones and teeth of the larger mammalia, and the implements of Man.

Chief among these ancient lakes are the basins at Ipswich (Foxhall Road), Hoxne and Hitchin. The flora contained in the upper part of the series of laminated clays indicates that the climate then differed but little from that of the present day. Reedy fens and alder-cars bounded the lakes, and elm, oak, birch, spruce, pine, and hazel formed the neighbouring woodland. Beavers were to be found in the streams and the horse and red deer roamed over the country.

In the gravels and brickearths lying in the basins are found ' floors ' of industries of Upper Acheulian type, a special feature being the beautifully fashioned and entirely unrolled hand-axes. The succession at Hoxne in particular consists of Chalky-Jurassic Boulder Clay overlain successively by (*a*) brickearth containing temperate plants like those of to-day, (*b*) a loam with dwarf birch and supposed arctic willow, (*c*) gravels and brickearths with late Acheulian implements, mammoth, and reindeer, (*d*) laminated clays with Early Mousterian implements and temperate plants and animals, and, finally, (*e*) deposits like boulder-clay, and disturbed gravels. While the successions at Ipswich and Hitchin are similar, only at Hoxne is there found, below the Acheulian layer, a bed, already referred to, containing the ' arctic ' plants, now considered to be evidence of cold but not of arctic conditions. Thus between two temperate climatic phases we find a cold oscillation, and this oscillation must be placed just before the Upper Acheulian. Sealing up these lake-like depressions are deposits of sand, gravel, and stony clay variously termed ' trail ' and boulder clay. Rafts of a Chalky Boulder Clay actually occur in the gravels, but may be in part derived. The great amount of disturbance to which the uppermost deposits have been subjected is a strong indication of the resumption of glacial conditions, especially as there is in places a thin deposit of intensely Chalky Boulder Clay. I cannot but regard the evidence for a post-Early Mousterian cold period in East Anglia as firmly established, even if the phenomena are explained as due to the slumping of snow and sludge rather than the work of ice. A more general term than ' Upper Chalky Boulder Clay ' is desirable for these variable deposits of post-Early Mousterian age, and I therefore adopt Dr. Solomon's designation for them of Upper Chalky Drift (his Little Eastern glaciation).

In the present state of our knowledge we cannot consider the Upper Chalky Drift in East Anglia to be due to a major glaciation of the same intensity as those that produced the Norwich Brickearth and the Great Chalky Boulder Clay, respectively, for the following reasons. Deposits of this age are not widespread, or at least have not yet been identified (possibly because of the absence of human industries) at more than a few localities. They occur more frequently in the valleys, but here again the evidence is conflicting, for on both the slopes and bottoms of the valleys Mousterian Man left ' floors ' containing Combe Capelle and Levallois types, as discovered near Ipswich by Miss Layard and Mr. Reid Moir. Probably all these industries, however, are referable to Early Mousterian, whereas the glaciation was apparently Middle to Late Mousterian.

To revert for a few moments to the pre-Upper-Chalky-Drift interval, let us consider the conditions that obtained in the river-valleys while the lake-areas were being silted up. The valleys had been partly infilled with Chalky Boulder Clay and its associated sands and gravels. The melting and retreat of the ice not only produced in the plateau-country spreads of glacieluvial gravel containing Chalky and Jurassic debris, but must have resulted in floods descending the valleys. A period, first of erosion and later of aggradation, appears to have set in, and the river-terraces situated at from 50 feet (River Yare) to 70–80 feet (River Stour) above present river-level were formed. The streams were doubtless braided, and, as they wandered to and fro in the valleys, formed gravel-flats of which the range from bank to bank extended from one to three miles. The terrace-materials are frequently indistinguishable from glacial gravels, and had undoubtedly the same origin. But in them rolled Chellian and Early Acheulian implements, especially hand-axes, are occasionally found. In particular, at Whitlingham, in the valley of the Yare near Norwich, Messrs. J. E. Sainty and H. H. Halls made a wonderful collection of nearly 300 implements, of which a few were rolled and striated Chellian types, but the majority unrolled and probably of Late Acheulian age. The absence of evidence of a land-surface and of peaty bands suggests that Acheulian Man was following the retreating ice-sheet, possibly at no great distance from it, and was temporarily encamping on gravel-banks adjoining the streams. Although negative evidence is never entirely satisfac ory, we may recall that no beds of peat or planty layers have been recorded in the lake-like areas of brick-earth that occupy hollows in the Chalky Boulder Clay of Norfolk ; it is conceivable that, being nearer the ice-margin, the area was subjected to more rigorous conditions and more scour from melt-waters than the country farther south.

At another interesting locality, Dovercourt, near Harwich, the ancient gravels of the river Stour lying at about 74 ft. above the river-level yielded to W. C. Underwood a series of implements and bones. The implements included rare Chellian types and a large collection of Early and Late Acheulian axes, unrolled and unscratched. The mammalian bones did not represent a distinctive fauna, but included fallow-deer, mammoth, and *Rhinoceros leptorhinus*. In a second (later) terrace of brickearth lying at a few feet above river-level at Stutton, *Corbicula fluminalis* occurred in association with other land and freshwater shells. This was the first appearance of *Corbicula fluminalis* in East Anglia since the late Pliocene (Cromer Forest-bed and Weybourn Crag), and in time (post-Chellian to Upper Acheulian) appears to correspond approximately with its appearance elsewhere in the British area. We have no evidence that it was present in England during the earlier (pre-Chalky Jurassic Boulder Clay) interglacial interval.

Our picture of East Anglia at the time of Acheulian and Early Mousterian Man will be completed by a glance at the Cambridge district, at present under re-examination by the officers of the Geological Survey. Already available to us, however, are the valuable results collected over a period of years by Prof. J. E. Marr, Prof. W. B. R. King, and the Cambridge school. In this district the Great Chalky Boulder Clay covers much of the higher ground, the river deposits being of later date, with the possible though not probable exception of the Barrington gravels. It is important to note that the Great Chalky Boulder Clay Ice retreated sufficiently from the area of the Wash to permit the Cam and Ouse to flow northwards into an early representative of the North Sea, and to allow the warm-water mollusc *Corbicula fluminalis* to re-establish itself at numerous localities in the area. Prof. Marr shows that aggradation of the valleys took place after the glaciation and retreat of the ice, the climate being at first rather warm, but later becoming cooler. During this stage, valley-gravels such as the Lower Barnwell Village Beds and lower evenly-bedded gravels of the Traveller's Rest Pit were formed; they contain worn Chellian and fresh Acheulian implements, together with *Corbicula fluminalis* and remains of hippopotamus. Succeeding these deposits are the unevenly-bedded gravels of the Traveller's Rest Pit, containing what appear to be La Micoque and Early Mousterian industries. It is Prof. Marr's belief that during this time of aggradation marine and freshwater conditions alternated in the lower part of the area of the Ouse drainage—the deltaic tracts of the March-Nar sea. Dr. J. D. Solomon, on the other hand, is inclined to refer the interdigitated marine and freshwater deposits to a later stage.

Resting upon the Early Mousterian gravels in Cambridgeshire is a deposit similar to that already referred to as Upper Boulder Clay, Upper Chalky Drift or Trail.[1] A subsequent period of erosion with minor periods of aggradation intervened, resulting in the formation of, first, the upper evenly-bedded gravels of the Traveller's Rest Pit, and later the Upper Barnwell Village and Barnwell Station Beds with a cold fauna, but without implements.

From the surface-deposits of the district have been recorded Aurignacian, Solutrian, Magdalenian and Azilio-Tardenoisian implements,

[1] Mr. S. Hazzledine Warren in 1924 suggested that the Trail of the Thames basin was of post-Mousterian age, but thought that it might be as late as Magdalenian.

but their relationship to the river-gravels, and particularly to the last cold episode of the Barnwell Station Beds, has not been determined.

The succession at the well-known locality of High Lodge, Mildenhall, raises problems which have not yet been solved. Prof. Marr recognised an Upper and a Lower Chalky Boulder Clay separated by gravels and brickearths which have yielded numerous implements of so-called Mousterian type, but including hand-axes related to the pre-Mousterian industry in Germany. The workmanship resembles somewhat that of the Clactonian flake-industry and may, according to Miss Dorothy Garrod, be a development from it. In the present state of our knowledge, we can only correlate the Upper Boulder Clay of this area with the Upper Chalky Drift, and the Lower Boulder Clay with the Chalky-Jurassic facies.

Traces of Man's existence in the area after the formation of the Upper Chalky Drift of southern Norfolk and Suffolk can be found only in the surface-deposits. These usually occur on the slopes or floors of valleys. Mr. Reid Moir has found what he claims to be implements of Mousterian manufacture in the Upper Chalky Drift (Boulder Clay) near Ipswich, but agreement on the nature of the flaking has not yet been secured. Moreover, he has recently stated that he has found the same type in the upper part of the Chalky-Jurassic Boulder Clay—a claim which, if admitted, would be difficult to reconcile with our ideas of the stratigraphical sequence. However, on the slopes of a small valley near Ipswich Mr. Moir has found a succession of floors, the two uppermost of which contain Upper Mousterian and Aurignacian implements respectively. These floors prove that the local and minor topographical features must have attained their present form before Upper Mousterian times, for only hill-wash (containing Solutrian blades) covers the deposits. Even more significant is his discovery of an excellent section at the bottom of the Gipping Valley, where at a depth of 15 feet below the river alluvium (about 1 foot to 5 feet below O.D.) is a peaty loam containing a floor of Early Mousterian (Combe-Capelle) age, associated with bones of reindeer. This peaty bed was succeeded by a blue loam with Early Solutrian blades, the whole being covered by gravel with many derived implements. The surface-deposits of sand and loam here contain Magdalenian and Neolithic types. In the estuary of the river Orwell, below Ipswich, the well-known 'Submerged Forest' or peat-bed, lying at about 30 feet or more below O.D. and containing teeth of mammoth, is covered first by shingly gravel and then by alluvial mud with peaty partings. At the base of the latter is a floor, believed to be of Magdalenian age.

The relationship of the industries of Aurignacian and Magdalenian Man to the glacial episodes thus cannot be determined in the Ipswich district, but there is evidence, like that in the Fen country, of a subsidence since Solutrian times. For the requisite connecting link we must turn to north-western Norfolk, where there is a Boulder Clay still younger than any yet mentioned. This 'Brown Boulder Clay' was recognised long ago by the officers of the Geological Survey as the latest Boulder Clay of the Wash area, being very different lithologically from the Chalky

Boulder Clay upon which it sometimes rests. In its erratics, as also in the mineral composition of its matrix, it resembles the Hessle Boulder Clay of the coast-sections of Yorkshire, a deposit which lies above the Upper Purple Boulder Clay. The easternmost exposure of this Brown Boulder Clay is seen at Morston, near Blakeney, where Mr. Solomon has demonstrated that it overlies a raised beach, which in turn fringes and is banked against the western edge of the Blakeney Esker and Cromer Moraine. Obviously, this important discovery shows that the raised beach is later than the disturbance that produced the hummocks of Contorted Drift, and also than the Ridge (Cannon-shot) gravels ; still younger, therefore, is the Brown Boulder Clay. Mr. Solomon argues that the Brown Boulder Clay cannot have been produced by the same glaciation as the Upper Chalky Drift—a conclusion supported by the fact that no Brown Boulder Clay or its outwash material is found in the Cromer Moraine.

At several sites in or near Hunstanton Mr. Reid Moir has found Middle Aurignacian burins, scrapers, points and cores in the Brown Boulder Clay. At one of these, the Gasworks Pit, the arrangement of glacial gravels, boulder clay and made ground is somewhat confused ; at another, the section at the southern end of the Esplanade, the Boulder Clay bed from which he actually obtained the implements has since been removed in the course of ' improvements.' The state of preservation and patination of the implements is similar to that of other flints in the Brown Boulder Clay. Thus we have here evidence of a glaciation subsequent to the occupation of the area by Aurignacian Man, but a glaciation which, as shown by the thinning off of the Brown Boulder Clay, did not reach farther south-eastwards than the north-western margin of Norfolk. That this glaciation is not likely to be the same as that which produced the Upper Chalky Drift and Trail of Suffolk is indicated by (*a*) the absence of Brown Boulder Clay and its outwash material in the Contorted Drift and Ridge gravels, and (*b*) the evidence of an interval between these deposits as represented by the raised beach of Morston. Were it not for this raised beach, however, we might be tempted to regard the Upper Chalky Drifts and Coombe Rock with their derived Mousterian and Levalloisian implements as the extra-glacial phenomena of the Brown Boulder Clay ice, due to snow-sludge and slumping under cold conditions.

Such, then, is the most complete succession in England of glacial and other deposits associated with the remains of Early Man—a succession to which the term ' standard ' may reasonably be applied. The attempt to trace the succession throughout England and Wales is probably worth while, although we shall find that, in the present state of our knowledge, and perhaps because of the less favourable conditions for the preservation of the remains of plants and animals and Man, minor difficulties of correlation have still to be faced.

Lincolnshire.

In endeavouring to recognise our sequence in Lincolnshire we have to travel to Kirmington, in the vicinity of the Humber, before reaching a multiple succession of glacial deposits. The deposits filling the Kirmington Channel were investigated in detail by a British Association Committee. The report of the Committee showed that the Purple Boulder Clay of the district (known from sections farther north in Yorkshire to be due to a later glaciation than the Scandinavian Drift) was succeeded first by sand, then laminated silts with estuarine shells and containing peat with marsh plants and fresh-water shells, next gravel, and, finally, ' Hessle ' Boulder Clay. The plants indicated a sub-arctic climate ; the estuarine shells recorded were *Cardium edule* and *Scrobicularia piperata*. The ' Hessle ' Boulder Clay here is that of inland sections and is apparently not the equivalent of that of the coast-sections, which is to be correlated with the Brown Boulder Clay of Hunstanton. The sands, silts and gravels may thus correspond to similar beds at Hoxne. The Purple Boulder Clay has usually been regarded as the time-equivalent of the Great Chalky Boulder Clay west of the Lincolnshire Wolds, a deposit which continues into the Eastern Counties as the Chalky-Jurassic and Chalky-Neocomian Boulder Clay, but the possibility of there being two Purple Boulder Clays must be borne in mind. The correlation of the Kirmington series with our standard succession will be open to doubt until the laminated silts or associated beds yield implements. Mr. J. P. T. Burchell's recent discovery of Early Mousterian (Clactonian) implements in the ' Hessle ' Boulder Clay (=? the Upper Purple Boulder Clay) of Kirmington is of great interest, for it suggests that the Purple Boulder Clay at the base of the Kirmington series is the Lower Purple Boulder Clay, a conclusion confirmed, in his opinion, by its petrographic characters. Although *Corbicula fluminalis* has not been found at Kirmington, it is recorded in gravels above a Purple Boulder Clay elsewhere in northern Lincolnshire.

Yorkshire.

So graphic a word-picture of glacial conditions in Yorkshire has been painted by Messrs. Kendall and Wroot that I need only refer to their book on *The Geology of Yorkshire* and recall that, as in East Anglia, a succession of at least three definite Boulder Clays has been established : the lowermost or Basement Clay containing numerous Scandinavian erratics, the Purple Clays (the ' Middle Series ' of Mr. J. W. Stather), and the Hessle Clay. Each has its special characters, and these throw light on its origin and on the course of the ice-movement. Unlike East Anglia, however, no datable interglacial faunas and floras have been found, and no very definite traces of Early Palæolithic Man. The relationships of the one implement obtained (of Acheulian type, from near Huntow) are obscure. What are claimed to be implements in chert, of supposed Early Chellian age, have recently been discovered in the moraines, and on the Moors, of Nidderdale. The sketches of these unabraded rock-fragments are unconvincing to a geologist, but if the workmanship is accepted by archæologists, the occurrence of relatively unabraded Early Chellian or even Mousterian implements in such late-glacial deposits associated with retreat-phenomena seems to upset our tentative sequence. Discoveries by Mr. J. P. T. Burchell of Aurignacian implements near

Flamborough, in a late-glacial deposit, which he regards as the equivalent of the coastal Hessle Boulder Clay, compare closely with the implements from the Hunstanton Boulder Clay, although the officers of the Geological Survey would prefer to regard the deposit in which they were found as a local kind of Coombe Rock. In the gravels of Kelsey Hill and Burstwick near Hull, long famous for their molluscan faunas (which include *Corbicula fluminalis*), and regarded by geologists as genetically connected with and overlying a Purple Boulder Clay, Mr. Burchell has found Early Mousterian artefacts ; as he rightly points out, the stratigraphical relationships may thus be similar to those at Hoxne, since he found below the gravels at one locality a boulder clay which he identified, from its lithological characters, as Lower Purple Boulder Clay.

Sections have been described where two beds of the Purple Boulder Clay, separated by sands and gravels, have been observed. Prof. Kendall and Drs. Hollingworth, Raistrick, and Trotter are now inclined to regard these two boulder clays as due to separate glaciations, with an intervening interglacial phase. Dr. Raistrick would correlate the Lower Purple Boulder Clay with the early maximum of the Yorkshire Dales glaciation, and the Upper Purple Boulder Clay with the Vale of York maximum (Main Dales glaciation) and the passage of the Lake District ice over Stainmore. Drs. Hollingworth and Trotter agree in linking the Upper Purple Boulder Clay with their Early Scottish glaciation and the eastward travel of Lake District ice. Thus Yorkshire would appear to have suffered four glacial episodes (as Clement Reid originally thought), comparable with those of East Anglia, the Lower and Upper Purple Boulder Clays corresponding to the Chalky-Jurassic Boulder Clay and Upper Chalky Drift, respectively. The return of *Corbicula fluminalis* to the British area here appears to be of correlative value, for the Kelsey Hill gravels containing it overlie the Lower and underlie the Upper Purple Boulder Clay ; but if, as Lamplugh was inclined to think, the specimens were glacially derived from a river-deposit lying towards the east, the gravels might be associated with the retreat of a later ice-sheet, possibly that which formed the Upper Purple Boulder Clay. The present archæological evidence does not support the latter view. Moreover, recent work by Mr. W. S. Bisat shows that both Upper Purple Boulder Clay and Hessle Clay overlie the Kelsey gravels.

In one respect, however, the Yorkshire succession supplements our knowledge of that in East Anglia, for below the Basement Clay or most ancient Till at Sewerby is a preglacial cliff and beach containing the remains of hippopotamus, the straight-tusked elephant and the leptorhine rhinoceros. These mammalian forms are often associated with implements of Chellian Man, although they may persist to later times. At first sight it appears that here we have another link with the Cromer succession, if the beach is correlated with the Cromer Forest-bed. In the sand-dunes overlying the beach but underlying the Basement Clay appears a fauna consisting of mammoth, urus, bison and Irish elk. The sand-dunes, together with a bed of chalk-rubble below them, are evidence of an old land-surface.

Durham.

It is generally agreed that the Basement Clay of Holderness finds its equivalent in Durham in the Scandinavian Drift discovered by Dr. C. T. Trechmann in hollows in the Magnesian Limestone near Sunderland. Overlying this deposit is a bed of loess, which was in all probability an interglacial deposit ; it is succeeded by Purple (Cheviot) Boulder Clay. The only record of Older Palæolithic Man in the district is that of a quartzite implement of Chellian type from below the Purple (Cheviot) Boulder Clay. Correlation based on this one implement of crude workmanship (if it be accepted as an artefact) would be premature.

Northumberland and the Lake District.

Our next problem is the question of the linking-up of the boulder clays of Yorkshire, Durham and Northumberland with those of the Irish Sea area. Recent work of the officers of the Geological Survey, admirable in its detail, has established for the Solway-Eden district three main ice advances and retreats, namely, (1) a Scottish ice-advance, (2) a maximum combined Lake District ice-advance which carried boulder clay eastwards over the Tyne gap and over the Stainmore gap into the Tees valley, and (3) a Scottish re-advance. There also appears to be evidence of a weathered boulder clay earlier than any of these episodes. In his valuable paper on the glaciation of eastern Edenside and the Alston block, Dr. F. M. Trotter has traced an ose-train westwards from Hexham by way of the Tyne gap, and has thus connected the maximum glaciation of the Lake District with that which yielded the coastal Hessle Boulder Clay. Previous to this, ice-sheets which advanced over Stainmore during the onset of the Early Scottish and Lake District glaciations fed the glaciers which helped to form the Purple Boulder Clays of Yorkshire, replete with boulders of Shap granite, Borrowdale lavas, etc. Drs. Trotter and Hollingworth are therefore inclined to correlate the Upper Purple Boulder Clay with the Early Scottish advance, and the Lower Purple Boulder Clay with the early weathered boulder clay of Silloth, and other places.

The Irish Sea and Cheshire Basin.

The main glaciation of the Irish Sea region extended to the coastal areas of North Wales and far into the Cheshire Plain. As is well known, during its retreat-stages at the end of this period, the ice gave rise to the glacial lakes Newport, Buildwas and Lapworth, and caused important diversions of river-drainage in the case of the Severn and other systems. In North Wales a boulder clay from the Irish Sea ice sealed up the mouths of several well-known caves in the Carboniferous Limestone, containing floors of Middle Aurignacian implements. Notable amongst these were Cae-gwyn and Ffynnon Beuno, in Denbighshire. Although for a time some difference of opinion was held as to whether or not the undisturbed boulder clay of the Vale of Clwyd actually sealed up the caves, the consensus of opinion was finally in favour of that view. The Snowdonian and Arenig ice-sheets seem to have been able to prevent the Irish Sea ice from advancing far into the hilly region of North Wales, for the deposits of Welsh and Northern Drift often lie side by side. It is now generally believed that the Welsh and Irish Sea ice-sheets were practically contemporaneous, although the northern ice seems to have arrived first and weakened and retreated first; thus, on the Welsh Borders it was overridden by the Arenig Ice which carried Welsh erratics as far as Wolverhampton and Birmingham—indeed, beyond the limits previously reached by the northern ice. That this phenomenon was but evidence of the give-and-take of glaciation has, however, been demonstrated by the officers of the Geological Survey, who have traced out the junction between the two ice-sheets, marked by morainic belts, kettles, meres and peat-bogs, along a line approximately through Wrexham and Ellesmere towards Shrewsbury. On the shores of Cardigan Bay, North Wales, and Lancashire, and also in Anglesey there are, however, two beds of boulder clay, sometimes separated by sands and gravels. In some places the boulder clays differ in composition, but in others they resemble one another closely. Also, Dr. Bernard Smith noted near Ellesmere, in the Cheshire Plain, the presence of a boulder clay lying above mounds of sands and gravels like those that overlie the boulder clay of the Newport district. The two coastal boulder clays have not yet been traced inland, but general opinion is that only the lower extends to Newport and Buildwas (the main Irish Sea glaciation), while it is the upper clay which seals the caves at Cae-gwyn and Ffynnon Beuno. In the mountain-district of North Wales, the evidence of two glaciations has not been clearly worked out, but several investigators have observed features referable to two ice-advances with retreat-stages between. In fine, the Lower Boulder Clay of Lancashire, Cheshire and Wales would appear to be correlatable with the Early Scottish glaciation of the Lake District, and the Upper Boulder Clay with the Lake District Maximum and Hessle Boulder Clay.

The Severn Drainage.

A study of the overflow-channels of the extra-glacial Lake Lapworth (with its earlier stages, Lakes Newport and Buildwas) at Ironbridge, which were formed during the retreat of the northern ice, has enabled Dr. L. J. Wills in a masterly paper to connect the terraces of the river Severn below the Ironbridge Gorge with the glacial phenomena of the Cheshire basin above it. He regards the ‘ Main Terrace ’ of the Severn as corresponding to his Stage II and subsequent stages of the ice-retreat, as deduced from glacial lake-levels and terrace-gradients. Another connecting-link with the drifts and river-deposits of the Midland area is provided by the overflow channel at Gnosall, which discharges into Church Eaton Brook and so into the Trent Basin. Mr. E. E. L. Dixon informs me that with this channel is connected a valley-train of sand and gravel that occurs at a low level, and is therefore later than the old Trent river-terrace.

The Avon-Stour Area.

The absence or rarity of mammalian remains and implements in the terraces of the Lower Severn has rendered very difficult Dr. Wills’s efforts to correlate these deposits with those of the river Thames. Meanwhile, Miss M. Tomlinson's excellent work on the similar deposits of the river Avon and its tributary, the Stour, enables us to continue the story over the Moreton watershed into the Evenlode Valley, where Dr. K. S. Sandford has picked up the threads. The Drifts of the Avon-Stour region consist of high-level gravelly deposits mostly containing boulders foreign to the district. These Drifts antedate the fluviatile deposits, which Miss Tomlinson has classified as Terraces No. 4, No. 3 and No. 2, in order of decreasing age. The earliest Drift consists of Plateau Gravels, and the latest, termed the Moreton Drift, is a chalky deposit which in places has the character of a boulder clay derived from the north. The Moreton Drift, which Miss Tomlinson would correlate with the Chalky Boulder Clay of the country farther east, penetrates the pre-existing Moreton gap into the Evenlode drainage, and, on considerations of gradient, seems to be connected with the Wolvercote Terrace-gravels of the Oxford district. Terraces Nos. 3 and 4 of the Stour-Avon drainage mark an aggradation accompanied by a 'warm' fauna (including *Corbicula fluminalis*, *Hippopotamus*, and *Elephas antiquus*). It is to be noted that *Corbicula fluminalis* here appears at about the same horizon as in the east of England. Terrace No. 2 carries a cold fauna (including mammoth and woolly rhinoceros), and, in the opinion of Dr. Wills, is to be correlated with his 'Main Terrace' of the river Severn, and therefore with the maximum glaciation of the Irish Sea area. Unfortunately, no implements that might assist in correlation have been found.

The Upper Thames.

To Dr. K. S. Sandford's valuable work we owe our detailed knowledge of the sequence of events in the region of the Upper Thames, where the problems are of exceptional difficulty. Dr. Sandford has recently (1932) correlated the Plateau Drift (containing Scandinavian erratics) with the Scandinavian Drift (Norwich Brickearth) of Eastern England, and the later-formed 100–140 ft. Terrace of the river Thames containing Chellian implements, with the overlying sands and gravels of East Anglia.

The Chalky-Jurassic Boulder Clay of the east of England does not reach the Oxford district, but the early retreat-stages of the ice may be represented by the formation of the Wolvercote Terrace. Next follow the Lower and Upper Summertown-Radley Terraces, with cold and warm faunas, respectively, which Dr. Sandford would now correlate with the lower brickearths at Hoxne. Thus the succeeding Lower Gravels of the Wolvercote Channel with their warm fauna and late Acheulian and Micoque implements would be the equivalent of the corresponding (Upper Acheulian) gravels of Hoxne and other East Anglian localities. *Corbicula fluminalis* appears in the Upper Summertown-Radley Terrace in association with the straight-tusked elephant and hippopotamus—that is, at just about the horizon at which we have by now been led to expect it. The upper beds of the Wolvercote Channel, of cold-temperate character, with their single Mousterian implement, are correlated with the Mousterian brickearths farther east, and the warp at the top of the channel with the Upper Chalky Drift, for it yields evidence of probable frozen-soil conditions. The latest deposits of the

Oxford district are then correlatable with the various post-Mousterian stages of East Anglia, as shown in the table accompanying this address. The Oxford succession can thus be fitted in fairly satisfactorily with our standard succession on the one hand and the Stour-Avon succession on the other.

The Lower Thames.

The terraces of the Lower Thames have been the subject of numerous papers. Thanks to the efforts of Messrs. Chandler, Leach, Reginald Smith, the officers of the Geological Survey (particularly Mr. H. Dewey and Mr. H. G. Dines), and other workers, our knowledge of the succession is now well founded, and I need only summarise the results of their labours. The river-deposits seem to be later than the Chalky-Jurassic Boulder Clay. The 100-ft. terrace marks a period of aggradation, and is divisible into three beds of sandy gravel separated from one another in certain cases by deposits of marly loam. In the lowest gravel are large cores and flakes of the Clactonian industry, associated with *Elephas antiquus* and *Rhinoceros leptorhinus*. The upper portion of this bed and the base of the succeeding loam contain land and fresh-water mollusca, including *Corbicula fluminalis* and *Theodoxus cantianus*. The middle gravel contains unabraded Early Acheulian hand-axes, and in its upper part, twisted ovates (Late Acheulian). In a brickearth of rather later age have been found Late Acheulian and Early Levalloisian ovate implements. The 50-ft. terrace contains rolled Acheulian implements and affords evidence of corrasion during the warm period when its lower beds were formed, and aggradation during the colder times when its upper beds were laid down. The Levalloisian tortoise-core industry appears approximately at the level of this terrace. The Crayford brick-earth, which succeeds it, contains at its base Levalloisian flakes; also, the cold fauna found at this time of aggradation foreshadows the oncoming of the arctic conditions which gave rise to the Coombe deposits, which may be correlated with the Upper Chalky Drift. The Coombe deposits here, as Dewey figuratively says, 'put an end to Levallois Man.' At Bapchild, in the Medway Valley, Mr. H. G. Dines found in the Coombe deposit Early Levalloisian implements in a battered and scratched state. These had probably been transported for a short distance. Late Levalloisian implements were found at the base of a brickearth which overlies the Coombe deposits, and Aurignacian (or even later) implements above them. The evidence of the Whitehall and Lea Valley deposits indicates uplift, erosion and aggradation under cold conditions, the 'Ponders End stage' of Mr. Hazzledine Warren. The age of these deposits has not been established with certainty, but the flakes found in them have been doubtfully regarded as Aurignacian; they are, in any case, pre-Neolithic. In company with other investigators, I am much tempted to correlate the Ponders End stage with the post-Aurignacian Hunstanton and Hessle Boulder Clays, for the cold conditions which brought boulder clay so far south as the Wash must have had a marked influence on the fauna and flora of the Thames Valley.

The correlation of the deposits and industries of the Upper Thames and Lower Thames has not been effected without some difficulty, but a recent and most useful review of the problem has led Dr. Sandford to general conclusions similar to those at which I had independently arrived. Dr. Sandford now correlates the 100–140 ft. terrace with the Caversham and Dartford Heath Chellian gravels, and his Wolvercote Terrace with the Chalky-Jurassic Boulder Clay. Further, he equates the Lower Summertown-Radley Terrace with the Swanscombe Clactonian-Acheulian gravels of the 100-ft. terrace, and the lower beds of the Wolvercote Channel with the 50-ft. or Taplow Terrace. The upper beds of the Channel are thus correlated with the Lower Crayford Brickearth (Early Mousterian). The oldest ' warp ' of the Oxford district would then appear to be comparable with the Coombe Rock (Upper Mousterian).

At Clacton, on the Essex Coast, Mr. Hazzledine Warren has discovered a river-channel of which the lower beds contain Clactonian flakes associated with elephant and other mammalian remains, and plants, indicative of warm conditions. Derived specimens of *Corbicula fluminalis* are also found. Correspondence is here suggested with the 100-ft. terrace of the Thames, although the deposit lies at only 43 to 48 feet above O.D. A few miles farther north, at a level of 74 feet above O.D., lie the gravels of the river Stour; also, the Stutton low terrace with *Corbicula fluminalis*, already mentioned. Thus the Stour deposits, which on field evidence appear to be more recent than the Chalky-Jurassic Boulder Clay, are probably to be correlated on the one hand with the Clacton gravel and 100-ft. terrace of the Thames, and on the other with the Acheulian deposits of Ipswich, Hoxne and Whitlingham, referred to earlier in this address.

The Midland Area.

We have now closed our traverse, but we shall hardly be able to avoid the feeling that there are weak links in our chain of evidence, especially concerning the south-western part of the Midlands and the borders of the Irish Sea, where the difficulties are greatest and the traces of Early Man scanty or absent. It remains to see whether any cross-ties of evidence, which will serve as checks on our correlations, can be obtained by way of the central and northern Midlands. Unfortunately, discoveries of the implements of Palæolithic Man are rare and sporadic in the counties of Leicestershire, Nottinghamshire and Lincolnshire. A few cave-deposits, like those of Cresswell Crags, have yielded a rich harvest of implements and confirmed the time-succession of Palæolithic industries, but the beds containing them are unfortunately not in contact with glacial deposits. The irregular driftless areas of Lincolnshire, Nottinghamshire, Derbyshire and Staffordshire suggest considerable denudation in late-glacial times rather than non-deposition of glacial detritus. In many parts of the area the officers of the Geological Survey have been unable to distinguish with certainty more than one boulder clay with associated sands and gravels, although Mr. R. M. Deeley long ago claimed to be able to distinguish three or even four in the Trent basin, separated by interglacial sands and gravels. Much excavation took place in the valley of the Trent after Chalky Boulder Clay times, and the oldest Trent gravel is more recent than the glacial deposits;

again, it has yielded but few implements, and those appear to be of Late Acheulian and Levalloisian types. Some part of the Irish Sea ice is known to have flowed over into the Trent drainage (as in Doveholes, the Rudyard gorge and the Gnosall gap), but the exact relationship of the various glacial and interglacial stages has yet to be established. In many cases the 'Older River Gravels' are intimately connected with late-glacial flood-deposits, the transition being gradual and difficult to trace. In the areas subjected to the influence of the Pennine and the Chalky Boulder Clay glaciers, the two ice-streams often appear to have met and coalesced, continuing their southward journey as though they were almost, if not exactly, synchronous. The faunas recorded from the valley-gravels are often of mixed character, including both the cold and warm faunas referred to above. In the case of old records, it is possible that collecting may not have been carried out with discrimination, but in the case of modern records the explanation must lie in the erosion and redeposition of gravels, whereby the faunas have been mixed.

In one area, that of Kenilworth, recent re-examination of the deposits of the Avon basin has yielded to Mr. F. W. Shotton what are possibly Early Acheulian hand-axes of quartzite. These were obtained from the Baginton gravels, which he regards as interglacial, for they lie below the local Chalky Boulder Clay at Lillington (the Upper Chalky-Jurassic Boulder Clay of Dr. Hollingworth) and above a lower Boulder Clay containing Keuper debris (the Lower Chalky-Jurassic Boulder Clay of the same author). The gravels contain a cold fauna, including mammoth and woolly rhinoceros. From the fluvio-glacial gravels above the Chalky Boulder Clay Mr. Shotton has obtained a doubtful Levalloisian flake. The stratigraphical relationships of these rare implements have not been established with certainty, and probably for this reason the succession cannot be correlated entirely satisfactorily with that in eastern England. Difficulties also arise in the correlation of these deposits with those of the Avon-Stour area described by Miss Tomlinson, but future work may be expected to resolve them.

At Biddenham and Kempston, near Bedford, in the Great Ouse Valley, Mr. H. Dewey has drawn attention to the occurrence of gravel at about 40 feet above present river-level, the lower evenly-bedded portion of which contains core hand-axes and Levalloisian disc-implements and blades. The upper portion of the gravel, which breaks its way irregularly into the lower beds, ravining and contorting the even bedding, contains masses of Chalky Boulder Clay and heavily rolled implements. The masses of Boulder Clay (Mr. Dewey argues from the field evidence) were obviously frozen hard when they disrupted the lower gravel. As he rightly suggests, the succession is similar to that at Ipswich and at Hoxne. Mousterian implements have been found at St. Neots by Mr. C. F. Tebbutt, in gravels of the Great Ouse, 10 feet above the river. Prof. Marr considers the succession here to be similar to that of the deposits of the river Cam.

Other records of Palæolithic industries in Britain are so scanty as to yield little evidence for purposes of comparison. Plateau Gravels in the Bristol district have been compared by Prof. L. S. Palmer with the clay-with-flints, and an abraded Acheulian implement, with remains of mammoth, woolly rhinoceros and the straight-tusked elephant, have been found in the 100-ft. terrace of the river Avon. The 50-ft. terrace has yielded an abraded late Acheulian implement, and the overlying brickearth a Mousterian point. The neighbouring caves of Aveline's Hole and Gough's Cave are well known for their Late Aurignacian and Magdalenian industries. But in this driftless area, the relations of the various cave and other deposits to the terraces and drifts farther north and north-east have yet to be satisfactorily elucidated.

From Barnwood, near Gloucester, Mr. M. C. Burkitt has described an axe-like implement of possibly Late Acheulian or Early Mousterian age, found in gravel and associated with bones of mammoth and woolly rhinoceros. A neighbouring gravel-pit yielded a Mousterian point, also accompanied by remains of mammoth.

I have as yet made no reference to recent discoveries of prehistoric human industries in definite geological settings outside Britain. We live in an age when such discoveries are made in rapid succession. To review the investigations on the border-line of geology and archæology that have been prosecuted in various European countries, in Egypt, East Africa, South Africa and China, would take more space than is available to me. The labours of investigators too numerous to mention here have furnished valuable results, but they also serve to demonstrate that it would be premature to attempt world-wide correlations of the geological and climatic phenomena accompanying human industries. In particular, the correlation of British glacial episodes with those of the Alps, as established by Penck and Brückner, seems always to have exercised a peculiar fascination for archæologists. I have refrained from any such comparison, although nothing would appear to be simpler than to correlate the four major glacial episodes of Britain with the Günz, Mindel, Riss and Würm ice-advances of the Eastern Alps. If the various human industries are broadly contemporaneous from the Alps to Britain, such a correlation would be strengthened, and the fifth glaciation of Britain (the Scottish re-advance) would be represented in the Alps by the Würm II or Buhl episode. In my opinion, however, it is still too early to claim that such a correlation has been established, for we have no proof (even if we admit the probability) that the first glaciation of the Alpine area was synchronous with that of eastern England. Moreover, reference to the works of such European authorities as Penck, Obermaier, Breuil, Wiegers and Wohlstedt, to mention only a few, shows astonishing differences of opinion regarding the correlation of the Alpine glacial and interglacial phases with human industries in other parts of Europe. In leaving the question still open, I would only remark in passing that a correlation such as that recently attempted by my friend Sir Arthur Keith is not likely to find favour among geologists. Sir Arthur uses the fourfold glaciations of the Eastern Alps in order to correlate the episodes with British glaciations ; then, since the sequence does not fit, he omits from the middle the Riss glaciation. Now, with all respect, I submit that this is like having your cake—in this instance an iced cake—as well as eating it; Sir Arthur cannot both adopt the Alpine succession and abandon one member of the sequence because it does not accord. Satisfactory correlation will doubtless be possible in course of time, but it must needs await fresh investigation of the successions of the Rhine Valley and Low Countries and of the river-deposits of France, which may be regarded as connecting-links between the deposits of the Alpine area and those of eastern and southern England.

The mention of southern England reminds me that within the limits of this address I have been unable to deal, even briefly, with the evidence of changes of level of the land and sea, and the consequent erosion and aggradation of the river-systems of Britain. In the area south of the river Thames glacial deposits as such (that is, as distinguished from deposits due to snow-sludge or movement of semi-frozen superficial material) are absent. Correlation must be effected, therefore, with river-terraces and raised beaches, and will depend on evidence of changes of level, combined with that of included implements. Information comes but slowly to hand, and the problems are exceptionally difficult. Two facts emerge: (1) the widespread submergence and aggradation of river-valleys in Acheulian times, and (2) the marked elevation and river-erosion of Mousterian times. The movements in southern and eastern England appear to have been differential, possibly of the isostatic type, rather than eustatic uplifts like those in the Mediterranean area described by Lamothe, Depéret, Gignoux and others. Nevertheless, the work that has been accomplished, notably by Prof. L. S. Palmer, is promising of fruitful results. While leaving open the question of correlating changes of level throughout Britain, I have therefore attached his sequence to the table accompanying this address.

Any attempt to measure the antiquity of Man in Britain in terms of years is bound to be speculative and unscientific so far as the geological evidence is concerned. No deposits similar to the varve-clays of Sweden have yet been found in Britain. From the varve-clays of Sweden, as is well known, G. de Geer and other workers have concluded that about 13,500 years have elapsed since the receding front of the ice occupied a position in southern Scania. Using this as a basis, he dates the commencement of the Gothi-glacial sub-epoch of the last glaciation (? Magdalenian) as from 15,000 to 16,000 years ago. Possibly the earlier sub-epoch (Dani-glacial) may also be dated, but any extrapolation of the time-scale in years to glacial episodes before the latest (the maximum of which was marked by the Baltic moraine) is, as de Geer and Sollas have emphasised, to add to 'a hecatomb of erroneous dates.'

In the foregoing review of our knowledge of British glacial deposits and their relationship to human industries, I have been compelled to summarise the work of a large number of investigators, many of whom I have been unable to mention by name. For this omission I crave pardon, and also for possibly misrepresenting their views in attempting to secure brevity, particularly when qualification of a bald statement would have been desirable. It may be that more agreement emerges from the foregoing suggested classification than might at first have been expected, but it is certain that the facile correlations so often made, although not usually by British geologists, cannot have lasting value. In any case, I hope that this exposition of the state of our present knowledge and theories may have an historical use hereafter.

Let me make a concluding summary by attempting a word-picture of Pleistocene conditions in the British area in so far as they affected the occupancy of the country by Early Man. We may assume that the connection of the Early Pliocene sea of the south-east of England with regions farther south was broken by an uplift of the Weald-English Channel region, which resulted in the formation of the ancestor of our present North Sea. In later Pliocene times, this sea became more and more restricted as its limits were forced northwards. With the removal of barriers to the migration of mollusca from the north, arctic species found their way in increasing numbers into East Anglia. Geographical and faunal changes about this time were so gradual and the effects of penecontemporaneous erosion so marked that it is by no means clear where we should draw the line between Pliocene and Pleistocene. In our picture we must visualise at this time a land-area populated by plants living under temperate conditions similar to those of the present day, and drained by a great river that carried down the remains of southern 'warm' animals, such as the straight-tusked elephant, the hippopotamus and leptorhine rhinoceros. Occasionally, however, there were also delivered into the estuary the remains of cold-loving animals, while the sea with which it was connected was the home of a cold molluscan fauna. The greater part of the east of England then seems to have been a land-surface, although there are now but few definite traces of it available for study. We have, however, the fissured surface of the Magnesian Limestone of Durham, the ancient sea-cliff of Chalk at Sewerby, and the surface of Pliocene deposits in Hertfordshire, Norfolk, Suffolk and Essex. Ice began to gather in Scandinavia, and eventually found its way across the North Sea; its accumulation seems to have been accompanied by a submergence of the land. Boulders of characteristic Norwegian rocks were dropped on to the Scottish shores, particularly around the Moray Firth and Orkneys, and the ice-sheet itself appears to have impinged on the Durham and Yorkshire coasts. The evidence rather suggests that, by the time the ice-sheet reached the position of the present north-east coast, its force was spent, but its movement towards the south was more definite, and, possibly behaving like the Great Antarctic Barrier, it discharged its boulder-clay over the low ground of eastern Norfolk and Suffolk. Icebergs may also have invaded the Fen country by way of the Wash gap, dropping detritus even as far south-westwards as Oxford.

In the long period of slow refrigeration which preceded this First Glacial Episode, Early Man must have passed through the primitive stages of his development as a tool-making animal, for the form and technique which characterise the subsequent Chellian implements could only have followed less easily-recognised efforts. The resemblance in fashion of flaking and the repetition of form observed in the rostro-carinate implements of the sub-Crag gravels is one of the strongest arguments for their human workmanship. Also, the adherence to type bespeaks the existence of even older and cruder forms. I must leave the debatable question with the picture of this very primitive man driven from his hunting-grounds by the advance of the first great ice-sheet, and only note in passing that the remains of Piltdown Man, although found in a Pleistocene gravel, are not datable with exactness, being accompanied by derived bones of Pliocene animals and flakes which, if referable to any particular period, must be attributed to the Chellian or even an earlier industry.

The retreat of the Scandinavian ice appears to have been followed by a long interval, during the earlier stages of which the area of East Anglia was a shallow sea or lake, inhabited by a cold molluscan fauna. Into its waters were discharged large quantities of sand and gravel, released from the waning ice-sheet. During the later stages of retreat the area was uplifted and the East Anglian valley-systems were carved out of the deposits of brickearth, gravel and sand. Little evidence is forthcoming regarding conditions in Yorkshire and northern England during this First Interglacial interval, but in the Midlands and Thames Valley certain high-level plateau-gravels may have originated as outwashes from the ice, and some of the oldest river-gravels may have been the products of the subsequent erosion and aggradation of the pre-existing valleys. By inference, Chellian Man advanced into such parts of the British area as were available to him, for, although we find no 'floors' of unabraded tools of the Chellian industry, derived and abraded implements are not infrequent in later deposits.

The First Interglacial interval was brought to a close by the development of 'home-grown' ice-caps on the Scottish mountains, the Lake District and the Pennines. The chief glaciers thus produced appear to have developed and flowed east of the Pennines, possibly because of the cooling effects of the proximity of the Scandinavian ice, for the manner in which the earlier Cheviot ice and the Purple Boulder Clay ice hug the low ground to the East Coast, taking a southward course parallel to it, suggests that most of the North Sea was still filled with ice. The Lower Purple Boulder Clay ice does not appear to have risen sufficiently high to override the Lincolnshire Wolds westwards. On the west of this escarpment the Great Chalky Boulder Clay ice, augmented by the sheets which had flowed down the Yorkshire Plain (together with Lake District ice which had come over Stainmore), travelled up the valley of the Trent and down that of the Witham, fanning out across the low ground of the eastern Midlands. Part of the sheet, which crossed the Fen district, spread eastwards and southwards over East Anglia, reaching to Finchley in North London. Other portions of the ice-sheet spread south-westwards over the central Midlands and may have given rise to the most far-flung example we know, the Moreton Boulder Clay of the Cotswolds. The ice which had descended eastwards from the Pennines seems only to have been sufficiently powerful to travel southwards side by side with the Great Chalky Boulder Clay ice, and thus to have been elbowed into the Avon Valley. At the same time, ice appears to have advanced from the North Sea in a south-easterly to southerly direction on to the Norfolk Coast, thereby influencing the course of the Chalky-Neocomian and Chalky-Jurassic glaciers.

Over the greater part of England this Second Glacial Episode was that of the maximum glaciation ; and we assume that Chellian, and perhaps Early Acheulian, Man retreated before it. The origin and provenance of the few implements found in the Cromer Till and Chalky-Jurassic Boulder Clay have been questioned ; if these implements demonstrate anything, they show that the ice advanced over a Chellian land-surface.

Milder conditions caused the recession of the ice-sheets of the Second Glacial Episode, and the interglacial phase which followed was characterised by a pronounced amelioration of climate, and an aggradation of the valleys. Little evidence is available for assessing the length of this interval, but there is reason to suppose that it was shorter than the first interglacial interval. Some diversions of drainage were caused in the more hilly country during the retreat-stages of the ice, but the main valley-systems were only enlarged and aggraded by swollen and detritus-laden streams fed by the melting ice. The change to a temperate climate is reflected in the return of *Corbicula fluminalis* to the British area, and in the rich fauna and flora found in numerous lake-deposits ; it is not surprising, therefore, that the evidence of the presence and activities of Early Man at this time is most abundant and satisfactory. Acheulian Man, in his middle and later stages of development, wandered over the country and encamped near meres and rivers, doubtless hunting the 'warm' big game, such as the straight-tusked elephant, hippopotamus, leptorhine rhinoceros, etc. He was succeeded as an occupant of the area by Mousterian Man, whose remains are usually (but not always) accompanied by evidence of colder conditions. Contemporary with the Acheulian industry was the interesting Clactonian type of flaking which may have marked a new human invasion from Central Europe. Climatic oscillations occurred during this interglacial stage, as indicated by the brief sojourn in eastern England of northern plants and animals ; also, the presence of faceted pebbles in some of the gravels points to vigorous wind-action, possibly connected with anticyclonic conditions during the retreat of the ice. In the main, the English area stood at a lower level than at present and, while the land oscillated in height from time to time, the story is one of gradual uplift, by reason of which the streams were able to erode their courses to lower levels, their braided sinuosities being restricted at the same time within narrower valleys.

From the general absence of Acheulian and Lower Mousterian implements in the north of England, even from the caves, we may conclude that the area was inaccessible because of its covering of ice. The Second Interglacial phase was brought to a close by cold conditions which, if not excessively severe, were sufficiently cold to produce Coombe deposits and Trail over the southern part of England, while a re-advance of the ice took place farther north. The most noteworthy effects of this re-advance were the production of the Cromer Moraine and the Upper Chalky Drift, in which, it is claimed, Mousterian implements have been incorporated from the pre-existing interglacial land-surface. The record of this, the Third Glaciation of East Anglia, cannot be distinguished with certainty farther north, but it may be represented by the Upper Purple Boulder Clay of Yorkshire in those cases where two Purple Boulder Clays with intervening sands and gravels can be identified.

The ice that had gathered on the Southern Uplands of Scotland was joined by the Lake District ice and swept over Stainmore into the Tees Valley and also down the Tyne Valley. It also appeared to have filled the Irish Sea and to have advanced on to the Welsh Coast and across the Cheshire Plain to the Shropshire hills.

The evidence for the Third Interglacial phase is not at present stratigraphically clear. By inference, the ice must have retreated on a large scale, for Aurignacian Man was able to establish himself on many sites and to reach the caves of Derbyshire and North Wales, and to leave, in the former case, examples of his *art mobilier*. He was accompanied by a fauna of arctic and tundra type. The situation of his 'floors,' at present below sea-level at some localities, indicates that the land-area stood higher than now, so that communication with France and Spain must have been relatively easy.

Corresponding with the evidence of a decrease of temperature in the Spanish and French cave-deposits, where the warm Aurignacian is followed by indications of a colder climate in the Magdalenian, is the development in northern England of great ice-sheets, the easternmost of which produced the Hessle Boulder Clay and was able to advance as far southwards as Hunstanton. Here its force was expended, and although it was able to pick up and include Middle Aurignacian implements on its way, it did not exercise sufficient influence to prevent Late Aurignacian and Magdalenian Man from living at no great distance from its front, as, for example, in East Anglia, and beyond the York Moraine in the Cresswell Caves. In the west of England and in Wales the Lake District and Scottish ice, having again filled the Irish Sea, invaded the marginal portions of the Cheshire Plain and North Wales. Aurignacian Man was driven from the country and the remains of his activities were sealed up in the North Welsh caves. We have considerable evidence of the retreat-stages of this Fourth Glacial Episode, and are at present led to believe that no subsequent glaciation of equal importance followed. While it may be true that the re-advance of the Scottish ice into the Lake District area marks a fifth glaciation, in the east and south of England Man appears to have survived free from climatic interruptions on a land-surface not very different topographically from that of to-day.

The passing of the Ice Age was marked by a slow but steady subsidence of the land-area of southern and eastern England, which commenced apparently after Late Aurignacian times, and continued until after the Neolithic period. Thus were produced the submerged forests, the drowned river-valleys and the buried valleys which occur just below the present-day flood-plain deposits of the rivers.

And so the final touches on our picture portray a land very similar to our country as seen by modern Man. Thenceforward its features become the study of the geographers, and its vicissitudes the concern of the historians. As geologists we piece together the earth's story, one of unending yet varied change, from the rocky remnants on which we live. But, as we receive our earth from the astronomers, a world chronologically remote in its early stages and void of life if not of form, so we must in our turn pass it on to the historians. For the close of Palæolithic times marks the end of our course, and, like the runners of old, we hand on the torch of life.

Valley.	*Portsmouth District.*	*Industries.*	
			? 5th Glacial.
		? Magdalenian, etc.	? Interglacial or Interstadial ?
End stage.	Last Coombe rock. Sandy deposits, Aurignacian ?		4th Glacial.
osition of ousterian to .	Land rising. 15-ft. Terrace-gravels. 50-ft. Lower Coombe rock. Land rising.	Aurignacian.	3rd Interglacial.
erian.	100-ft. Lower Coombe rock. 50-ft. Gravels. 15-ft. Littoral sands, Mousterian. Land sinking.	Mousterian* Levalloisian	3rd Glacial.
kearth. earth, with ce. *Corbicula* ccession of and Mid-	100-ft. Terrace gravels. 15-ft. Estuarine beds and Lower fluviatile gravels, Acheulian.	Acheulian Micoquian Clactonian	2nd Interglacial.
ler Clay.		Chellian	2nd Glacial.
			1st Interglacial
		-Chellian	1st Glacial.

Suffolk and Norfolk		*Cambridge District*	*Eastern Midlands*	*Lincs and Yorks.*	*Northumberland and Durham.*	*Lake District*	*Irish Sea, Cheshire and N. Wales*	*Avon-Stour Drainage*	*Upper Thames Valley*	*Lower Thames Valley.*	*Portsmouth District*	*Industries*	
				Arctic peats and plant beds	Scottish Re-advance	Scottish Re-advance.	Bride Moraine, Isle of Man						? 5th Glacial
					Sands							? Magdalenian, etc	? Interglacial or Interstadial ?
…stanton Brown Boulder Clay …th Middle Aurignacian im-		Barnwell Station arctic beds	? Terrace gravels	Hessle (coast) Boulder Clay. Later retreat of Dales glaciation York Moraine	Tyne-gap ose train. Tweed, Cheviot and Western ice-advance	Main Lake District glaciation	Upper Boulder Clay of Welsh Coast, sealing Mid-Aurignacian floors		Deep channel filled at base, cold. Flood-plain gravels	Lea Valley, Ponders End stage	Last Coombe rock Sandy deposits, Aurignacian ?		4th Glacial
… washes, Aurignacian to Solu-		Upper Barnwell Village beds, cold		Marine shingle ? raised beach sands, laminated clays and estuarine warp	Plawsworth sands, etc		Sands and gravels.		Excavation of deep channel		Land rising		
…raised beach … river …ts and brick- … Upper Mousterian		Upper evenly-bedded gravels	Fluvio-glacial gravels ? Levalloisian.						Erosion, warp and hill-washes	Erosion, and deposition of Coombe rock, Mousterian to Upper Mousterian	15 ft Terrace gravel 50-ft Lower Coombe rock Land rising	Aurignacian	3rd Interglacial.
…r Chalky Drift, ? Lower … implements		Upper Chalky Drift	Upper Red Boulder Clay, and Chalky-Jurassic Boulder Clay of Northants	Upper Purple Boulder Clay. Main Dales glaciation. Vale of York maximum. Stainmore glaciation.	Western ice-advance. Stainmore and Tyne glaciation	Early Scottish, joined by Lake District, ice-advance	Main Terrace of River Severn. Lower Boulder Clay of Welsh Coast and Shropshire	No. 2 Terrace, cold	Warp, frozen soil, top of Wolvercote Channel	Coombe rock, Mousterian	100-ft Lower Coombe rock 50-ft Gravels 15 ft Littoral sands, Mousterian Land sinking	Mousterian*	3rd Glacial
Early Mousterian brickearth, temperate		Unevenly-bedded gravels, Mousterian and Micoquian	Sands					Excavation of terraces	River-clays and peat, with Mousterian, cold to temperate	Upper Crayford brickearth. Lower Crayford brickearth, with Early Mousterian.		Levalloisian Micoquian	
Upper Acheulian gravels		Lower evenly-bedded gravels, Acheulian		Sands, gravels and laminated clays with *Corbicula fluminalis*				Terraces No. 3 and No. 4, warm *Corbicula fluminalis*.	Lower gravels of Wolvercote Channel. Late Acheulian, Micoquian	Taplow (50-ft.) Terrace	100-ft. Terrace gravels 15-ft Estuarine beds and Lower fluviatile gravels, Acheulian	Acheulian	2nd Interglacial.
Brickearth, cold Peat Brickearth, temp	River-gravels and brickearths with *Corbicula fluminalis*	Lower Barnwell Village beds, *Corbicula fluminalis*, etc. Barrington gravels	Gravels, warm above, cold below, Acheulian						Upper Summertown-Radley Terrace, warm, *Corbicula fluminalis*. Lower Summertown-Radley Terrace, cold	100-ft Terrace, with *Corbicula fluminalis*, and succession of Clactonian, Early and Mid-Acheulian		Clactonian	
…alky-Jurassic and Chalky-Neocomian Boulder Clay. …ntorted Drift.		Chalky-Jurassic Boulder Clay.	Lower Red Boulder Clay	Lower Purple Boulder Clay. Early Dales maximum.	Scottish-Cheviot ice-advance.	? Maryport and Silloth Boulder Clay.		Moreton Drift and No. 5 Terrace	Wolvercote Terrace	Chalky-Jurassic Boulder Clay			2nd Glacial
…acial sands and gravels.				Gravels and sands				Fluvio-glacial gravels	100–140 ft. Terrace, with Chellian. Handborough Terrace.			Chellian	1st Interglacial
…rwich Brickearth ? Cromer Till …omer Forest-bed				Basement Clay. Sewerby Beach and cliff.					Plateau Gravels.			Pre-Chellian	1st Glacial

* In using the term Mousterian, in addition to Levalloisian, I have followed the published records.

SECTION D.—ZOOLOGY.

THE PIONEER WORK OF THE SYSTEMATIST

ADDRESS BY

THE RIGHT HON. LORD ROTHSCHILD, Ph.D., F.R.S.,

PRESIDENT OF THE SECTION.

I FEEL greatly honoured by the position I occupy at this year's meeting of the British Association, and am truly grateful to the Council for having chosen me as President of Section D. As the type of work pursued by us at Tring is well known to the Council, I may assume that I am not expected to speak from this chair on the advances made in Zoology during recent years, of which many of you are much better qualified to give a survey than I, but to set before this meeting some biological problems as seen by a systematist who has devoted much the greater part of his life to the study of species and what some among you may be inclined to call 'that sort of thing.' Biology is such a vast and many-sided subject that there are naturally many directions of approach, and if one branch of research works in one direction and another branch from the opposite side, it has for the uninitiated often the appearance as if there were antagonism between such opposite lines of attack, while in reality all the different lines support each other in their quest after a solution of the secrets of Nature. Biologists are in the happy position that, whatever theories they may favour at one time or the other, they have nothing preconceived to defend at all costs; for they all strive towards the same object: the advance of natural knowledge, wherever that may lead.

The inquiry into the secrets of organic Nature may be divided into three categories of questions: (1) what organisms creative forces have produced on Earth; (2) how they have produced them; and (3) what is the nature of the creative forces. The animal world, which appears almost infinite in the number of different forms, their diversity of food, behaviour, fertility and details of their life-histories, presents a picture of life confusing in its endless variety. Yet there is orderliness underlying this seeming confusion, and it is the first task of the systematist to discover this orderliness and sort the multitude of organisms accordingly. It was at the time of Linnæus a comparatively simple achievement for one man to have enumerated all the animals then known, his *Systema Naturæ* of 1758 containing altogether fewer than 4,300 species. That task is in our days a hundred times more difficult, not only on account of the vast number of species which have poured into collections, are still pouring in and will continue to do so for a long time, but especially because research in systematics requires a much deeper knowledge of the morphology and bionomics of the animals classified. At the time of Linnæus and after, when systematics were in their infancy, individual specimens showing marked differences were as a rule diagnosed as representing distinct species, the unit called species being looked upon as essentially a constant. This old view was at the time a new view. With the gradual discovery of the great range of variability exhibited by many organisms, the attitude of the systematist has changed. If formerly distinct-looking specimens found in the same locality had to be proved to belong to the same species before they were accepted as specifically the same, the modern systematist approaches the question from the opposite direction, regarding morphologically similar specimens, whatever their outward appearance may be, as specifically alike until their specific distinctness is established by convincing evidence. This attitude renders research in systematics far more subtle and difficult than it used to be and the results far more reliable. Experience has furnished a guiding principle in the facts that similarity does not necessarily mean relationship of the forms under observation, that dissimilarity is not necessarily evidence of specific distinctness, and that variability obtains in every species and every organ; and if these facts are kept in mind by the systematist, the reproach of superficiality often justly levelled at work in taxonomy can be borne with equanimity. Variability is an essential character of everything alive. The concept of the constant species of former days is replaced by the concept of the flexible species, and the saying that like breeds like requires modifying into the statement that a population breeds a population with the same extent of variability. If like breeds like were being taken literally, we should have to alter it into like breeds unlike. For, strictly speaking, individuals are never alike whatever their relationship to each other. A calculation, for instance, of the number of specimens required of the commonest British mouse-flea (*Ctenophthalmus agyrtes*) in order to find among them two absolutely alike in the number and position of the bristles on the body arrives at the amusing figure of many million billions, a figure certainly in excess of that of the whole flea-population of Great Britain, and tantamount to proving that there are no two specimens alike. In spite of all this variability the apparently chaotic mass of organisms is cut up by specific barriers into units represented by populations of numerous individuals, each population living its own life alongside other populations, as anybody can ascertain in his own garden or as a matter of fact in his own flat, particularly if there are a cat and a dog about.

In studying the characteristics of each specific unit and drawing up diagnoses for purposes of recognition, the systematist renders service in two quite different spheres of work and thought. Being alone able to identify the species in the difficult group in which he specialises, he assists defensive biology in its task to safeguard humanity against the ravages of health- or food-destroying organisms. Applied biology can only be a science if based on sound systematics. You will forgive me, I hope, if I refer, as a case in point, to an instance in the work of my late brother; it is a story well known to all who are interested in tropical diseases and perhaps a little worn by now, but will always remain a very instructive illustration. When the Commission investigating bubonic plague in India had become definitely convinced that the plague was a rat disease transmitted to human beings through the agency of a particular species of rat-flea, no satisfactory explanation could be found why in Colombo and the city of Madras an outbreak of plague did not last long, although rats and rat-fleas abounded. The puzzle was solved when Dr. Hirst took the matter up and sent to my brother the flea material collected in the towns mentioned during a period when there was no plague and again when an outbreak occurred. The examination of the material proved that the flea ordinarily infesting rats at Colombo and at Madras was not (as the Commission had assumed) the plague-flea *Xenopsylla cheopis*, but *X. astia*, a very similar, but different species, which, by experiments, Dr. Hirst proved to be an inefficient carrier of the disease. Outbreaks of plague occurred in those cities only when grain infested with the plague-carrying *X. cheopis* was brought from the Punjab. For some reason or other the environment at Colombo and Madras does not suit *X. cheopis*; it dies out, and consequently the plague disappears. When during the campaign in Mesopotamia camps became infested with rats, the British Museum could give the reassuring answer to an inquiry that there was no danger of a serious outbreak of plague, because the rat-fleas collected were *X. astia*, none belonging to *X. cheopis*. This close connection between applied biology and systematics is well understood by the scientists who are at the head of applied biology, but as yet not by every young scientist full of ardour and pride of knowledge, inclined to rely on his own identifications and therefore apt to go astray. The help which the systematist can extend to applied biology, however, is for him only a side-issue or a by-product; he is a student of pure science, devoting his time to the discovery of new species, of new connections between them and of new facts bearing on the relation between the species and its surroundings, the driving force in this pursuit of knowledge being the irresistible attraction which the subject has for him.

The describing of new species and finding the right place for them in a given scheme of classification and the identifying of species may seem work of an elementary kind, necessary and useful, but nevertheless rather superficial. If systematics ended there, they might satisfy the collector perhaps, but hardly the scientific mind. But this preliminary work is only a part of systematics, differing from the deeper study of the species as the cataloguing of literature does from the critical study of the contents of literature. A natural classification is based on blood-relationship, and therefore entails an inquiry into the evolution of the species classified. Systematics change from a static study of form into a dynamic study of evolution. For that purpose it is not sufficient to know some characteristic by which species A can be distinguished from species B, or which places A and B into the same genus or into different genera. A species is like a book, which must be read critically and in its entirety. Unfortunately the systematist is much handicapped, as in the case of mammals, birds, insects and some other classes he has to be content with the portions of the animal which it is customary to preserve in collections. But even so, the contemplation of the skins and skulls of mammals, of the skins of birds, and of the dried insects reveal to him the latitude and the kind of variability and variation in the species of which he has adequate material, and enables him to compare results with the biologists who have studied the flexibility of species with the view to ascertain whether the variability is purely fortuitous or whether there is system in the apparent confusion, many so-called laws of development having been discovered in the course of such inquiries. Now, according to the experience of the systematist, such laws are rules with exceptions, sometimes the normal and the exceptional balancing each other, and it may be stated in general that the opposite must always be expected to occur. That is somewhat distressing, but very true to living nature, where there is little need for logic and where the mathematical constant expressed by ' one equals one ' does not hold good, as any farmer can tell you. Exceptions have a certain fascination, not only for the writers of novels and plays, which are mostly based on exceptional characters or exceptional situations, but also for the biologist. As exceptions are comparatively rare, it requires large collections or long observation to discover them, and if there is no known exception to a certain rule of development, one has the feeling that it will some day be discovered. Take as an instance the bright colouring found among birds and butterflies. In sexually dimorphic species the male is the brighter coloured as a rule, but there are also butterflies and moths in which the female bears the gayer garb, this being particularly often the case in mimetic species, where conspicuousness plays an important rôle, such as *Archonias bellona*[1] and *Hibrildis norax*.[2] An interesting case of exceptional difference in colour and behaviour among birds and another among moths may be mentioned in this connection. In the swift moth of our meadows the white ♂ dances up and down a foot or two above the ground, keeping to the same spot and being in the twilight a very conspicuous object. The dark-coloured female, barely visible as it slowly booms along in search of a mate, does not take the first male it encounters, but makes a selection, there being evidently a difference in the males not noticeable to our dull senses, probably a difference in scent, the ♂♂ having the hindleg converted into a scent-organ. That the male makes itself conspicuous agrees well with the general behaviour of that sex in animals, but that the female takes the initiative is an exception. A parallel instance occurs among Gallinaceous birds ; among these game-birds are found the most striking instances of sexual dimorphism, the cocks exhibiting an often marvellous display of colours, as in the Peacock, Pheasants, Fowls and others, the females being comparatively inconspicuous. It is therefore somewhat startling to find just in this order a genus in which the colours and behaviour of the sexes are reversed. In most species of the Oriental genus *Turnix*, a kind of Quail, the females are larger than the males, bear a much brighter plumage, utter the call-note, fight each other for the possession of a male, and leave it to the male to incubate the eggs and to take care of the young—a state of civilisation of which we notice the beginnings in the human race. It is rather odd that in this instance the weaker sex, the male, attends to the young. For

[1] ♂ Cramer, Pap. Ex. I., tab. 13 (1775) ; f. *id.*, *l.c.* ii, tab. 177 (1779).
[2] *Cf.* Poulton, *Trans. Ent. Soc.*, 1928, p. 380.

it would surely be safer for the chickens if the stronger parent took charge of them, for the sake of defence ; but perhaps the heavy hand, or in this case, the strong beak, is, in the bringing up of the young, not always superior to gentler means of persuasion. In the Struthiiformes we find likewise that the male attends to incubation and to the nursery, with the exception of the African Ostrich, where both sexes incubate alternately, as is the rule in birds. As an example of birds of which only the female incubates we mention the Hornbills, the male ensuring the continuity of incubation by so blocking up the entrance to the hole containing the female on the nest that the female cannot get out. During the whole period of incubation and until the young birds are fully fledged the male feeds the female and young through the minute hole in the plastered-up nest opening. Of the two classes of animals which I have studied more particularly, birds and Lepidoptera, the coloration is on the whole more constant in birds within the species at the same locality, apart from differences of sex and age, than in butterflies and moths, and individual di- and polymorphism is decidedly more common in the insects than in birds, but it is by no means absent among the latter. Dark and light phases long known to occur regularly among certain raptorial birds—for instance, harriers—have during recent years been discovered to exist also here and there in other groups of birds, where they have formerly generally been described as distinct species. Such a correction had also to be made in the systematics of the American genus *Rhamphocœlus*, where red and yellow forms differing only in colour are now regarded as being individuals of one species, intermediate examples of an orange colour also being known, as well as very exceptional examples, such as the aberration *Rhamphocœlus dunstalli* Rothsch., in which the red and yellow colours extend to parts of the body other than those normally so coloured. The gaily-coloured parrots furnish other examples of dichromotism ; for instance, the parakeet *Eos fuscata* Blyth, which is a fairly common bird in New Guinea, appears in a red and a yellow form in the same place, both forms being about equally frequent, the red one slightly preponderating, and the lory *Charmosyna stellæ* Meyer, which appears in a black as well as a red form. This replacement of red by yellow recalls numerous Lepidoptera in which a similar change of colour takes place. Sometimes this change is sex-linked, the male being red and the female yellow, or the male yellow and the female red, the one happening about as often as the other ; the same is true of the change from orange to yellow, and from yellow to white. Pierine butterflies of the genera *Teracolus*, *Pereute*, *Anthocharis* may be mentioned. Occasionally species are found which, independently of sex, regularly occur in red and in yellow individuals, or in yellow and white ones, red specimens being on the whole more frequent than yellow ones, or yellow specimens than white ones—as, for instance, in *Papilio deiphobus* L. and *P. deiphontes* Feld., from the Moluccas, and the Agaristids [3] *Xanthospilopteryx karschi*, *X. africana* and *Rothia eriopis*, from Africa. The colour scale red, orange, yellow, white agreeing with the sequence in the ontogenetical development of the colours in the wing of the Lepidopteron, an acceleration of the physico-chemical process

[3] *Cf.* Seitz, *Macrolep.*, vol. xv, p. 38 ff. (1913).

in consequence of some stimulating factor, would account for the later step in the colour scale being so often obtained. This phenomenon is so frequently observed that one expects every red-coloured species at least occasionally to produce yellow specimens. According to the combined experiences of many observers, there is undoubtedly this tendency of a development from red in the direction to white, and if we find that in one species the male is orange and the female yellow (or white) (as, for instance, in some *Colias* and *Soritia*), there is reason for considering the female the more advanced sex, and *vice versa*. Now there is a curious discrepancy in the frequency of occurrence between red and yellow (or orange, yellow and white) in species where only *occasional* specimens bear the different colour, being so-called aberrations among a normally coloured population. To ascertain the frequency of a comparatively rare occurrence of this kind requires large collections brought together over a long period. Collectors, as a rule, are very keen on such aberrant specimens, and what we see therefore in collections is a disproportionately large number of aberrants among the normals. There is a collection of Lepidoptera at Cologne (Dr. Philipps), consisting almost entirely of aberrants; a madhouse the late Prof. Study, of Bonn, called the collection. The discrepancy alluded to is this: whereas the number of yellow aberrants among red normals (and white among yellow) is large, the change in the opposite direction from white to yellow and from yellow to red is excessively rare. I have in my collection only two instances of such inverse aberrants: an orange male of the yellow (♂) and white (♀) *Dercas verhuelli* Hoev. from China, and an Indian specimen and a Javan one of *Troides helena* L., with the abdomen and hindwings partly reddish instead of yellow. If the yellow aberrants of red species are due to accelerated development in the chrysalis, the red or orange aberrants of yellow species must be considered the result of retarded development. But why this enormous difference in frequency? As a systematist I can only present the riddle and must leave it to the experimentalist to find the solution of this contradiction.

Besides colour and pattern, the size and shape of the specimens and their appendages and the structure of the secondary sexual characteristics of many kinds are found to be of great help in species classification, but experience has shown that none can be relied on unreservedly any more than colour or pattern. The comparison of the frequently exaggerated distinctions of the males, such as the horns of stags and beetles, the long forelegs of beetles, the stalked eyes of certain flies, etc., has led to the discovery that the size of these organs is not always proportionate to the size of the body, but that the ratio in the development of such appendages increases disproportionately with the size of the specimens; in a small male of a species of Longicorn beetle the antenna may be a little longer than the body, while in a large specimen of the same species it may be several times longer than the body. Collections bear out this law of growth almost completely, but only almost. The Stag-beetles are one of the families that have early drawn attention to the remarkable development of their mandibles, which are sometimes so large, and the point of gravity therefore placed so far forward that the specimen has to assume a semi-erect position in order to keep its balance. As far back as 1885 Leuthner [4] showed that in the genus *Odontolabis* the size of the mandibles of the males increased with the size of the body, but that there was nevertheless a certain amount of dimorphism, some large males having short mandibles, in one species the largest measured male having shorter mandibles than a smaller male. Similarly, it has recently been shown by Arrow [5] that in *Onthophagus*, a genus of Dung-beetles, the horns of the males conform in general with the above law, but that in one instance there are long-horned males and short-horned ones of the same body-size. Such exceptions from general rules are of great interest, and it is therefore the duty of the systematist who comes across an exception—generally accidentally—fully to record it. Does it not seem evident from the cases mentioned that Nature can break a rule of development, just as Nature has created species and destroyed them ? After all, the law is only our deduction based on the organisms we find provided by working methods of Nature we endeavour to discover. Circumstances may arise which interfere with the usual ' routine ' of growth. In *Papilio memnon* L., for example, one of the many Swallowtail butterflies with a polymorphic female, one of the female forms has a spatulated tail and therefore a larger wing-surface than the other females, but its body is not larger than in the specimens which have no appendage. The species is derived from an ancestor in which all specimens had tails. The direction of development in this and other species is towards taillessness ; but mimetism stepped in and preserved the tail by modifying the course of evolution. The rule of growth illustrated by the Stag-beetles, and corroborated by breeding of plants and animals, leaves no doubt that the characteristics in size and weight of an individual are not inherited and therefore are of no importance in the evolution of species. The test can be made in collections by comparing the closely related species of a genus with each other. In *Xenocerus*, for instance, a genus of Anthribid beetles, of which we happen to have the largest collection at Tring, the largest specimen (♂) of the largest species has the antenna two and a half times as long as the body, while in several smaller species the antenna is five times as long as the body in the largest male. If the proportional size of body and antenna were constitutional, the largest species in a group of nearly related species should always have the longest antenna, which is not the case. An interesting contradiction of another type in the evolution of allied species has lately come to our knowledge while I was arranging the American *Syntomidæ* and *Arctiidæ*, families which are among my favourite groups of Lepidoptera. The families are separated in Hampson's classification by vein 8 of the hindwing being present in the *Arctiidæ* and absent in the *Syntomidæ*. Variation in the state of development of this vein, therefore, is of some importance in the systematics of these families. Now, in the genus *Neidalia* one species in my collection has vein 8 represented by a distinct spur in the ♂, whereas in the ♀ it is a fully developed vein ; in a second species the vein has disappeared in the ♂, but remains unreduced in the ♀. That is to say, in the evolution of the neuration of the

[4] *Trans. Zool. Soc. Lond.*, vol. xi, p. 385 (1885).
[5] *Trans. Ent. Soc. Lond.*, 1928, p. 76.

hindwing from the Arctiid type with 8 fully developed to the Syntomid type with 8 suppressed, the ♂ *Neidalia* is in advance of the ♀. In a second genus, *Aclytia*, on the other hand, 8 is present in the ♂ of some species, absent in the ♂ of others, with intergradations, and absent in the ♀ of all species. In this case, therefore, the process of reduction is farther advanced in the ♀ than in the ♂, just the opposite of what obtains in *Neidalia*. The morphology of *Aclytia*, however, offers an explanation of the contrast. The ♂♂ of this genus have the costal margin of the hindwing enlarged in conformity with the development of a scent-organ, and vein 8 acts as a support of the lobe. Though the vein is absent from the imago of the Syntomids and ought to be absent from *Aclytia*, which belongs to the Syntomids, it has reappeared in the ♂, being presumably in a recessive or dormant state in the larva and chrysalis, capable of resurrection in the imago if the necessary stimulus arises, which in this case would be the development of a scent-organ. This explanation is perhaps not palatable to those who believe that lost organs are lost for ever ; much depends on what is meant by the word 'lost.' Vein 8 of the Syntomids is probably not really 'lost' in the individual, but merely suppressed in the imago.

It must be clearly understood that in speaking of the unimportance for evolution of the bulk of individuals and the size of certain appendages, we referred to specimens of the same country—*i.e.* individuals belonging to the same interbreeding population. In comparing the populations of two different countries the question assumes quite another aspect. In the systematics of birds the study of subspecies or geographical races has developed into a fine art. Size and shades of colour furnish the main distinctions between subspecies, and here we observe this important contrast that, while the difference of, say, 6 mm. in the wing-lengths of specimens from the same country is of no importance, because not inheritable, the difference of 2 mm. between the populations of two countries is an inheritable quantity and therefore qualifies the two populations as being subspecifically distinct from one another. The evolution of the subspecific size-difference evidently starts with a shifting of the *average* size. A series of English sparrows has not the same average wing-length as a series from Central Germany (large numbers have actually been measured by Dr. Kleinschmidt) ; in other birds there is only a more or less moderate overlapping in size, and in others again the averages are so far apart that there is a gap between the largest bird from one country and the smallest from another country. The size of birds is remarkably constant as compared with that of Lepidoptera. In these insects size depends to a great extent on a variable outside factor, the supply of luscious food for the caterpillar. In the dry season of the tropics and in the late summer and autumn of the temperate regions food is hard and the resulting butterflies, therefore, as a rule smaller than those resulting from caterpillars which have fed up in the wet season or in spring and early summer when food was plentiful and soft. Size, therefore, is as a rule of no great weight in the diagnoses of subspecies of butterflies ; but there are such which are definitely smaller or larger than others—a case in point being the races discovered by Wallace on Celebes and characterised by large size and falcate forewings. If there is no corroborative evidence in the specimens themselves, the subspecies based on slight differences in the shade of colour or in the size, and especially the subspecies which overlap each other in size and colouring, urgently require testing by controlled breeding experiments. That such differences are inheritable has to be proved ; the systematist assumes they are, but he may be wrong. The differences between geographical races, however, are frequently very considerable.

In our researches on the Swallowtail butterflies we came across a combination of distinctions which is most instructive in an inquiry how the subspecies have come into existence. In a large number of species of butterflies and moths the geographical forms are separated by differences in the structure of the organs of reproduction and in colour and pattern. The important point is this, that the two sets of differences vary independently of each other within each subspecies. In *Papilio euchenor*,[6] for instance, the yellow markings of the forewing are less extended, and the hook on the inside of the clasper is less curved in the New Guinea subspecies than in the one from the Bismarck Islands. If a New Guinean specimen somewhat approaches the Bismarckian race in colour it does *not* show an approach in the shape of the hook of the clasper, and *vice versa.* The chance that a specimen of one race approaches the other both in colour and structure is very remote—we have never come across one—and the *identical* combinations colour plus structure of the Bismarckian race cannot be expected ever to occur among the New Guinean population. Therefore the Bismarckian subspecies cannot have come into existence by arrivals from Guinea, having already possessed the characteristics which distinguish the race of the Bismarck Islands ; consequently these special distinctions must have been acquired after the islands had become populated from New Guinea, no matter whether the immigrants were average or not. The individual characters of the ancestral specimens do not influence the formation of the new race, only what is inheritable is of importance, and what is non-pathological and therefore adaptable to new and possibly less congenial surroundings. It is perhaps necessary to emphasise that the breaking-up of a species into geographical races (subspecies), often into a large number, is not exceptional, but is the rule with all species with wider distribution, and that the above combination of structure and colour has been tested in many species. A chain of races each confined to its district is a beautiful illustration of the workings of evolution. The differences evolved during isolation depend on the constitution of the animal and the nature of the environment, and the change may be visible only in externals, or may affect also internal organs. In mammals the subspecific characters relate generally to the skull and the colour, texture and proportions of the skin ; in birds to wing-length, proportions of the bill and to colour ; in insects, where the whole skeleton and the soft parts, at least in a dried-up state, are preserved, distinctions may be found in any part of the body, but, apart from colour and pattern, are often most pronounced in secondary

[6] *Cf.* Roths., *Nov. Zool.*, vol. ii, p. 339 (1895) ; Jord., *l.c.*, vol. iii, p. 469 (1896).

sexual organs—certain subspecies of Ectoparasites [7] are even mainly based on differences in the ducts of the sexual organs and their accessory glands. Systematics and morphology are different expressions for the same kind of research, and I have no doubt that experimental biology will likewise have such a deepening influence on systematics that the superficial gap existing between the two lines of research will disappear too. Knowledge *begins* with the observation of phenomena, not with the experiment. The areas inhabited by the geographical forms of the species we have studied are either strictly separated, as in the case of island forms, or they are contiguous, there being between the areas no gap uninhabitable for the species, such as water would be for a dryland species, or a desert or savannah for a woodland species ; or the areas may overlap. What happens when the areas touch or overlap and the geographical forms come in contact with one another ? In a critical survey of the birds of Kenya Colony, lately published by Dr. van Someren in the Tring Museum periodical,[8] every now and again the author records the observation that perfectly distinguishable subspecies intergrade in the intermediate district, where the two evidently have interbred and produced an impure population, not strictly distinguishable from, nor identical with, either present subspecies. The phenomenon occurs very frequently, as must be expected ; for the breaking-up of a species into geographical units cannot at once result in sexual aloofness. This, however, is a point which should be further investigated. Standfuss [9] mentions, for instance, that, according to his experience, specimens from different districts do not mate so easily when brought together as do specimens from the same district. It is therefore quite possible that geographically separate populations which the systematist considers identical, because he does not find any morphological differences, may nevertheless have acquired a physiological difference, the rudiments of a physiological barrier, which the experiment only could detect. Though hybrid populations are of common occurrence, they have not been thoroughly tested with some exceptions. Prof. W. F. Balfour-Browne made the interesting discovery among the water-beetles of Great Britain—and Mr. J. O. Cooper has corroborated the discovery in other species—that there is a certain species in the south of Great Britain and another in the north, clearly differentiated, while in the intermediate area both are found with all intergradations. The species-pairs, as Prof. Balfour-Browne calls them, are of great significance. The systematist does not know what to do with them ; he generally treats the hybrid population as an intermediate race and gives it a name or leaves it without one of its own ; the insect catalogues abound with the name ' intermedia.' I need hardly point out that the frequency of the occurrence of mixed blood is a snare for the geneticist who bases his conclusions on the assumption that the original specimens for his series of experiments were pure, while his experimental results may in reality be due to the hybrid nature of the parent stock. Intermediate races fluctuating in character are often indefinable morphologically, but are definable

[7] *Cf.* Jordan, *Trans. Fourth Intern. Congr. Entom.*, p. 498 (1929).
[8] *Nov. Zool.*, vol. xxxvii, p. 292 (1932).
[9] *Handbuch*, p. 107 (1896).

ecologically—*i.e.* by the kind of country inhabited : desert, savannah, forest. In fact, the peculiarities of a race are best understood if it is considered as part of the environment.

Not all geographical races amalgamate when they come together. Many of them have become so different that they can live side by side, each being an independent community not interbreeding with the other. As instructive examples I will mention some Swallowtail butterflies : *Papilio thoas* L. occurs, split up into many races, in South and Central America, its range reaching into U.S.A. A very closely related species, and evidently originally its northern race, *P. cresphontes* Cram, flies in U.S.A. and extends far south into Central America, the two common insects keeping perfectly distinct in all characteristics, no hybrids being known. In the Oriental region *Papilio eurypylus* L. ranges in various subspecies from the Bismarck Islands westward to India, and *P. doson* Feld., which we only recognised as a separate sister-species after a more careful study of the male genital organs, occurs from Ceylon and South India eastwards to the Philippines and the Lesser Sunda Islands. The two species, therefore, are found together over a large area, but the most western districts are inhabited only by *P. doson* and the most eastern by *P. eurypylus* ; originally they were the Western and the Eastern forms of one species. It is evident that these butterflies represent a further step in the evolution of species than the species-pairs which still amalgamate in the area common to them.

Sometimes we find both amalgamation and specific distinctness among the forms divided from a parent stock, as is the case in the sister-species Cat-flea and Dog-flea. The home of the genus *Ctenocephalides* to which both belong is Africa. Tropical and South Africa are inhabited by a subspecies with short head, and the Nile countries by one with a long head, the two intergrading in the Sudan and Uganda. From India to the Papuan countries, with the exclusion of Australia, a third race occurs, and in Europe and Central and North Asia the cat-fleas were represented by the flea occurring on dogs and wolves. When the Egyptian house-cat came to Europe, it brought with it the long-headed form of *Ctenocephalides felis* Bouché, which thereby came into contact with the Palæarctic shortheaded dog-flea. One might have expected that they would hybridise and amalgamate, but they did not. The morphological differences are but slight, but a physiological barrier had arisen which kept and keep the cat- and dog-fleas as species, although they may occur together on the same individual of the host. When my brother pointed out the specific distinctness of the two fleas, he encountered a good deal of criticism before his opinion was generally accepted as correct.

Before leaving this subject I will mention a type of local form which stands apart from the usual kind of geographical race. In gregarious mammals, such as the African buffalo, one herd seems frequently to differ from another herd, and as herds keep to their particular district, the difference has all the appearance of being geographical and having originated in the same way as the geographical distinctness of which I have spoken. But we know that family likenesses are inheritable, and it appears to me that the herd distinctions are really family characteristics impressed on the herd by the dominant bull. The point requires further investigation by the systematist, as the result may be quite interesting and perhaps important for our understanding of localised differences encountered among other animals.

Systematics, however, are not concerned with the study of species and their variations only. The species have to be grouped into genera and then into higher categories, all according to relationship—*i.e.* according to descent. As in the study of subspecies the systematist must enter upon geography, so in the search for the past connections between genera and families his research becomes linked with the past history of the Earth and sometimes throws light on this history. If he can prove that two genera now widely separated geographically are really of common stock, then there must have been a means of communication in former times which is now absent. If I may draw again on my brother's studies for an illustration, we will take the distribution of the queerest-looking fleas as yet discovered, the Australian *Stephanocircus* and the American *Craneopsylla*, in which the anterior portion of the head is divided off as a laterally compressed helmet. They are closely related, and the group originated in South America, where occur several allied genera and a genus connecting the group with more normally built fleas. They are only found in the Andesian countries from Patagonia to Ecuador (possibly occurring farther north), and in a modified form as *Stephanocircus* in Australia, nowhere else. The assumption that there was at one time a bridge between South America and Australia is the only explanation at all satisfactory. This conclusion is supported by another genus (or group of genera), *Parapsyllus*, which is plentifully represented by species in the same Andesian countries (not in Eastern Brazil, the Amazons and Guianas), and recurs in one species on the islands in the South Polar Sea and in southern districts of Australia. The distribution of both genera evidently took place from West to East. To this example, affording positive evidence of a geographical bridge of some kind, may be given a comparison which is a negative witness. One of the most remarkable lacunæ in the butterfly fauna of Africa south of the Sahara is the total absence of swallowtails which feed as larvæ on *Aristolochia*. The species are numerous both in America, especially in the tropics, and in the Oriental region, but not a single one has reached Tropical and South Africa, though food plants occur, only one species of Ceylonese affinity being found on Madagascar. In face of this evidence it is impossible to believe that after the appearance on Earth of the butterflies there ever existed a bridge between Africa and South America.

Although the systematist is primarily concerned with the organisms as produced by Nature, and not with the creative forces which have evolved them, his researches extend to so many different species that he is bound to collect evidence bearing on those forces and their working. There are, in fact, certain questions which can only be answered with the help of extensive systematic collections: Convergent development, for instance, which looms rather large in discussions on natural selection, particularly its frequency and its geographical occurrence. It is a fairly common phenomenon, which however I shall mention only in passing, for similarity in colour—such as shown in the mountains of New Guinea by an unusually large percentage of butterflies which have the upper side white with a black border to the wings, as in *Pieridæ*, even a number of Blues having acquired this colour—involves one unavoidably in arguments about mimicry, a subject outside this address and concerning which I will say no more than that there are numerous cases of convergence in appearance unexplainable to me if mimicry were not a reality. I will, however, refer to a few non-mimetic illustrations of convergent development in which the influence of locality is very apparent. In a number of Oriental Papilios, with a tail to the hindwing, this appendage becomes reduced as we proceed eastwards, and in some instances disappears altogether on the Papuan islands. New Guinea has produced very striking metallic coloration in two groups of animals, the Birds of Paradise and the Geometrid moths *Milionia*. A number of butterflies of the island of Celebes are large and have the forewings strongly curved. The home of long-tailed Geometrid moths is South America, where also occur long-tailed Riodinid butterflies similar in habits and sometimes in appearance to these Geometrids. We do not always have a satisfactory explanation of such convergences; but the darker coloration of certain West African butterflies as compared with their East African representatives, and of some Sumatran forms as compared with those from Java, is probably explained by the damper climate favouring the production of black-brown. The wings in a number of migratory birds are shorter in several Algerian subspecies than in the European ones—for instance, in the House-Martin, the Hawfinch, Goatsucker, and others, possibly due to these subspecies having to fly a shorter distance to their winter quarters than the northern birds, and therefore short-winged individuals having a better chance of surviving than in the case of northern migrants.

Another point of significance revealed by collections is the frequency of monomorphism in the outlying districts of polymorphic species. *Papilio ægeus* Don., for example, is polymorphic in New Guinea, appearing in two forms of the ♂ and several female-forms; the various subspecies flying in Australia and on the Moluccas have only one kind of female. The polymorphic *Papilio memnon* L. has a monomorphic female in its most northern area, Japan. The African *Papilio dardanus* Brown is monomorphic in Madagascar and the Comoro Islands (the female being but slightly different from the male), whereas on the African Continent the species is not only strongly sexually dimorphic, but moreover polymorphic in the female.

The simplification from the centre of distribution outwards, indicated by the examples mentioned, obtains also in some insects where the sexes of the species remain monomorphic in the whole area. According to the researches of Onslow,[10] the conspicuously different geographical forms of *Papilio priamus* L., the orange one inhabiting the Northern Moluccas, the blue one found in New Ireland and the Solomon Islands, and the green forms occurring in the interjacent countries, differ from each other (in the tint of colour) in that the orange form has an orange pigment in the scales, the blue form no pigment, but a structural blue, and the green forms a combination of the yellow pigment with the structural blue.

[10] *Philos. Trans. Roy. Soc.*, B 211, p. 39 (1923).

Although the green forms combine the colours of the other two, they are not hybrid products, but the original stock from which the blue and the orange forms have descended, the blue form having originated by the loss of the yellow pigment, and the orange one by the loss of the blue structural colour. A gradation of the loss of the yellow pigment is observed in the three subspecies from the Bismarck Islands: the green *bornemanni* Pagenst., from New Britain, with the metallic green scaling similar in distribution to the scaling of the blue New Ireland specimens, a second subspecies, *miokensis* Ribbe, from Miotio, intermediate in geographical position and in the blue-green colour, and the deep blue *urvilleanus* Guér., from New Ireland, New Hanover and the Solomon Islands (which has occasionally one or two golden dots on the hindwing). This case of great outward contrasts with so simple an explanation of them is probably unique.[11]

In the vast majority of species the geographical differences are quantitatively small and frequently so concealed (or even inside the body) as to exclude the idea that a process of selection through enemies takes place in such cases. This elimination of one factor in their evolution, however, does not answer the question how these small differences have arisen and become hereditary. A new subspecies being the old plus the surviving and accumulating effect of mass and energy of the environment, perhaps observations of another kind give a hint. In an instance here and there it has been found that the larvæ of a Lepidopteron, usually monophagous on a definite plant, through force of circumstances or accidentally feed upon another species of plant, and that then the offspring of this brood will rather die than take to the normal food-plant of the grandparents. Does it not look as if here a habit had become fixed in one generation? Now, if we look upon the component parts of an insect specimen as if each part were an individual and apply the above observation, it is quite conceivable that in a new environment one or the other factor affecting the development of the growing body will stimulate this or that individual organ, or group of cells, or retard its development, and when an acceleration or a retardation has taken place in one generation, a predisposition, a habit, is acquired by that organ which will persist, like the habit of eating the strange plant. The crested lark, which is common on the south shores of the Channel, but never crosses the twenty odd miles of water, except by accident (about half-a-dozen specimens being known from England), teaches us that habit is a pertinaceous factor in life.

From the remarks to which you have so patiently listened it must have become clear what my attitude is towards the staff to whom the study of systematics is to be entrusted in public institutes. If I could carry out an ideal, I should leave the preliminary work only to less thoroughly trained members of the staff and continue to appoint for research work the best brains to be got, trained at the University in scientific thinking, who do not merely float, but can dive.

[11] Incidentally it may be mentioned that green specimens of *P. priamus* which have suffered from damp assume a bluish tone in consequence of the deterioration of the yellow pigment.

SECTION E.—GEOGRAPHY.

THE GEOGRAPHICAL STUDY OF SOCIETY AND WORLD PROBLEMS

ADDRESS BY

PROF. H. J. FLEURE, D.Sc.,

PRESIDENT OF THE SECTION.

I. Introduction.

It has been assumed in many discussions that mass-production and commerce on a large scale represent a new mode of life, a form of society, that is conquering the world and must disintegrate older modes of social life and organisation. However true this is, there are limitations obvious now that production far beyond immediate selling possibilities is causing so much difficulty. It is truer to say that various types of society, the world over, are trying to graft on to their ancient heritage this new scheme of mass-production. In vastly increased numbers the peoples of the world, some more, some less, touched by the idea of mass-production, are jostling one another as never before, and various types of society have become, willy nilly, standing dangers to others.

Whether Adam Smith really willed it or not, his plea for specialisation between individual and between parts of a nation became a plea for specialisation of nations, and the *laisser-faire* doctrine which followed it was an idea that all would be for the best if economic rivalry were unbridled, and the best were allowed to win freely. One might caricature this, a little unfairly no doubt, by saying that unlimited commercial warfare was to be the way of progress, peace and plenty. A few thinkers were not so sure of this ; Disraeli saw its dangers, and, on the other side of our politics, Leonard Courtney, back in the seventies of last century, expressed alarm at the growth of British industry and population, which he saw would call up rivalries leading to war ; and at the end of such a war there would be a breakdown of the network of credit and millions would be unemployed. His foresight has been all too fully justified. It may have been useful, up to a point, to think out the increase of production through specialisation as Adam Smith does in his famous argument about pins, but there was need for far more thought than seems to have been given to the maintenance and development of social life in the various environments nature provides and man adjusts. Study of that kind has lagged behind for many reasons. There were those—and they had immense power in the days when British industry was spreading—who, on religious grounds, held that one had but to propagate the faith western Europe had assimilated and all would be well ; for them there was one type of ideal society for all. The development of science and the multiplication of contacts have made thought more complex. Social forms result from interaction between men and their environments, and the lessons learned and the ideas selected and developed in different cases have been very different. This is a legitimate and important sphere of work for the student of geography. In each case, the people and their form of society are so much a part each of the other that, whatever changes mass-production may bring, they want to, they must in fact, keep a large measure of continuity from their past. They have nearly all once been, in the main, self-contained groups, or, at least, external commerce has been subordinate to internal exchange. Socially and economically the village group was in large measure an autarchy, whatever political organisations might come and go above its head. One recalls the well-known answer of a Polish villager that his lord was a Pole but he was a peasant. The idea of the self-contained unit is thus very deep-rooted. With great effort, using the opportunities of cheaper printing in the nineteenth century, the village has come to feel itself part of the nation, which has clamoured for opportunities of self-expression. Many a nation naturally, therefore, seeks to be self-contained, all the more if it feels that specialisation and consequent dependence on imports is going to give it an inferior position. We may declaim against the follies of economic nationalism ; we must, however, go beyond criticism into sympathetic examination of the people in their geographical environment with their need of ' a place in the sun ' and their claim upon the world's help, if we are to become constructive thinkers.

The old self-contained national group might have a centralised administration efficiently organised for defence ; but it was usually an agricultural group and, in the nineteenth century, found itself at a disadvantage in comparison with a group of industrial producers in commercial organisation. In the first burst of mass-production the future for manufacturer and merchant seemed boundless. The exchanges that developed, unless there were some restriction, tended at first to make profits and credits accumulate among the industrialists rather than among the agriculturists. These credits might be loaned to the agricultural countries to start them on the new line of development or to build railways and roads, and the debtor country might, and in some cases does, profit by its indebtedness. But industrial groups, to keep their works going, have not seldom been willing to get payment in bonds, or banks in creditor countries have issued bonds the produce of which has been used to pay for goods sent to debtor countries when cash and exports did not suffice. There has often been an eagerness to put off the day of reckoning in this way because direct payment would depreciate the debtors' currency. Moreover, in far too many cases, an evil chain of consequences works itself out. Part of the loan spills over into unauthorised channels on its way to its destination ; much is probably spent on railways that may not earn a cent for a century ; not a little may go in various schemes of display to try to conquer what is now called an inferiority complex. It is true that default is not infrequent, and, in this way, international debts that are not represented by substantial assets do wipe themselves out in time ; but the process is harmful to the society that defaults. In other words, the spread of mass-production and commerce needs to be looked at less from the point of view of how as many pins as possible may be produced as quickly and as cheaply as possible, and more from the point of view of the health, and especially the continuing mental and moral health, of the societies concerned. A historical geography of international indebtedness is much needed.

We need to think of forms of society the world over not merely as examples of halts at various stations along a road on which the industrialist nations have advanced farthest. To do that is to choose out and emphasise points in our own experience and to make thence a kind of footrule wherewith to measure the world. An Oriental sage, with as little or as much justification, might invent a very different measure for us, and say that patriotism, for example, is a relic of barbarism that has brought calamity to twentieth-century Europe. Human societies are primarily associations between men and the earth in particular areas, and must be studied objectively as such, and also in relation to what they receive from outside.

II. Hunting Groups ; their Geographical Distribution, Past and Present.

When men developed the hunting habit, social life probably took a great step forward and was furnished with a new dynamic influence of psychical nature in that the men hunted while the women collected food, reared the children, and began to make the home centre, temporary at first, with its attendant arts of dealing with fire, skins of animals, grass bags, and so on. The group was as yet not fixed in one abode, nor could it look or think far ahead. Its observations led, no doubt, to the emphasising of coincidences rather than to much real argument, its cosmogony was very fragmentary and poor, but it is doubtful whether M. Lévy Bruhl has justification for saying that the mental processes of pre-agricultural peoples are entirely different from ours. In the Old Stone Age hunting was the leading scheme of life, and finds of implements allow us to trace at least three main waves of dispersal. The first resulted from their acquiring the power to chip stone, and probably to make fire as well. While some of the early implements are associated with ancient and apparently extinct types like the Neandertal race, the chief series, called the Chelleo-Acheulean, has no skeletons definitely associated with it in Europe, but there is an *a priori* possibility that this series, or a part of it, is associated with *Homo sapiens*. The claim that Oldoway man is contemporary with the Chelleo-Acheulean culture of the bed in which it lay is not confirmed and it is likely that the skeleton is a later burial. Leakey has, however, apparently found *H. sapiens* with tools of this series elsewhere in East Africa. The Chelleo-Acheulean series is found over much of Africa, save the equatorial forest regions, in south-western Asia and parts of southern India, and over south-western Europe.

The second great move forward seems to have come with the use of multiform tools for different purposes, though the recognition by their makers of definite types of tools must not be over-emphasised ; the mounting of stone points and edges in wood, the beginnings of artistic skill, were other features. Finds of the so-called Upper Palæolithic series of tools are again characteristic of much of Africa, the north and the east at any rate, of south-western Asia and central and south-western Europe. Within this area the Aurignacian variety of this culture bears characteristic marks over wide areas. It is definitely associated in Africa and Europe with *Homo sapiens* and there is a considerable range of form among the skeletons found, suggesting that *Homo sapiens* already had a long history.

It is at any rate possible that the makers of the earlier Pleistocene tools (Chellean and Acheulean) belonged to *Homo sapiens*. If so, they seem to have flourished in Africa during early phases of the European Ice Age (probably the Mindel phase of Penck), and to have spread into Europe when aridity ensued in the next interglacial phase (probably the phase which included the formation of the Hötting breccia which is allocated to the Mindel-Riss interval by many students but by some to the Riss-Würm). A set-back was followed by a new and much more capable advance, that of the Aurignacian-Capsian hunters.

In the interval, however, another culture-spread occurred. Utilisers of flint flakes have left their traces in early and middle Pleistocene layers in various parts of Eurasia, and the developed form of the culture has been called Mousterian. In China, Palestine and Europe it is associated with beings who do not belong to *Homo sapiens*, but we do not yet know what type or types of men were associated with it in North or East Africa, and it is quite possible that there its ideas were taken up in varying degrees in different parts by *Homo sapiens* who had already used flakes a good deal. This is an archæological rather than a geographical question, but the possibility is relevant to our present purpose. For, beyond the area of the Capsian-Aurignacian cultures, to the south and south-east especially, there is evidence of spread of a hunting culture that seems best described, provisionally, as based on a mixture of Mousterian and Aurignacian ideas. The tools in question are known from South Africa, as well as from India, and they linger on in use as the basis of Australian culture, as Sollas long ago pointed out, though there they are affected by fragments of later cultures. The importance of what is now the African-Arabian arid zone in the days when hunters were the most advanced social types is understood if we reflect on the importance of the ungulate herds, especially Antelopidæ, on African grasslands, and if we realise that, during glacial conditions in Europe, North Africa and Arabia would get considerably more winter rainfall, though parts of the eastern Sahara, for example, may well have been arid throughout. Long after the spread of the Aurignacian-Capsian hunters, who reached Europe *via* Spain across the Straits of Gibraltar during an ice retreat, there occurred a third dispersal indicated by finds of implements of flint and chert as before, but many of these are very small and are called pygmy flints. Men were spreading more widely over Europe and Asia, probably because the ice sheets had retreated. It is quite likely that there was no first-class advance of civilisation at this stage but rather a driving force behind, namely, the intensification of the desert in northern Africa and south-western Asia.

With the next great movement we meet agriculture, so we must pause here to note the fate of societies that have lingered at this stage of hunting and collecting.

If we use as a hypothesis the idea of drifts from northern Africa and south-western Asia, we have a key to some modern distributions of hunting peoples. These societies are either in what are ultimate corners or in areas of special difficulty; elsewhere they have been superseded by agriculturists. The pygmies of the equatorial forest of Africa are remnants in a region of hot wet climate where debilitation makes achievement difficult, and one may discuss in what measure these lowly people are primitive and in what measure they are degenerate. Biologists find the same type of question arises concerning the lowliest members of various animal groups. The Bushmen of south-western Africa are in a region of sheer poverty in a far corner. The Veddah and some jungle tribes of southern India are in another far corner under conditions that forest or jungle makes difficult. The Australians and recently extinct Tasmanians are in a far corner, isolated by orographical changes. The pygmies and some other hunting groups of the Malay and the East Indies and Philippines are, again, in what are almost ultimate corners, isolated by land-sinking, and, also, in regions of warm wet forest. North-eastern Asia also has some hunting groups, but here it is possible that some of the peoples, as Demolins thought, may have given up pastoralism as they drifted north-eastward from the interior of Asia. The pre-Columbian hunting peoples of the New World are omitted from this sketch, as they would need separate discussion, for the story of spreads of culture into America is a complex one, as the hunting peoples of pre-Columbian America have a more intricate cultural history than have many of those of the Old World.

III. Agricultural Peoples—Origins.

The third, or epi-Palæolithic drift, it has been suggested, was correlated with the intensification of the desert in northern Africa and south-western Asia. That great change apparently had the further effect of causing pressure of population on the Nile and Euphrates and possibly the Indus as well, all rivers with regular floods running through dry, or, then, fairly dry open country with a warm season. In or near these river-valleys, and probably other minor ones of the Syria-Palestine region, there arose, perhaps at one, perhaps in more than one, place the art of cultivation. Barley apparently is native to south-western Asia and north-eastern Africa, and the wild ancestors of our wheats include plants native to south-western Asia, but it is well known that the story of domestic wheat is a complex one. These facts suggest that the Fertile Crescent and Egypt are the first homes of agriculture, while the Indus civilisation may be an early derivative. All these rivers permitted and encouraged irrigation, and the deposit of silt from floods gives a renewal of fertility, so exhaustion of the soil, a serious difficulty in later extensions of agriculture to other lands, was not a problem of early cultivators near the rivers, and this was no doubt a great help to settlement. The courses of the Euphrates and Indus were conspicuously subject to variation, whereas the Nile is confined in its famous slot and its peasantry has gone on from time immemorial until near our own day with a remarkable measure of constancy as regards the economic basis of life. In Mesopotamia and on the Indus there have been more marked fluctuations; cities grew up and then died down when a stream left them to take a new course, and there was thus much wastage of momentum, with, no doubt, compensations in the direction of freshness of attack on environmental difficulties. The Nile slot contrasts so sharply with the plateau desert on either side that the peasantry now, and probably in the past, know little of the desert and fear it; Egypt basically seems to have been at first a self-contained unit receiving stimuli from without; Mesopotamia with its fluctuations seems to have exercised more influence over regions of Asia and Europe. How far the Indus civilisation affected the pre-Aryan life of central and southern India and thus the cultures associated with the speakers of Dravidian languages, which are still so important in southern India, is still a matter for pioneer research, though Slater has to some extent made an attempt to work this out—an attempt the more striking in that it was made before Sir John Marshall had discovered the Indus civilisation.

It is important to note here the immensity of the change that modern ideas have effected in Egypt. Perennial irrigation has made it possible to grow different crops in the different seasons, and the population has increased phenomenally. But the new schemes draw more from the soil and give it less silt, so Egypt is needing to import manures, and her agricultural life is drawn into commercial relations in revolutionary fashion.

IV. Cultivators and Herdsmen.

It is probable that the earliest cultivators were still without domestic animals, and the old view, still so often quoted, that hunting developed *via* pastoralism into agriculture, is now to be considered very doubtful. But domestication of animals was an achievement of very early times too, and, in such regions as the Fertile Crescent with its grass zones, it undoubtedly assumed great importance and led to the beginning of agelong conflicts and interactions between herdsmen and cultivators. The herdsmen, basically a close corporation gathering around the flocks and needing men to add to their strength for defence, as well as discipline and organisation to maintain unity, have often dominated peasant neighbours, but this special ability appears to have been much developed when the horse was acquired as a companion and helper—and that belongs to a later stage of this argument. The close nomad corporation, with little opportunity of expressing itself in luxury and building, has as features family pride and the idealisation of the hero ancestor. A measure of endogamy is a natural expression of this mentality, whereas some amount of exogamy is often encouraged by cultivators, probably as a means to peace.

V. Social Features accompanying Cultivation.

The bearings of the introduction of cultivation on social life and organisation have obviously been of the first importance. There was involved the idea of sowing for a crop to be reaped weeks or even months ahead—that is, there was now an incitement to prevision and provision. There was an observable sequence that made argument more solid than it was likely to be in the days of hunting when accidental coincidences loomed larger. In fact a growth of rationality must have been a feature, and with it came increased power of choice that is described in the account in Genesis as the knowledge of good and evil. The habit of prevision extended itself through calculations of the coming of the floods and correlated study of the heavenly bodies to the framing of a calendar. So society acquired a learned tradition and lifted itself some way above the old level of dependence on the personal power of medicine-men and the like. There was a further extension of prevision beyond that to a succession of years—namely, to a succession of generations specially associated with the domestication of animals and with the family, and with this came the growth of the idea of a mother-goddess or goddess of fertility which has so widely influenced society. Thought, drawn out towards the future, seems just as naturally to have run back into the past, giving rise to genealogies which are one of the germs of history and also to rites of reverence paid to ancestors. These rites, not unnaturally, are specially marked in regions such as China which owe so much of their civilisation to early interactions of herdsmen and cultivators on the ways from central Asia. It is of interest to note that the large household, linked by real or sometimes assumed blood relationship, seems a social feature of basic character among the cultivators of northern China, and in other forms is notable among other cultivators around the edges of the great steppe, the famous Zadruga of parts of the Balkan peninsula being a case in point in a region in which interactions between herdsmen and cultivators have been and still remain most important features of life. The Russian Mir sometimes had a like origin. It is naturally a social development in large measure antagonistic to the growth of nationalism.

Along with the primarily psychical development accompanying the rise of cultivation went the linking of society with a definite piece of land through the establishment of the settled life. This association is one of the most important features of settled society, and, occurring more or less in the same phase of development as the mental changes just named, it seems to have led to what has become a most widespread characteristic : this is the idea that the living hold a trust from their forefathers and will pass it on to future generations. This trust includes both the land to which the society is linked, and the customs, traditions and rites of the group. It must defend these when necessary, and it is likely to resist violent and deliberate change in them, though change of the ' common stock of ideas ' of the society is always going on. The old local unit, large household or village, worked rather by ' declaring the custom ' of the people than by debating projects of change.

There was, in the same phase of development, a marked growth of specialisation as between individuals in some, at any rate, of the settled societies. Marked advances of the potter's art, of the arts of stone grinding and metallurgy, apparently of carpentry, weaving and so on, all belong to early stages of cultivation. There appears also to have been, even in early stages, some exchange between different groups and a good deal of fusion, as well as division, of groups. But in spite of these last two considerations, the early cultivator-society seems to have been primarily self-contained, with external exchanges as a subordinate matter, however important.

Whatever may be found hereafter concerning the phases through which the early cultivating societies developed in their primary homes, there is little doubt that the spread of their scheme of life occurred in most directions in two stages. The first went with the hoe, used chiefly by women, and with domestic animals for food or milk, but not for work, and the second with the plough drawn by domestic animals under male control, as well as with the increasing use of domestic animals as carriers and workers in other ways such as the turning of a water-wheel. At a later stage comes the relief given to women from the work of crushing grain.

VI. The Spread of the Idea of Cultivation, and its Primary Modifications.

The first of these two rather artificially contrasted stages is the one that spread into intertropical Africa. There were special difficulties here. Firstly the climate made steady prolonged efficient exertion difficult in many areas. Then the fundamental crops, wheat and barley, would not thrive in most parts and inferior grains and other plants became the important crops. Further, there were practically no wild plants in intertropical Africa that the native cultivator contrived to domesticate ; so progress depended largely on plants deliberately introduced, as for example *via* Egypt or by Arabs, Portuguese, etc., in later times. The introduction of maize, manioc, etc., from America has made a huge difference to Africa. Fly belts in several regions, also lack of salt and phosphorus deficiency, and no doubt climatic factors, limited the value of domestic animals in Africa between the Tropics. The plough reached the Niger in due course, and Abyssinia also presents a special case, but, these apart, it is the lowlier stage of agriculture, supplemented by survivals of hunting and collecting, that is characteristic of the region. Nevertheless, the social life of African cultivators generally has at its base some feeling towards the idea of a trust handed along the generations. Systems of land tenures and utilisation vary greatly but usually gather around an idea of the land as the basis of the group's life, and that land, however utilised by families or individuals, is basically the property of the group or of the chief or king as a sort of personification of the group. It is something either given by nature or acquired or lost through war rather than something bought or sold, and leases are nearly always subject to customary limitations and not intended to lead to alienation in permanency.

Archæologists think agriculture spread into central Europe at first with the hoe and the non-permanent village that is a feature of parts of intertropical Africa ; and there are indications of the same scheme in forested and therefore backward parts of central India and elsewhere in south-east Asia as well as in north Korea. It is a useful hypothesis, not as yet proved, that this was the first stage of agriculture in most regions, save where irrigation offered the simple method of flooding with water containing fertilising silt.

Agriculture with the plough has now ousted this scheme from Europe and most of Asia and, in this superior stage, the village becomes more permanent: either a rotation in the use of lands is established and the households have their strips in each of the village lands, or a portion of the village land specially enriched by manure from stock folded on it may be cultivated nearly every year, and some portion of an ' outfield ' may be used as may be required or may be possible. There seems to have been, with the growth of this phase, an increase of the social or conjoint activities of the group. In many parts of Europe harvesting had to be completed by a certain day, on which a bell was rung and the fences around the crops removed to allow the cattle to feed in the stubble fields and give them manure. This is but one of scores of activities regulated for the village by custom and continuing through centuries, a scheme of life which maintained and developed the idea of a trust handed along the generations. Communal agriculture has largely passed away in Europe, but it is the basis on which later systems have been built, and its idea of the soil as a trust underlies much that is still important. It is important perhaps most of all because of a long continuity of inheritance, but it is in danger from the fact that our industrial culture is so drastically unconformable above these deeper layers, and has so diverged from the idea of a society living in close relation with a particular piece of the earth. The danger of unconformable superposition of cultures, when very extreme, is illustrated by the fate of the pre-Columbian life of America, and the peoples concerned, in the last few centuries.

In the regions with irrigation or plough agriculture or both, the differentiation of crafts went much farther than among societies with hoe cultivation. Exchange developed more considerably and there are towns or cities, fundamentally centres of exchange and of handicraft, and often of a priesthood and government. Cities are not found in intertropical Africa save in a few spots where they are due to intrusive influences of fairly recent date. The typical social unit in Africa is thus the village or the little group of villages; in Europe and Asia the village may be the fundamental unit among settled peoples, but it also forms part of a larger unit made up of a town and a number of villages.

The nomadic or semi-nomadic societies of intertropical Africa live on their cattle, and by hunting and collecting, as well as by raiding those who are more sedentary and less ready for war. The nomadic and semi-nomadic societies of Europe, Asia and northern Africa have in many cases the important auxiliary activity of trade, and use their beasts as carriers. Moreover, they have typically developed or contributed to the development of stations, which have in many cases become centres of trade and religion, *i.e.* sacred cities, near the bounds of the waste or in oases. The names of Mecca, Medina, Jerusalem, Damascus, Ur of the Chaldees, Babylon itself, Khiva, Bukhara, Merv, Samarcand, Lhasa and many another crowd on one's memory. In China, India and the Fertile Crescent the semi-nomad, especially after he acquired the use of the horse, found it possible to dominate the cultivator, and seems often to have contributed an elaboration of organisation to the group of social units, villages and their focal towns become grouped into larger entities. In Africa, too, pastoral groups have repeatedly conquered cultivators and, in such cases as that of the Baganda, have attempted a considerable amount of organisation with a hierarchy of units, but all this remains far cruder in regions where the hoe is the instrument of cultivation than where the plough is used and especially where the horse is available.

It is important to bear in mind contrasts between the various steppe lands of the Old World. In the first place, one may distinguish the northern steppe, north of Iran, from the southern steppe including Iran, Arabia and parts of northern Africa. For considerable periods in the Pleistocene the southern steppe was in many parts better watered than it now is, and included much land that is now desert. On the other hand, much of the northern steppe was apparently either under ice or under the water derived from the melting of ice. Parts of the southern steppe were of special importance as a home of hunting groups ; of the northern steppe at that stage we know little. Parts of the southern steppe have a little rain in winter, the northern steppe is subjected to the fiercest cold at that season.

The rivers of the southern steppe lend themselves to fertilisation of land tracts as well as to movement of trade, and, with the aid of the climate, agriculture developed far earlier and far more highly than it did in the northern steppe, and there are far more ancient cities.

In the southern steppe, ass, sheep, goat and camel are characteristic and traditional, with cattle in the vicinity of water. The camel appears to have reached Egypt, presumably from Arabia, at a very early period (in or before the First Dynasty), and it no doubt promoted trade. The northern steppe by way of contrast had large herds of cattle, sheep and horses, and milch mares gave a very valuable and complete food which was not available on the southern steppe. The latter is so dry and hot that the horse does not seem to have been fully adapted until the days of the Arab horse, inured to abstinence and evolved in Nejd in post-Roman times. The horse was, however, of great importance in the southern steppe before this. It is thanks to the horse, acquired from the Hyksos, that the Eighteenth Dynasty of Egypt transformed that once self-contained country into a far-flung empire. It is thanks to the horse that the lowland ways of Palestine became important under the kingdoms of Israel and Judah, and Israel broke away from the old-fashioned Judah to throw herself more fully into the new life. The horse was the ally of the Persian Kings of Kings, whose cradleland was among the hills of Fars with grass and streams. But all these earlier mentions of the horse are connected mainly with the fertile border of the steppe.

The multiplicity of relations between nomad and cultivator in the southern steppe has led the conquering herdsman to use the scribes of the cities he took in order to get written records of his prized genealogies and ancestral achievements, once he had become too busy with administration and policy to carry these in his memory as in the old days of the simple life and the blood feud. There is naturally far less of all this on the northern steppe, which a French writer has described as the land of *peuples sans histoire*. The many contacts of the southern steppe, and its nomads and its citizens, have led to the exchange of ideas and the broadening of the religious vision, so that this is the cradle of the monotheistic religions ; in so far as the northern steppe has become monotheistic it has been by the spread of influences from the southern. One may look upon this as a return gift for the horse, passed on from the northern to the southern steppe and effecting there so many of the contacts which made big religious ideas develop.

The southern steppe may be divided into regions such as Iran, Arabia, north Africa. The northern steppe in its turn is divisible into the low steppe of Turan or Turkestan with extensions into Europe, the plateau steppe around Gobi and the Takla Makan, and the mountain steppe or, rather, desert of Tibet. Moreover, the borders of the northern steppe, towards the rainier lands both west and east, have been in many ways rather distinct. Their nomads have been able to use oxen to draw wheeled carts, on which the tents were built. The wheeled nomads near the cultivators of the loess, the fertile soil of the steppe edges, offer a special case of contact of nomad and peasant. The nomads with control of large spaces and transport by horse and wheeled ox carts have been able to make their power seriously felt.

VII. Consciousness of Kind in its Geographical Settings.

The social group gathered around land held in trust along the generations has added to the expressions of its common life and to its consciousness of kind by developments of language and religion, of peculiarities of clothing and hairdressing, and other shibboleths, but it would apparently be exaggerating matters were we to think of our modern idea of linguistic nationalism as at all widely developed in early times. As already stated, the village, or the *pays*, or other small district was, of old, the effective unit. Consciousness of kind might be strongly developed in the Hebrew group that came back from exile in Babylon, but speaking generally that consciousness had to grow much further before modern nationalism could arise from it. In India distinctions between pastoralist conquerors and cultivator subjects gave impetus to the growth of caste, and this was an alternative channel along which consciousness of kind could grow. Nationalism in India is quite a modern political reaction. In China conquerors from the steppe have always had to merge themselves in the people, for the great mass of whom there has been no urgent need of common action against the outsider, at any rate until our own time ; and in China, again, nationalism is just in its birth-throes. In Japan, on the other hand, there was a prolonged struggle, on a relatively narrow front, for the conquest of land inhabited by aborigines, remnants of whom have been absorbed into the group of the intensely nationalist conquerors, organised as a feudal hierarchy.

In the classical lands of the Mediterranean, a variety of environmental and other causes, too familiar to need discussion here, made the city the general unit of society, and it is a commonplace that in many parts of the Mediterranean region even a place that has a population of what we in north-west Europe call a village affects the form and lineaments of a city. Consciousness of kind in considerable measure developed among these small units, and only the middle of the nineteenth century saw the rise of Italian nationalism in the guise of a struggle against foreign domination. Greek nationalism, also, came to birth as the struggle against Turkish rule became possible. Spain on the other hand, with its long fight foi Roman Catholicism against Islam, developed nationalism earlier, and naturally gave it an intensely zealotic flavour. That this feature has limited its growth seems beyond doubt.

In west, north-west and parts of central Europe early development was slow because the food-plants and animal breeds had to be acclimatised, and the problem of soil exhaustion was serious even if mitigated where the subsoil was of loess or related material. Nevertheless, there can be no doubt that settled populations in central and western Europe practising agriculture and living in villages were much more numerous in far pre-Roman times than it was customary to think a generation ago. It would appear that the languages in use in those days changed from time to time with conquests or migrations, and that Roman influence affected language far and wide. Thus, in west, north-west and central Europe, language up to Roman times appears to have played at most only a minor part in developing durable consciousness of kind. The centuries following the fall of the Roman Empire are dubbed the Dark Ages, and it is as they pass away that the germs of the future linguistic national groups become clear, with attempts to organise governments that were more than local in the small sense, while leaving the fundamental village units in large measure to themselves.

The spread of Islam in the Mediterranean region cut old trade routes for a time, and this increased the poverty following the decline of the Roman Empire, so that towns and cities went through a bad time, but apparently in several areas there was a marked increase of rural settlement, notably in central Europe, where this is called the *Rodungszeit* from the amount of forest clearing. Apparently the large plough worked by an ox team came into use, or, at any rate, wider use, at this time, and helped to develop the three-field in place of the two-field system—that is, a scheme in which two-thirds, as against one-half previously, of the village lands bore crops in each year. The unsettled state of affairs as well as this more elaborate system of communal cultivation made the village a very self-contained unit with a very definite routine. Neighbourhood in many cases came to mean as much as, or more than, kinship. The spread of clerical celibacy meanwhile caused the Church to recruit the clergy from the people, and thus the clergy often belonged to the locality in which they functioned, so the structure of society came to be built around local units, the majority of them rural.

As a hierarchy of social units re-established itself, growing mainly from local roots instead of from an external influence such as that of Rome, it is natural that such hierarchies should spring up where there was mutual comprehension of language in groups of villages and their focal market towns, and cathedral cities in France. Moreover, charters and grants and agreements written in the vernacular came to be increasingly important, while the use of the vernacular in courts of first instance developed folk-speech. It is apparently a combination of all these factors that has maintained the distribution of the peasant languages of Europe without any change of great importance since the Middle Ages.

The idea of the city can be traced eastwards and northwards from

France and the Rhine in the early Middle Ages, and, in relation with this, often, at the present day, the life of a town connects it with regions farther west, while the peasant life round about knows nothing of this. The Renaissance, being essentially an urban movement, accentuated this, and we note the French leanings of part of the upper classes in Alsace contrasted with the Alemannic tradition of the peasantry, German aristocracy and Danish common folk in parts of Slesvig, German (including Yiddish) affiliations of towns in Poland as against Slavonic life among the peasantry, Polish affiliation of towns and the upper classes in East Poland as contrasted with Lithuanian (in the north) and Ruthenian (in Eastern Galicia) traditions of the peasantry. This difference in the fit of the traditional frames of life has become one of the most troublesome difficulties of Europe, by no means diminished in 1918–20 through the decision to follow now the urban and now the rural tradition in rearranging boundaries to suit political exigencies and a greatly intensified consciousness of kind following the bitter struggle of 1914–18.

VIII. Traditionalism and Individualism in various Geographical Environments. Mass-Production.

But the problem was greatly deepened by another sequence of development. The Renaissance, whatever else it may have done, was a potent factor of the rise and spread of individuality. After it, much larger numbers of men in Europe became less members of a traditionalist community and more definitely persons with ideas of their own to express.

In agricultural life the introduction of seed grasses, sown clover and root crops, and, later on, of the potato, helped to break down the old communal cultivation, perhaps most of all by interfering with the old right of stubble pasture. Individualism in farming made its way in the end, and the last eighty years have seen further revolutionary changes due to modern transport developments.

In urban life, the increased wealth that more elaborate agriculture brought, and the growth of commerce, coupled with the individualist spirit, made craftsmanship become more differentiated, and guild systems gave place to independent enterprises, with apprenticeship continuing the old idea of maintenance of a trust handed down and passed on.

But in some parts, notably in France, these changes, and even great political convulsions, long left some basic facts of society untouched. The peasantry long remained attached to, almost worshippers of, their soil, even if in parts of the west and south of that country this is no longer the case. The peasant acquired more dignity, but the village remained an entity; men still often make it their main ambition to hand on an improved farm to their descendants. The town too is often still essentially the focus and market for its region, and it often still carries on a number of smallish industries for the benefit of its neighbourhood. Its bourgeois are peasants only slightly modified. The idea of maintenance, rather than that of expansion on an English, German or American scale, is strong in many minds and France, characteristically, makes external trade subordinate to internal production for use and exchange. The reasonable assurance of her wheat, root-crop, potato, and, but for a few calamitous years, vine and apple harvests, thanks to sunshine, has contributed a great deal to this, and has helped the French people to modify into modern forms the age-old feeling of a trusteeship (of the sacred soil) handed along the generations. With ideas of this kind shaping social life the population of France has grown only relatively slowly, and a country which led in population a century ago now has far fewer people than Germany and fewer than Great Britain, countries which have pursued a different course of evolution.

Britain's harvests have long been less secure because of summer rains and coolness, and, in the eighteenth and early nineteenth centuries, there grew first a widespread maritime commerce, and then manufacturing industries—in fact, the Industrial Revolution with its financial successes and its notion of taking a profit wherever that could be made. This new and enormous development in Britain almost made people forget the old feeling of trusteeship and maintenance ; what would pay for the next few years became more important than any question of its lasting as a means of livelihood for the third and fourth generation. An immense increase of population was an accompaniment of this, and for a while the surplus found outlets in distant lands, so that British expansion has become one of the outstanding facts of the world's history.

But the home population came to exceed by a great deal the numbers that could be kept busy supplying the needs of their fellow-citizens. Britain's export trade came to be her mainstay, and few recognised the dangers of the position thus created, for, in early stages, Britain's industry was far ahead of that of other countries.

The contrast between French and British development was thus extreme and startling. That it did not lead to more trouble between them after 1815 was due partly to the opportunities for expansion of trade, and of settlement, outside Europe.

Industrialism spread from Britain to Germany and led to a parallel increase of population, but this time with less facility for its emigration, because by this time there were few new lands without organised government, and German emigration, therefore, now meant the ultimate loss of the direct link with the Fatherland. Then, also, the German effort had its aim moulded politically by the desire to rise out of an old position of political inferiority and disunion. Further, the historic cities of Germany in several cases, such as Nürnberg, Frankfurt-am-Main, Köln, Leipzig, and so on, had their situations predetermined by major physical considerations, and must be important centres so long as Germany is a land of organised civilisation. This fact and the related one of the finding of coal near the zone of gradation from the hills to the northern plain—*i.e.* a zone of cities—led to the development of modern industry in several cases in historic towns, whereas in England the greatest developments took place in what had previously been small places. Both national and municipal authorities in Germany, therefore, had a larger and more direct share in the directing of industrial growth than was the case in Britain. Manufactures, mining and agriculture were made to interlock where possible, and the profits derived from new growth of cities often came to the municipal treasury. The tendency was for the nation to become one great organisation, with agricultural, manufacturing, mining, financial and commercial aspects of its life interwoven much more than in Britain. As a result it often planned for years ahead, and redeveloped in modified form the old idea of a trust to be handed on.

If we think along these lines we see why, quite apart from wars and questions of external political ambition on one side or the other, it has come about that the French people have been gravely anxious. Here are two enormously increased units, England and Germany, both dependent on export trade, neither able to live with any reasonable standard for the great multitude mainly on the produce of the national soil; both, before 1914, becoming able to lend abroad, both liable to crises with the spread of industrialism to other lands, especially outside Europe, and to the consequent checks to old lines in staple export trades. France, urged, not very willingly, and to a smaller extent, along the same lines for fear of being outclassed, could not but cherish the idea of the peasant nation with external commerce as a secondary feature, and a system that, at any rate, seemed to promise more continuity of economic activities through the generations. There is thus a conflict between different ideas of society underlying the present difficulties of Europe and the world, and, naturally, nowhere is it so acute as it is between France and Germany. It is well known that M. Clemenceau summed up the problem of Europe by saying that there were too many millions of Germans and British. He might have added 'and too few millions of tons of coal in France.' His statement was less a callous gibe than an anxious thought, fearful lest a society cherishing social continuity and economic stability should be overwhelmed by one that had grown suddenly through an expansion that was likely to receive a sharp check and must, therefore, face a serious crisis, sooner or later, when more of the world's peoples came to make things for themselves.

The spread of large-scale industrialism to U.S.A. and Japan and the prospect of its emergence elsewhere make the attendant problems still more serious. There are now several states that have populations exceeding what their soils can support unless science intervenes afresh; all therefore compete for an increasingly precarious export trade, all are in danger of finding groups of their people, with highly specialised machine-tending activities and corresponding inelasticity of mind, suddenly thrown out of employment and unable to adjust themselves to new lines of enterprise.

Meanwhile nearly half mankind, in the monsoon lands of Asia apart from Japan, is being shaken out of its traditionalist schemes by contact with the west, and nationalist ideas are germinating in various ways alongside of schemes of industrial development that borrow from the west to such an extent as to be a danger to indigenous society. Then the newer lands which have received the later overflow of modern Europe, and which seemed likely to become producers of raw material for Europe, are also being forced along the same line of nationalist development. They have borrowed freely from Europe (chiefly Britain and France) and more lately from America, and have consequently found themselves faced with the duty of finding large amounts of interest. This interest often, as already stated, is not by any means earned by the working of the schemes on which the money was spent. To meet this call for interest, exports must largely exceed imports, and so tariffs are introduced to keep down imports, and local industries are started.

Both in the teeming monsoon lands and in the new lands, therefore, industrialism spreads, and both react strongly against the danger of a position of inferiority. The risks and evils attendant on international indebtedness without strict control have been publicly emphasised of late by Sir Arthur Salter and Mr. Loftus and others. The evils attendant on the disequilibrium that has arisen between producers of food and raw materials on the one hand, and producers of manufactured goods and merchants on the other, have not been studied as much as they should be. Means must be found to increase self-respect among primary producers, not least among those who are natives of intertropical Africa.

On all sides, in the first great burst of mass-production, local boundaries seemed to have been swept away. It is probable that our social thoughts and plans will have to regain contact with Mother Earth, each group basing itself on its own soil, but evidently not in the old sense of a self-contained isolation. Interdependence of all on each is a new feature that will become increasingly important, and one of the geographer's tasks is to try to see both the roots of each society in its own soil, and its relations to others. He must try to see which factors are likely to go on operating from generation to generation, and which are temporary, and perhaps carry in themselves the germs that will bring their own decay: the industrialist society with its accumulations of capital in the hands of the grandchildren of able men, and its specialisation of machine tenders lacking seriously in the skilful adaptability of the man who thatches to-day and ploughs to-morrow—the overpopulated agricultural area losing its fertility and driving its people out because of the spectre of famine and disease, and perhaps finding no land ready to receive them. It is admittedly a most difficult phase of the world's life that has now been reached. Traditionalism is challenged everywhere in economic, social and religious life as never before. The local group is inevitably part of a great future whole, and yet is being forced to think more of its roots in its own soil. Each group has its problems and needs the help of others. England has her population problem, France her need to safeguard her peasant tradition, Germany her need to develop her schemes of welfare planning, and so on. But development of each without domination by any is a very difficult idea to work out, and in our attempts we are all too likely to try to crystallise out some condition of *status quo*, forgetting that life has change as one of its basic characteristics. The study of men and their environments that we geographers pursue is necessarily always relative to a particular time, and must always be looked at in the broad frame of the life of mankind as a whole.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

BRITAIN'S ACCESS TO OVERSEAS MARKETS

ADDRESS BY

PROF. R. B. FORRESTER,

PRESIDENT OF THE SECTION.

There have been within the last few years a number of reports of special British Economic Missions [1] sent to various dominions and foreign countries to inquire into the difficulties which are being met in marketing British products overseas; in addition, there have been Government Committees [1] specially devoting their attention to this subject. Their efforts are an indication of the increasing anxiety with which the British export position is being regarded, and it is proposed to consider some aspects of their inquiries in the light of the events of the years after 1920. Statistical surveys have indicated that Britain had failed to recover in the post-war years a position comparable to that which she occupied in 1913 in the export trades; this lack of recuperative power was not merely absolute, as shown in the decreased quantity of her sales, which in the favourable years 1925–29 was estimated to be 10 per cent. below her level in the years before 1914, but it was relatively unfavourable in so far as world trade and the trade of some of our leading rivals was increasing at a more rapid pace and had easily surpassed its pre-war quantities.

The reasons advanced to explain this generally admitted slowing down of overseas sales have varied with the passing of years but have fallen into two main groups: the first may be said to place emphasis upon the natural course of world development in production combined with the long series of casual misfortunes to which British trade has been specially subject; the other tends rather to urge that there is some special retarding cause operating in the case of British sales which is not present in the case of other countries, at least to the same extent. It finds this underlying cause in non-adjustable costs and in the suggested rigidity in the British income and price structure which has put it out of gear with the economic levels of price and remuneration in other countries.

[1] Among these reports may be mentioned the following:

Report of the British Economic Mission to the Far East. 1931.

Report of the British Economic Mission to Argentina, Brazil, and Uruguay. 1930.

Report of the Cotton Mission to the Far East. 1931.

Interim Report of the Committee on Education for Salesmanship: British Overseas Marketing. 1929.

Final Report of the Committee on Industry and Trade. 1929.

Influences Limiting the Expansion of British Exports.

It is obvious that the two reasons advanced are not necessarily separate and mutually exclusive; the second becomes prominent after 1925–26. Passing these influences in review, it may be said that the growth of local manufacture and the desire of many countries to develop what they believe to be their industrial resources has always been recognised as a main factor in the changes which have taken place. It is clearly a permanent influence which received special stimulation in the years after 1914; large groups of markets outside Europe found themselves cut off from their usual sources of supply for industrial products owing particularly to the absence of the two countries which held industrial leadership, Britain and Germany. New industries therefore grew up in India, China and Japan, in Brazil, Argentina and Chile, in Canada and Australia, which required some measure of protection to entrench themselves against the competitive power of long-established foreign organisations. This new effort was usually directed to the common grades of staple goods, leaving the upper ends of the markets and the specialities for later attention. The tendency is one which was familiar before the war period, in the textiles at least.

There is little need to labour the difficulties which accumulated in the years 1914–21 for the British staple export industries: fuel production, the textiles, the heavies, comprising general engineering, steel smelting, iron and steel rolling, together with shipbuilding, became, after 1921, the depressed group; the war period had naturally led to extreme over-development of the heavies and of shipbuilding, and had given to Japan and to the U.S.A. unrivalled opportunities of making new business connections in former British markets. For coal-mining the prospects seemed at first bright; neither the Ruhr nor the Nord coalfields recovered rapidly; but the return of these areas to full output, the development of the German lignite beds, the new Dutch coalfield, the Polish efforts in Silesia, as well as the technical advances in fuel economy, the growth of hydro-electric power, the use of oil fuel for shipping, the expansion of road transport, placed a serious limit on British power of export. The industry was also damaged by the strike of 1926, and by the dislocation of its marketing through the method of paying reparations in kind.

The textiles began to affect the position from 1924; the difficulties in the Far Eastern markets, the troubles in India, the successful competition of Japan, all played their parts.

The decline in the purchasing power of local populations was also commonly advanced as a cause of difficulty; it was stated that in the immediate post-war period the populations of certain regions, such as Russia, India, the Near East, the Far East, and Mexico, had suffered a decline in their standards of living, and that for a considerable period they would be bound to buy goods less expensive than those offered by Britain; they had drifted to a cheaper class of article than formerly. The evidence upon this matter is far from satisfactory, and it will be the subject of comment later in this survey.

The heritage of restrictive tendencies and of financial and exchange troubles left by the war years is a further factor which is held to have retarded recovery. No doubt the multiplication of customs tariffs, the enforcement of prohibitions and of trading by restrictive licences, the presence of special privileges in trade to particular industries such as national shipping, the use of state control and social monopoly by governments to avoid the ordinary liabilities of commercial trading, all exercised a limiting influence upon international trade, but by 1925 great progress had been made in removing the most serious obstacles, and the actual level of European tariffs was relatively little higher than that of 1913.[2]

The years after 1925 represent the second phase of recovery from war dislocations—namely, the growth of production, trade and general material well-being throughout the world; they were distinguished by rapid technological advance in agriculture and in certain new manufacturing industries, such as wireless apparatus, electrical goods, automobilism, and artificial silk. This somewhat unbalanced development led among other effects to a great cheapness of foodstuffs and raw materials. Britain benefited in so far as her exports fell relatively slowly in price while her imports of food and raw material fell severely; she herself had no significant agricultural output of this type which was specially injured by falling prices, but many of her chief markets were found in regions of primary production to which her industrial output was mainly complementary, and in this direction she was subjected to losses.

The return of Britain to the gold standard in April 1925 made the exchange position prominent and was held to have imposed a special handicap on the British export trades. The General Strike of 1926 and the inflationary movements in France, Belgium and Italy followed in turn; each administering its special short-period shock to the business system.

The list of unfavourable events leading on to the crisis which began in 1929 could be made more comprehensive, and it could be argued that Britain has been compelled through the pressure of events to recognise that her traditional dependence on a large overseas market to assist in the full employment of her people at relatively high standards of living is no longer feasible, and that her struggle to a new equilibrium position in world trade will involve an increased dependence on the home market and on those overseas markets where her special characteristic products hold their own at remunerative price levels, and the products of which are mainly complementary to the chief British industries. Britain might be held to be tending to an international position more like that of France, where the home and empire markets form the centre block of the foreign trade structure.

The difficulty with this form of interpretation of post-war development is that it does not make clear why Britain is in this special position of retreat or at least of slow advance as compared with countries whose resources seem less than her own. Mr. Loveday and others have stressed this point, and the following sentence from his essay on *Britain and World Trade* may be quoted: 'The evidence is, it may be hoped, adequate at least to suggest that the difficulties [of Britain] are confined to no

[2] Cf. *Tariff Level Indices*. League of Nations Publication, 1927.

particular type of industry, major or minor, new or old, that they are due neither to the special prosperity in the Far East (or West) nor to the chaos in Europe which is passed, neither to inflation nor to deflation, that our successful competitors are drawn from all quarters of the globe and have pursued currency policies wholly dissimilar. Disorder and prosperity, depreciating and appreciating exchanges, tariffs, and dumping, subsidies and prohibitions may all in fact have proved damaging ; but there must surely have been some special reason connected with our internal economy which rendered them more disastrous to the United Kingdom than to other countries. But this view is too rarely expressed.' [3]

The basis of this statement is the examination of international trade statistics from 1924 to 1929, which indicates that in a period of general prosperity, Britain's rate of advance was relatively much slower than that of any other important trading country. It is not so much the depression of the depressed industries as the failure of the new industries to grow adequately which Loveday deems serious. The trade of the world had increased but Britain's share had diminished. Mr. Loveday goes on to suggest that the Rueff [4] diagram, showing the numbers of unemployed and their relation to the ratio between wholesale prices and wages, leads one to think that a lack of adjustment of wages to prices is a serious cause of disequilibrium. This evidence seems hardly adequate as an analysis of labour costs ; Mr. Cole [5] has worked over wages rates in different countries without finding that British wage levels had gone notably out of line with those of other industrial countries; and the question of labour costs raises broad issues of technical efficiency in industry. As the Macmillan Committee [6] have pointed out, several of our important industries are not among those which have been showing, of late years, the most rapid technical advance ; they state that 'in 1929 our exports of manufactured goods, though declining, were still greater than those of any other country in the world. At the same time our real wages, whilst comparing unfavourably with those in the United States (which country, however, is unable to compete with us in world markets in our principal staple exports such as coal or textiles and many iron and steel products), were much higher than those paid by any of our chief European competitors.' The maintenance of so great an export trade makes it unlikely that British technical efficiency is much behind that of her chief competitors. On the other hand, they blamed the return of sterling to pre-war parity in 1925 as a cause of the difficulties in export, while indicating that the organisation of British industry as distinct from its technique was often defective, and that we had been slow in applying ourselves on an adequate scale to certain of the newer industries.

Those who offer the above explanation of the export trade difficulties arrive, therefore, at the conclusion that it is the relatively high costs of certain British industries which have weakened their hold on old markets, and that the remedy is to reorganise output and reduce cost until it

[3] Loveday, *Britain and World Trade*, pp. 170–171. 1931.
[4] Jacques Rueff, *Les Variations du Chômage en Angleterre*. 1925.
[5] G. D. H. Cole, *British Trade and Industry*. 1932.
[6] *Report of Committee on Finance and Industry*, p. 53. 1931.

returns to its efficiency level with that of foreign competitors. It is then thought that the elasticity of demand for British exports in the world's trade will be such that expansion of a more rapid kind will take place.

It is at this point that attention is naturally drawn to the side of demand and markets, to inquire if they cast any light upon these issues. The missions sent from this country to selected markets went to find out why Britain was losing her status in those areas, and within the limits of their opportunity gave certain answers.

The evidence bears upon three issues of importance affecting Britain's access to overseas markets :

(1) The characteristics of the market.
(2) The structure and efficiency of the distributing organisation.
(3) The position with regard to tariffs and the use of commercial diplomacy.

The Sales Position in the Markets.

It is, no doubt, difficult to make any generalisations which cover so many different types of markets and so many commodities without introducing undue simplification. It is obvious that there are markets like India where Britain sells 5*s*.[7] of manufactures per head of population each year, and the Far East, where in a good year she may sell 1*s*. 6*d*. per head of estimated population, at one end of the scale, and at the other end countries like Australia and New Zealand, where £10 per head is sold, whilst in between come areas such as Canada and Newfoundland with £2·10*s*. per head, the South American States with 36*s*. to 40*s*., and Scandinavia with 28*s*. to 30*s*. In a populous low-grade market such as China, an increase in general prosperity is a most influential factor on purchases, whereas in a highly developed country an increase in numbers is for most industries an equally favourable sign.

In spite of these difficulties and limitations a few general matters raised by the Economic Missions may be surveyed. It seems generally agreed that an increased choice of all classes of goods has become open to the overseas purchasers, and that the field of effective competition has broadened in most classes of goods, so that traditional business connections of a semi-monopolistic kind have lost much of their value. As this heritage of predominance was often British, it has followed that the offer of alternative choices affected her more than most other countries ; the passing of exclusive markets has also meant that a much closer degree of adaptation to market requirements must be aimed at, since standard articles of consumption have to bear an increased psychical wear and tear. This raises serious difficulties for the producer who had hoped to maintain mass output methods, but it appears to be a definite trend both in highly developed markets where it might be expected and also in more general markets such as India where it might not be expected. It must be kept in mind that methods of sale in the home market and in countries such as the U.S.A. and Australia have made rapid advance within recent years, and this striking change in outlook regarding sales and demand is bound

[7] 1927 estimates.

to spread through the whole field of international commercial intercourse. The outlook is away from broad general sales towards differentiation of consumer groups.

Closely associated with the range, choice, and adaptation of the goods as produced, there has come increased emphasis on all those services which the purchaser requires to accompany a successful sale; these include 'no trouble' quotations as regards language, prices, weights and measures, considered action regarding packing, its weight and suitability, a clear position regarding terms of sale, time of delivery, and terms of credit, and with some classes of goods the producer or his agent may require to instruct the purchaser both in the proper methods of use and upkeep. The net terms of purchase have come to cover much more than a price, and in some markets have given rise to considerable friction between buyers and sellers.

A somewhat widely quoted criticism of British selling methods has been that which urges that the quality of British goods is too good for their market, while their price is beyond its paying capacity. In the poorer markets like China, this point has, no doubt, substance, but it raises difficulties in industrial policy. If what is meant is that Lancashire, for example, is sticking to the upper end of the market and offering a better article at a higher price, then the question whether such extra quality is really dearer in actual use arises. If, on the other hand, an article with a short life at a low price is deemed adequate for the job, then this cheap grade must be provided if the connection is to be held. No doubt British industry cannot view with equanimity the loss of the cheap ends of markets; at the same time it must be recognised that there is more risk at the cheap end, since it is more open to competition from the foreign country's own industries as well as to that of other countries; the whole trend has been to leave the cheaper and rougher work to beginners or to countries with low levels of remuneration.

The evidence seems to suggest, however, that there has grown up a special type of cheap market for articles, either machine or textile, which are rapidly scrapped either through the influence of fashion, invention, or through having served some limited purpose. The example of a special type of shovel,[8] light and fragile, used for unloading a cargo of coal and then thrown away so that no collecting, storing, or reissuing troubles might arise, is a case in point. It was not considered that this article compared in any way with a sound standard article, but its net advantages were deemed greater to the purchaser. Low price is, of course, vital for such sales, and as many such cases can be given, it seems worth further investigation whether recent invention in many fields is not creating a cheap substitute article to many old-established standard articles of such a character that an appeal is made to people with relatively high standards of living, and not merely to those who cannot afford anything better. A further difficulty emphasised in most of the reports is the credit and finance of sales, particularly of machinery and the more elaborate forms of capital equipment. It is not possible to consider in this paper how far British methods of export finance can be said to curtail unduly the period

[8] *Interim Report of the Committee on Education for Salesmanship*, p. 27.

of credit granted to customers or to make it less liberal than before 1914 in important markets. It is clear that a sound policy would depend upon a considerable number of general and special factors : the duration of overseas credit must usually be longer than the period of domestic credit to cover transit time ; the credit worthiness of the firms in a particular country or trade must be examined, the customs of the area under observation and the general attitude towards meeting obligations ; agricultural countries require consideration of their crop position. No doubt sales may be stimulated by long credits, but if this merely means a loss of all profit or an accumulation of market risks and losses, it is simply unsound business dealing. Most countries, including Britain, have attempted within the years after 1920 to develop schemes of export credit, and of credit insurance to cover certain kinds of exports where a period of years was involved, but the state schemes have been carefully guarded in their scope and in their bearing of risks, and it seems doubtful how far they represent a useful approach to this problem.

The subject of suitable publicity and advertisement is one which is of considerable importance in most markets, and can be made a matter of joint effort between firms ; advertisement is one of the best methods of conveying information to the consumer ; if incomes are rising in a market it is a valuable aid in attracting part of the additional available purchasing power to the class of commodity concerned ; in addition it constitutes a useful check upon the marketing organisation, since it strikes through to the consumer and keeps the commodity before his notice. In so far as other commodities are competing either directly or indirectly with the article of the advertiser, it may be necessary to engage in combative publicity in order to preserve a share of the market. The evidence suggests that British traders have not as yet developed so definite an outlook upon this form of expenditure as those of certain other countries.

The Structure and Efficiency of Distributive Organisation.

The structure and working of the intermediary system have been the subject of examination and criticism within recent years, both in the home and overseas markets. Fundamentally, no doubt, the problem of providing a cheap and efficient marketing system is the same in both cases, but overseas distribution involves greater elaboration and complexity of services.

Broadly considered, the alternative channels are :

(1) The sale to merchants in Britain who sell overseas.
(2) The sale or consignment of goods to merchants overseas.
(3) The sale direct by the manufacturer's organisation abroad either through agents or through its own staff of commercial travellers.
(4) The employment of central selling agencies of a cartelised type, or joint selling organisations of an independent kind.

All these systems except the last are found on a considerable scale in British overseas trade. The view has been expressed that the merchanting system is the weak link in the chain, and that efforts should be devoted either to the creation of more direct and highly centralised methods of marketing or in other cases to various methods of strengthening the intermediary system to enable it to undertake the heavier modern task of keeping in touch with the market.

The main difficulty with the merchanting system is held to be the lack of incentive to push British goods ; it is immaterial to foreign merchant houses whether they push the goods of a particular country or not ; so long as British sales were the chief part of the market, it is said, the system grew up satisfactorily. An importer, of course, may aim at control of his market and attempt to screen it off from the producer, or alternatively, with a powerful manufacturing interest, he may become practically an exclusive agent for one firm. The method which has grown up particularly in American business is to put manufacturers' direct representatives or service men alongside of the merchants, not to sell but to keep in touch with consumers and their outlook, as well as to use methods of publicity and marking of goods to acquire the goodwill and indirect control of the market.

There has been a tendency in many markets towards direct methods of marketing, even where the countries are not highly developed industrially ; with some commodities, such as chemicals, cigarettes, and oil, it has even been possible to do up-country direct trading from depots managed by agents in China. These efforts to strike more directly through to the consumer are very familiar in domestic market organisations, but in these days of sensitive national feeling it seems prudent that the directness should be associated at least in part with the employment of citizens of the country the market of which is being served, either in associate companies or subsidiaries ; it may also be wise to associate the market served with processes of assemblage, repair, and equipment, which confer on the commodity concerned a certain national status.

A main difficulty in overseas distribution is that small and medium-sized firms have little chance of using direct methods unless they combine. If they are cartelised, they may develop the central selling agency method, but if not, then the difficulty of access to overseas markets can only be overcome by some form of joint selling agency supported by firms the products of which do not directly compete with each other.

It is obviously impossible to say without detailed examination and trial which of these forms of distributive organisation is best able to survive and serve a given market, nor has any evidence of the relative costliness of these forms of marketing been available.

It is clear, however, the British Economic Missions have found in most of the markets they examined that high price is the chief difficulty facing British expansion, that demand has become much more sensitive and exigent in its requirements, that the intermediary structure is subject to serious criticism in many areas, and that new experiment and effort to keep in closer touch with consumers' outlook is due to be made in foreign as in domestic markets. A suitable illustration of these difficulties in selling organisation is found in the account given by the Cotton Mission to the Far East (1931) of the Chinese market for Lancashire piece goods, with its reliance upon importing houses and Chinese dealers, its troubles with credit and with dealers who depart hastily to ' Ningpo more far ' in lieu of paying their accounts. The mission examined the possibilities of centralised selling, and the warehousing at central points of stocks adequate to the market. The views expressed by those engaged in the trade laid stress on the necessity of continuing to use the Chinese intermediary system, whatever change might be made in creating a central body with depots to introduce and carry the goods.

The Need for Market Investigation.

It may be asked, however, whether general surveys of market difficulties, such as the British Economic Missions have made, are either adequate for their purpose or convey any clear conception of the marketing position. In rapid visits they are bound to collect the faults and the fault-finders, without having time to get a sense of proportion. No doubt there are weaknesses in selling organisation, but Britain has no monopoly of shortcomings and her methods are much the same, it may be urged, as those of most of her competitors. Such questions are not capable of being directly answered ; it is obvious that if the missions have found serious faults, attempts should be made to remedy them, even if the U.S.A. methods are also faulty; and further, with changing trade conditions it would indeed be peculiar if the field of selling organisation did not show tendencies to change, develop and experiment with new ways of adjusting demand. It is in fact well known that selling method has been changing rapidly in the large domestic markets of Britain and the U.S.A. within the last twelve years.

This is ground for asking if such missions get close enough to their work, and have a broad enough conception of their task.

What is really wanted is a thorough inquiry into the general market position as a background for action. There is the grading and grouping of consumers, the amounts of their family budgets and standards of living, their habits of expenditure, prejudices, preferences, methods of purchase; the general character of the distributive structure, the position of merchanting, agency, direct trading, and so on; the variations by regions and the variations by season in demand. Last comes the commodity marketing investigation, the position of old products and of new ones. The position of an established product may be described with reference to its users and present uses, the price limits within which it sells, the existing brands and qualities, reasons for successful expansion of sales or of failure, the completeness of its distributive arrangements and its usual terms of sale, delivery and so on. Methods of introducing new commodities to the consumer, the use of laboratory shops, estimates of potential demand, satiation points in consumption, all may be the subject of close observation. It may be asked, Who is to undertake such laborious investigation? Much of it is already done in the U.S.A. and a little in Britain ; the task would not be so overwhelming if it were systematically approached. No doubt manufacturers' own organisations and private agencies could undertake some of the work, but the suggestion may be made that the Department of Overseas Trade, which is in touch with all Britain's overseas markets, might be provided with a staff of marketing specialists[9] who would examine sales problems from this angle and who could undertake both general studies and commodity marketing studies. Such work would give a balanced view of the market examined, and could be carried out without offence to other countries ; it is an entirely different type of task from that which the U.S.A. Tariff Commission imposed on its agents when it instructed them, some years ago, to inquire into the costs of production of certain industries in foreign countries. It should be possible to define the strength and weakness of a seller, to make some estimate of the extent of the existing market and the shares of different exporters. In addition, it should cast some light upon the elasticity of demand, and whether changes in the product or in its price would enable it to reach new groups of consumers. It is not a question of finding out whether a few firms sell badly and lose trade, but an entirely different attitude towards the possibilities of selling organisation which is most to be aimed at.

The Position with regard to Overseas Tariffs.

From the standpoint of this paper the only issue which it is proposed to discuss in connection with tariffs is whether Britain is at any disadvantage compared with her trade competitors in gaining access to overseas markets. The central feature of her policy within recent times has been the unconditional interpretation of the 'most favoured nation' clause : this has meant that Britain claimed by treaty, convention and custom that her goods should be admitted at the lowest rates into overseas markets ; even if nations such as the U.S.A. did not accept the unconditional interpretation but insisted on 'reciprocity,' Britain has commonly enjoyed the benefit of the lowest available rates. The exceptions to this position have been few and unimportant in their relation to the export trades. The special circumstances where the clause would not apply would be, for example, if there were a complete customs union between two countries which maintained their tariff against other countries : no third country could claim in virtue of the clause to introduce its goods duty free into the united territory. Colonial and Empire unions are commonly outside the scope. The case of the preferential rates between the U.S.A. and Cuba may be quoted as a general illustration. It can therefore be said that British trade is at least as favourably treated in foreign markets as that of any other exporting country, and it must be added that it is more favourably treated by certain of the overseas Dominions.

In so far, however, as Britain is the chief world exporter of manufactured goods, tariffs do in fact partially discriminate against her, since if the proportion of her exports be taken as 75–80 per cent. manufactured, while that of the U.S.A. is only 37–44 per cent., it follows that since finished goods tariffs have, until the last two years, ruled much higher than agricultural tariffs, Britain has faced the barrage on a larger portion of her trade than any other country except, perhaps, Germany. Again, the

[9] The Economic Mission to the Far East (Report, p. 128) did recommend a service of specialists and experts, but the task assigned was not purely market investigation.

so-called ' new industries ' tariffs which have grown up since the war have probably proved a more serious obstacle to British and German trading interests than to those of other countries, since it is commonly fuel, power, textile, iron, steel and engineering developments which are first attempted in making the transition from the agricultural to the industrial state. A third matter seems to deserve mention: that the elaboration and differentiation of tariff ratings which has grown up has to some extent neutralised the favourable position given to Britain by the M.F.N. clause; it has made it possible to conclude bargains on those qualities of a commodity which lay outside Britain's scope, while making no change in those ratings which affected her trade.

Earlier in this paper it was pointed out that up to 1925 there was a distinct tendency towards freeing international commercial intercourse from its war fetters, and towards tariff simplification and stabilisation at levels not much higher than those ruling before 1914. That promise has not been fulfilled, and from 1927–28 there has been a rapid upward movement not only in finished goods tariffs but in agricultural duties; no doubt this tariff marathon may be in part a passing phase due to the extraordinary rapidity with which prices have fallen, but it has raised one problem which may affect future British policy. It now appears as if bilateral treaties with the M.F.N. clause were not an adequate method of dealing with the tariff situation, and the only obvious alternative is group negotiation and group treaties: if groups of nations begin to create tariff *blocs* within which lower duties prevail than those which are granted to outsiders, then the whole question of the unconditional interpretation of the M.F.N. clause would arise. It would hardly seem feasible for a European *bloc*, if it were formed, to allow the clause to operate in the case of high tariff nations like the U.S.A. British commercial policy would have to secure that she was favourably received into all groups on similar terms to the constituent members, particularly into those which included many countries whose productive resources are mainly complementary to her own. Examples beyond the Empire would be the Scandinavian countries and the South American markets.

Looking therefore at British overseas trade from the angle of demand and sales, there seems a reasonable probability that its position would be relatively improved compared with that of other countries if special efforts were made to study and analyse the features of most of the overseas markets, and if the distributive organisation were developed to that level at which the British firms were able to keep in much closer touch with the sale of their goods overseas. The world is tending for many industries to become a ' home ' or ' domestic ' market, and it will have to be cultivated, developed, stimulated and studied with the same care and by many of the same methods as are applied by firms within their own country's frontiers. It need hardly be said that any policy which led to general reduction of tariffs to even the level of 1914 and imparted to them some freedom from continual change would assist particularly in the sale of British goods. Of the countries which have been most prominent in foreign trade development within recent years the U.S.A. is the chief; although she has displaced Britain as leading source of supply for many markets, a glance at her foreign trade shows that many of her exports are not directly competitive with those of Britain: as already mentioned, only 37–44 per cent. of her exports come into the finished goods class, and among these comes refined petrol as well as the typical American industries providing the ' amenities ' of life—motor-cars and accessories, films and cinematograph goods, electrical appliances, radio apparatus, typewriters, cash registers, office appliances, sewing machines, domestic refrigerators, gramophones, new types of agricultural and road-making machinery, oil-well plant, and so on. Motor-cars, gramophones and radio sets may mean, however, less Irish linen, less Sheffield cutlery and less English china and glass. Japan, which has proved so successful a competitor in the Far Eastern textile markets, is a country which shows 47–49 per cent. of her exports as finished goods, and of this 34 per cent. consists of cotton and silk textiles and allied products. It must be recognised that an able and industrious population, propinquity to the large Eastern markets, and an excellent geographical position between Asia and the American market are bound to make her a permanently serious competitor in the textile market, to which she has devoted her main efforts. Germany, which resembled Britain to a much greater degree in having 70–75 per cent. of her exports finished goods, finds markets for over 70 per cent. of her exports in Europe itself. Redistribution of markets has always been a normal incident in foreign trade history, and Britain's problem is to work her way through to a new equilibrium in foreign sales, and also to a new distribution of industries, both in the home and overseas markets.

SECTION G.—ENGINEERING.

THE CALL TO THE ENGINEER AND SCIENTIST

ADDRESS BY

PROF. MILES WALKER, D.Sc., F.R.S.,

PRESIDENT OF THE SECTION.

It is nineteen years since Gisbert Kapp in his address to this Section at Birmingham reviewed the position of railway electrification. The particulars he gave related mainly to foreign railways, as it was mainly on the Continent and in America that main lines had been provided with electric locomotives. Few of those who listened to his address would have guessed that in 1932 main line electrification in this country would have extended as little as it has to-day. And yet the delay has been all to the good. Had we hurriedly adopted some system which for the moment appeared the most promising, it is probable that the whole of the plant would have been old-fashioned to-day, and, in the light of recent developments, would have had to be reconstructed.

Electricity in 1913 was such a big infant that there were many people who laughed at the saying that it was still in its infancy ; and yet, when we see the advancements that have been made since then, we are inclined to think that the saying was true after all. The largest generators then were rated at about 10,000 kw. ; now they are ten times as great. Electric traction on main lines had then well begun ; now we find thousands of miles of it. In those days electric light and household appliances were luxuries for the middle classes ; now they are fast becoming the necessities of the poor. Wireless telegraphy was the achievement of the technician. Now it is the plaything of the schoolboy. Instead of a few thousand receivers in the hands of experts, we have millions of sets in the homes of the people.

But what is more remarkable than the total advances made in two decades is the speed of advance during the last few years. If we could evaluate the importance of discoveries made from day to day, and plot the values in a curve with time as abscissa, we should find that this curve slopes more and more rapidly upwards, and makes us wonder whether it can still go on with increasing steepness. If so, what will it bring us ?

Already electrical appliances have pervaded every field of mechanical engineering. The electrical driving of factories has become so general as greatly to reduce the smoke and waste of factory chimneys. The very heaviest kinds of machinery, such as the rolling-mills for rolling boiler-plate and rails, are now driven electrically. Some of the rolls call for loads of 10,000 h.p. at times of peak load. In our mines electricity is becoming more and more widely used for driving coal-cutters and conveyors, as well as for hauling and winding. In the deposition and refinement of metals, electrical processes are all-important. The electric furnace is the most perfect one for the treatment of metals at high temperatures. The electrical equipment of motor-cars has become an important industry in itself, employing millions of capital.

One of the directions in which rapid strides will be made in the near future is in connection with electric transmission. Following fast on the construction of the national 132,000-volt lines and the Weir Report, which showed what economies might be effected by the electrification of our railways, comes the wonderful development made possible by the grid-controlled mercury-vapour arc. The mercury-vapour arc (which for some years has been capable of carrying thousands of amperes) is now provided with a grid much in the same way as a trinode valve in a wireless set. Make the grid negative and no current will flow either way ; make it positive and the arc acts as an ordinary valve. Thus, by connecting two grids to an alternating voltage, a pair of valves will deliver alternating current from a direct-current source. This makes possible the transmission of power at a D.C. pressure of 180,000 volts easier than when A.C. is used at 130,000 volts. It does away with many difficulties due to capacitance and inductance.

Another application of this device is to change a power supply from one frequency to another. It is possible to take power from a single-phase trolley line and convert it into three-phase power at any frequency, so that three-phase motors can be started at a low frequency and the number of cycles per second can be increased as the speed of the train rises. Moreover, the voltage can be regulated over a wide range without the necessity of transformer taps. There are also great facilities for arresting the current on an accidental short circuit. This revolutionises the possibilities with polyphase traction and gives it some advantages over D.C. traction which were quite unexpected a year or two ago.

But there is yet another surprising improvement in electric traction along entirely different lines. The Drumm storage battery employed in the Great Southern Railway of Ireland has shown such remarkable characteristics as a traction battery that it has revived the hope held by many of us that some method of storing electrical energy could be found which would make the electric locomotive independent of any connection to a trolley. If it be possible to build powerful, efficient electric locomotives independent of any connection to an external system, and capable of long journeys without recharging, it is obvious that they would provide a more desirable method of electric traction than that generally adopted at present for main lines. Battery-fed shunting locomotives are already widely used and effect a great saving in time and personnel. It would seem that the Drumm battery or some of the other new traction batteries may give a sufficiently long range to the pure-electric independent-running locomotive. In a country like ours, where we have no very large supplies of oil, the pure-electric locomotive is of course to be preferred to the Diesel-electric. For we would rather get our power from our own coal than from imported oil. It would be worth while for the nation to carry out very extensive researches on batteries possessing the required characteristics. One can conceive methods of changing batteries so rapidly that no excessive weight need be carried, and the speed between the stops might be so great that a very satisfactory express service could be run. In this connection we must remember the great advantages that can be gained by using some kind of adjustable speed-torque conversion system between the electric motor and the axles. The performance of a locomotive can be enormously improved by the addition of such a system of transmission. This is of especial importance in a battery-driven locomotive, as it does away with complicated control gear and the necessity for high rates of discharge. Two very great advantages would result from the adoption of such a locomotive : (1) the change over from steam to electricity could be made gradually and without requiring any special equipment of the line ; (2) in times of war the railway system could be kept running. To make our railways dependent on the continuity of overhead lines is to present such a vulnerable feature to the enemy as almost to invite war.

As soon as the characteristics of the battery-driven locomotive are sufficiently good, see what an opening we have in this country for the battery-driven motor-car ! Instead of thousands of cars burning petrol, costing the nation eighteen millions per annum, and polluting the air of our towns, we would have cars driven by home-generated electricity. Imagine hundreds of battery-charging stations, twenty miles apart along our main roads, at which we could in the course of a few seconds drop our partly discharged battery and take a new one that would carry us for the next three or four stages. The batteries would probably belong to the Central Electricity Board, and would afford a very nice load for the early hours of the morning. I do not say that we see our way to such perfect batteries yet, but they will probably come some day. The best figures at present seem to be about 10 watt-hours per pound of material, but the theoretically possible figures are much better than this. Experiments on very light motors for traction purposes show that it is possible to make motors of about half the weight of those ordinarily used.

We live in the hope that with all these developments, and with the continual cheapening of the cost of generation, electricity is going still further to simplify our factories, lighten the work of the housewife, and make our cities clean and healthy.

So far as the work of the engineer is concerned in the building of super-power stations and the equipment of overhead lines and sub-stations, everything has been done in a most praiseworthy manner. The increase of output of some of the power houses feeding the grid is remarkable.

In thirty years from 1901 to 1931, the capacity of the stations of the Newcastle Electric Supply Company has increased from 3,000 kw. to 311,000 kw., or more than a hundredfold.

Power is generated and supplied to the grid at well under one halfpenny per unit. In some districts (even rural districts) it is sold to the consumers at reasonable prices, and the slogan ' Cheap electricity for the people ' is well justified. But in other districts the middleman (that curse of civilisation) steps in and sells the electricity at ten times the price at which it is supplied to the grid. I know a farm where electricity is being generated by means of a small plant at a cost of threepence per unit. The owner would like to take 20,000 units per annum from the national grid at three-halfpence or twopence per unit, and a neighbour is prepared to take 50,000 units at a reasonable price ; but the authorised distributors only offered to supply him at prices far above that at which he could generate himself. If the owner were to put in a Diesel-electric plant for himself and his neighbours and offer to light the village at twopence a unit, the authorised distributors would prohibit him from poaching on their concession, although they will not supply the villagers at less than sixpence. Instead of ' Cheap electricity for the farmer ' the cry is ' Keep off my profitable concession.' I mention this case to illustrate the difference between the work of the engineer and the work of the middleman. The engineer tries to generate and supply at the lowest possible price. That is his triumph. The middleman tries to sell at the highest price he can get. That is his triumph. No wonder we have not enough load on the national grid. There are hotels in the heart of the system of distribution in Scotland generating their own electricity at threepence-halfpenny per unit, and they will continue to do so, because they cannot get power from the grid at less than eightpence per unit.

All through our ' civilisation ' vested interests block the way to improvement. Long after science has shown the way to make things better for the people, unintelligent control and stupid prejudice preserve the old evils and refuse to be convinced.

There are many things to be ashamed of in our great cities. Not the least of these is the waste that goes on. There is waste of heat in domestic fires, waste of by-products in the consumption of coal, thereby producing dirt; waste of fresh air by pollution; waste of sunshine; and, above all, the waste of labour that might be applied in stopping all the other desolation and loss ; waste of money by paying dole while there are obvious jobs for everybody.

If engineers were in control, they would so order matters as to neutralise this waste at the source. All soft coal should be treated by a low-temperature carbonisation process or some similar process so as to extract the gas, oil and other by-products from it. People should be prohibited by law from burning soft coal, as they are in Paris. They would then be compelled to burn carbon in a bright cheerful fire making no smoke, or to use gas. Of course it requires labour to do this, but the labour is available—why not use it ? As things are at present in a district like Manchester, more than one hundred thousand housewives are making a continual fight against dirt. It is a hopeless fight, for every time they open a window black specks float in to settle and dirty everything. Patients at a nursing home are told that they cannot have the windows open because to do so dirties the curtains. The perfectly ineffective and hopeless labour of these housewives is ten times as great as the total labour required to treat the coal and extract the valuable by-products. Even if the carbonisation process carried out on a limited scale did not show a profitable return, the objections to it disappear when we contemplate the process carried out on such a scale as completely to rid our towns of smoke, and when the by-products are utilised in a national scheme.

The waste heat and power stations might be used in agriculture. A power station having an average load of 50,000 kw. will waste more than 8,000 million British thermal units per day. This is sufficient to warm 500 acres of greenhouses. Two very important items of cost in the forcing of vegetables are—(1) the capital cost of the greenhouses, and (2) the cost of heating. The capital cost to a nation possessing sand, lime, soda, and a surplus of labour need not be very great. If we can utilise the waste heat of power houses to do the warming, we ought to be able to save hundreds of thousands per annum, at present sent to foreign countries for vegetables and flowers. At the same time we could do away with the objectionable discharges from power houses.

It is not only in connection with engineering and scientific matters that the engineer can help to improve the lot of mankind. It is in connection with all economic and social matters. There is a certain quality found in some men which has been called 'eudemonistic.' It is a quality very often found in engineers and scientists, so much so that in the original draft of this address I said that men who were possessed of this quality were 'engineeringly minded.' I am told that this latter phrase is misleading, because it seems to claim that only engineers have the quality, and of course there are many people who are not engineers or scientists who are eudemonistic or, as Stuart Chase has phrased it, 'engineeringly minded.' A man has this quality when he throws the whole of his energies into the carrying out of sound, practical and beneficent projects for the sake of those projects themselves, and not primarily from selfish motives or in pursuance of some irrational prejudice. But besides the motives, the definition involves a certain faith in the obtaining of good by logical procedure to that end. This quality of logicality is partly inherited, but only brought to full efficiency by being trained and spurred to overcome difficulties successfully. The man who gets into the habit of shirking problems, the answers to which are not obvious, will never acquire this quality.

The distinction between the activities of the eudemonistic and the rest of mankind can be best seen by taking a few examples of the activities of the latter by way of contrast.

Consider the wasting of the energies of the inhabitants of a town (say of 50,000 inhabitants) on the interchange of wealth between individuals instead of their utilisation in the making of wealth—the payment of doctors by people who are ill instead of by people who are well ; the employment of lawyers to transfer real estate when the thing can be done more efficiently and more cheaply by registration ; the building of free libraries and cinemas when people have not decent houses ; the lending of money to states that have recently repudiated their debts. Or consider a Board of Education trying to teach boys and girls to spell English ; or the continued distribution of dole to the unemployed without asking anything in return. The verdict of an intelligent observer of these activities would be, ' How can people be so stupid ? '

Consider in contrast some eudemonistic activities : the organisation of the Boy Scouts ; the provision of technical education ; the generation of electric power at a cost of less than one penny for 7 horse-power hours ; the manufacture of a yard of cotton fabric containing 15 million interweavings of thread for sixpence ; the broadcasting of speech, audible in any part of the world ; the manufacture of a machine that will fly from America to Great Britain in 15 hours ; the discovery of the internal construction of an atom by noting the position of the bands of the spectrum.

The verdict of the intelligent observer of these and many other beneficent activities would be, ' How can men be so wonderful ? '

In this time of world-depression the question not unnaturally arises whether the engineer (in which term I will include the scientist for brevity) cannot make a useful contribution towards the bettering of conditions—something more promising than the totally inadequate measures already proposed. I have chosen this subject because I believe that the application of the engineering mind to our difficulties is much more likely to lead to a satisfactory solution than hopeless debates and discussions upon side-issues that have little to do with essential factors and problems. I propose then to consider shortly—(1) What is wrong with the world ? (2) Why are the proposed solutions inadequate ? (3) How could engineers make things better ?

(1) There are so many things wrong with the world that I must here confine my remarks to the three main defects, the poverty in material possessions, the poverty in outlook, and the incompetence of the rulers.

Notwithstanding the fact that civilisation has been developing and extending for centuries and the application of steam power to manufacture has been in operation for one hundred years, by far the greater portion of the inhabitants of Europe and America are very poorly supplied with the things that make life full, free, and enjoyable. Indeed, a very large number of these inhabitants exist in want and squalor ; and in some cases the conditions of life are so insanitary and loathsome that we are tempted to ask whether civilisation is not a failure. If we go outside the modern states to the teeming millions of China and India we find that only a little has been done to improve the lot of the peasant, who still lives by bodily toil, and receives no share of that fullness of life which we know to be possible when the machine lightens our labour and education opens the mind to the beautiful things around us. Even in cases where the machine has been introduced, it has often brought about conditions more unhealthy than with the original peasant labour.

This is a very unsatisfactory result in view of the enormous natural resources available and the huge possibilities of manufacture and distribution of wealth with modern systems of transport. If there had been a central organisation looking after the world's welfare for the last fifty years, and if it had made as bad a mess of things as we find to-day, it would have been condemned as hopelessly inefficient. As a fact, we have had no central organisation, but only governments looking after the welfare of individual states—an easier task, one might suppose. Yet these governments have made this mess of things within their states.

In spiritual matters the failure has been as complete as with material things, but I will leave the consideration of this until later.

This failure of civilisation to attain its purpose is not surprising when we remember that the chief principle in operation has been 'Every man for himself and the devil take the hindmost.' This is supposed by some economists to be the only principle which will work satisfactorily and automatically. It certainly does automatically give the hindmost to the devil. There has not been any logical plan in the old states in Europe or in America to enable all citizens to create their own wealth and enjoy it. The word 'wealth' is here used in its proper sense to denote the material things that contribute to man's well-being. And there being no plan, it is not surprising that things have come to their present pass.

The main business of the world, to-day, is buying and selling. Things are manufactured to be sold at a profit. When prices are low, business is said to be bad. This shows how inverted is the position under our ridiculous system. It ought to be just the other way. Buying and selling should be a mere unavoidable incident in the distribution of wealth. When prices are low, it should be evidence of economical manufacture and distribution, and the standard of life should accordingly be higher. The main business of the world should not be to buy and to sell, but to make the things that men want and distribute them in the simplest way without adding any more to the cost than is absolutely necessary. At times when trade is supposed to be good, things are sold at three or four times the price paid to the people who make them, and as a consequence the people who make them cannot buy them, so there is a slump on the market.[1] If things were sold at a price which represented the exact cost of manufacture and distribution, then all the people concerned in the manufacture and distribution would have money enough to buy all the things that they have made. They would go on making more and more and getting more and more wealthy. Instead of this many are out of work because the shopkeepers cannot sell the things that they have in stock. They cannot sell them because the people who make them and want them have not received enough money to buy them. Many attempts are made to justify the prices at which things are sold, but the real reason for high prices is that in a so-called civilised country there are only about 15 per cent. of the inhabitants making a real contribution to wealth : the remainder are hangers-on such as landlords, merchants, retailers, servants

[1] In my first draft I gave several examples, but they are well known to everyone.

of the rich and retainers of all sorts. Then, of course, there are the young people who are still being educated and the pensioners. The cost of supporting all the extra people must be added to the legitimate cost of manufacture and distribution.

Imagine a state in which the majority of the inhabitants are at work using the most efficient machinery. They can supply their material wants and the standard of life may be very high. If, on the contrary, only 15 per cent. of them are doing useful work, then the standard of life is necessarily lower. The mere fact that some of the inhabitants are very wealthy, and have a large amount of money to invest, does not help very much the man who is out of work and has no facilities for making the things he wants. It is not a solution to set him to make roads which he does not want. Nor is it a solution to make him into a gardener, a butler or a footman. The rich man may flatter himself that he is giving work to one hundred people. He is possibly doing his best according to his lights, but he may be a part of a system which is withdrawing one hundred workers from the really useful tasks and thereby impoverishing the state. I say ' may be ' because some servants of the well-to-do are very useful members of society. The chauffeur who enables a master of industry to get about quickly may be doing more useful work than if he were employed in the factory. But the greater part of the money spent by the well-to-do goes into channels that do not contribute to the welfare of the state as a whole.

For all the inhabitants of a state to be as wealthy as possible two conditions are necessary :

(1) Things that contribute to well-being shall be manufactured at the greatest speed possible at our present state of knowledge, and with the best appliances available.

(2) The method of distribution shall be so efficient that the people who make the things are able to buy the things that are made. Anything that interferes with the second condition will prevent the obtaining of the first.

Consider the hundred million inhabitants of the United States of America. They have at hand all raw materials, all food supplies, capital equipment in the way of factories, expert advisers and means of transport. What is to prevent every inhabitant from enjoying a very high standard of life ? What is it that condemns the great majority of them to a very poor standard ? It is the system of trading, in which most men are traders and only a few are real workers. And why are there so many traders ? Because under the present rules it is more profitable to trade than to work. Alter the rules so that only the useful workers, useful distributors and providers of useful capital share the things that are made, and there will be hardly any limit to the material wealth of the individual.

In the past the engineers have been busy with their own jobs. They leave the making of the laws, the controlling of the state and the general management of things to the politician and the tub-thumper. This is especially so in the U.S.A., but most countries suffer from the absence of special intelligence and expert knowledge in the make-up of their rulers. A man becomes a town councillor or a member of parliament without any proper test of his ability to put two and two together or to arrive at a logical conclusion from a given set of premises. No test is imposed for the purpose of seeing whether or not he has the ability to tackle very difficult problems. The kind of mental training required to find the right solution of a difficult economic problem is exactly the same as the kind of training required to tackle engineering problems. How many members of parliament could solve a simultaneous equation with three unknowns? And yet they are paid £400 per annum to solve problems involving many more unknowns. How many of them have the most elementary knowledge of the laws they are amending? When they voted for the Law of Property Act, 1925, how many of them understood it? How many of them have the most elementary knowledge of the scientific facts upon which the manufacture of wealth is based or have the organising ability that is necessary to carry through a great project? There are, of course, exceptions, but as a class, apart from lack of education, they have the wrong mentality.

An example will make my meaning clear. A certain factory receives an order to equip an electric railway in Australia. The carrying out of the order involves the manufacture of many hundreds of different kinds of machines, instruments and apparatus. Each machine and instrument consists of many parts made of special materials and manufactured by processes requiring expert knowledge. A good deal of abstruse mathematical calculation is involved in the design. The directions to the shops are contained in hundreds of documents and drawings, each compiled after intense attention to detail. Thousands of workmen are engaged, each directed by these minute instructions, and in a few months the various parts take shape. They move along pre-arranged channels until they are assembled and the machines and instruments are tested. These are shipped to Australia, taken up country, each to its appointed place, to power house, sub-station, or locomotive. On a certain day the equipment starts up. Thousands of passengers are carried successfully and we have this wonderful addition to our civilisation. Now I assert that if the men who form an average committee of our House of Commons were in charge of that factory, whatever might have been their previous training and whatever facilities they might have had to gain experience, they would make a dismal failure of the whole thing. The reason would be that they are not engineeringly minded, and that is the reason why they make a failure of state management. They can talk but they cannot do things successfully. They do not know their job. They have not the minds that can think out intricate problems. They have not faith in the obtaining of good by logical procedure to that end. They are not as a class eudemonistic.

The very parliamentary procedure which they permit to hinder them condemns them. Every session for years past there have been desirable measures which no one has expected to get through, because, as it was said, there was not time. A large business house in its annual conference with salesmen assembled from all parts of a continent can get through more work and come to more useful decisions in two weeks than are reached in a whole session of debate in the House of Commons. If parliamentary procedure were to take a leaf out of the book of one of these business houses, it would enable ten times as much useful work to be done in a session. Here are a few suggestions. Cut down the number of members to a number that can comfortably sit in the House. Give each an appointed seat fitted with an automatic recording apparatus to show the constituency when its member is at work. Each seat should be provided with two press buttons for voting 'Aye' or 'No' (also recorded). Let all bills be circulated some weeks before being read and all members who have anything to say asked to dictate their remarks to a typist or otherwise prepare them. These remarks are then to be sent to a staff of under-secretaries, who make a synopsis of the whole. When a bill comes up for consideration an official reads Clause No. 1 and says, 'Twenty members have said so and so, eleven say so and so. As against this fifteen express this view, nine express the opposite view and give the following reasons.' In fifteen minutes all members in the House will have a better idea of the pros and cons than if they had listened to a debate lasting many days. If any member is misrepresented by this synopsis he would have an opportunity of amending it, but woe to the member who takes up the time of the House by any unnecessary remarks. Having fresh in their minds the views of far more members than could possibly be heard in a week of debating, the question is then put. Members press the buttons and go on to Clause No. 2. Or if a clause has to be amended, the amendments can be dealt with in the same business-like manner. Such a procedure with suitable extension would enable members to have before them, not only the views of the other members, but the views of outside experts. The necessity for Royal Commissions would in this way be sometimes avoided.

One of the things wrong with democracy to-day is that its representatives come to decisions upon matters about which they know very little after long desultory discussion. The listeners find these discussions very uninformative and their votes as a rule are uninfluenced by anything that is said. If these discussions could be replaced by short, clear synopses of the pros and cons put forward in an impartial way, law-making would be very much more efficient.

I have made reference to this matter because if ever the world is managed at all, it will probably be managed by some sort of committee, and no committee can work efficiently until desultory discussions are absolutely barred.

When we understand what is wrong with the world, it is easy to see that such solutions as have been proposed are inadequate. Some people say war debts are the cause of the trouble. 'Wipe out war debts,' they say, 'and things will be better.' At present Germany is a debtor country, while the U.S.A. is a creditor country. It is difficult to believe that both debt and credit have the same effect in creating unemployment. How can the fact that the U.S.A. have money owing to them, giving them power to buy even more raw material or manufactured products than they have already, be in any way disadvantageous? The existence of ten million unemployed in the U.S.A. is due entirely to internal causes, such as I have outlined, and would not be helped in the least by the extinction of the war debt.

Some people blame the gold standard, forgetting that the monetary transactions of the world are carried out mainly by cheque, which would operate in exactly the same way whatever might be the standard. Banking accounts are nothing more than the book-keeping of services rendered, and the cheques are given for such services. The gold standard does at least help to steady the value of the £, and that must be all to the good in commerce. Some complain that there is a scarcity of money and say that an inflation would be useful. Whatever may be the temporary effect of inflation, it is clear that only the world's useful activities can ultimately result in greater material wealth.

Some say that it is the deficiency of trade between states that is at the root of the evil. Trade between states is useful in bringing about the exchange of commodities, but otherwise it does not contribute to man's well-being. It is languishing now because the average standard of life of the inhabitants of the world is low. Let the engineer raise that standard and world trade will flourish because there will be a greater need for the exchange of commodities.

Given a central authority of sufficient power to preserve peace, general disarmament would undoubtedly help matters because it would release machinery and personnel to raise still further the standard of life. But until we get a powerful and wise central authority, nations will prefer to trust to their own strength. A comprehensive world plan under which each individual could be provided for independently of the strength of his nation would do more than anything else to relieve the tension between nations and bring about disarmament.

I now come to the question, 'How could the engineer make things better?'

A committee of engineers given control of the whole world would not attempt to tackle the whole problem at once. The world would have to wait for the growth of an organisation operating at first over a small area, and extending as it gained experience.

A suitable place to begin might be one of the states of North America, already provided with most of its raw material. Or it might be better to begin in Europe. France would be suitable as it is already nearly self-supporting, but only a small self-supporting part of that country would at first come under the scheme.

An estimate would be made of the standard of life that could be obtained by the average inhabitant provided he worked well and was aided by the best machinery and organisation. A promise would then be made to provide the houses, furniture, clothing, food, fuel, education and entertainment in exchange for the services of the individual. Payment would be made by cheques the nominal values of which would be adjusted on the low side so as to allow for accidental losses and defective workmanship. Though the state would need a gold backing for these cheques to begin with, the real backing of the cheques would be the wealth produced.

The cheques would be honoured by the production of the goods and not by the production of gold. A man working well for a year might earn cheques valued at 40,000 francs. Some of these he would exchange for food and necessities; but after each one had done his share of the work, he would enter into his inheritance and the cheques would be balanced against the things he would receive.

To get over labour troubles, the arduous duties would be given to all the young men and women irrespective of class. The greatest honour would go to those who did the most arduous tasks.

There is a spirit of adventure in youth that makes the taking on of new work easy. Anyone who has lived in a mining village knows the eagerness with which a young miner takes up the work to help his father. The learning of new processes in our factories by young hands is in most cases a matter of a few weeks. Only in some specially skilled trades does it take long to become expert. The machine is fast taking the place of the expert craftsman. The number of years that young men and women would be required for manual work need not be too great in these days of machinery, and the number of hours' work per day would be few. A very high standard of life can be earned in a few hours of work per day when all are useful workers and all operations are carried out in the most efficient manner. Think of all the young men and women standing behind counters in shops all over the civilised world. Not one-quarter of them would be required under a really efficient system of distribution. The other three-quarters should be at work a few hours a day, contributing their share to the work of the world. Some of the hours not required for manual labour would be given to higher education, and it would, of course, be possible to give special facilities to the best brains and put them to do intellectual work. Physical culture would form a part of the day's programme for all young people.

The present factories need not pass out of the present management. That is in most cases very efficient. But the object in view would be to produce goods wanted by the people. Many factories at present concentrate more on making a profit than on making commodities that are useful to the buyer. Interest would be paid on the capital invested in factories and other undertakings. That interest would be paid by cheques and the cheques would be honoured by commodities or other services rendered. The fundamental idea in the scheme is, of course, that all wealth comes from the soil by the application of labour and intelligence, and it is possible by good organisation to create and distribute ten times as much wealth as is being done at the present time. In a country like America, where they have available vast natural resources and manufacturing facilities, the average standard of life should not be less than the equivalent of three thousand dollars per annum. This comfortable state of affairs does not exist in the United States or in any other states. The reason is that no arrangements are made whereby everyone does his share of the work; and even when a man does his share, and more, he very often does not get his share of the product. Things will never be better as long as they are controlled by people who are not engineeringly minded.

These people talk about 'over-production,' 'low prices,' 'effect of the gold standard,' and other things that are mere incidents. They have not enough logicality to see the real cause.

One cannot in a short address of this kind propound a complete plan for the reformation of the world; but it is easy to see how the methods of distributing wealth might be made very much more efficient than they are at present. The first step, of course, is that there shall be a definite plan with that end in view. Instead of having as many persons as possible making profits out of the needs of the people we should have as few as possible engaged in distribution, and they should be concerned with the problem of how to supply the goods rapidly and efficiently. As things are at present, a small town of twenty thousand inhabitants may have as many as three hundred shops. None of them will have a really good stock to choose from. Two really good departmental stores would be of very much more service to the inhabitants, especially if these stores directed their energies to efficient methods of supply instead of useless display for advertising purposes. At present we have hundreds of men and women standing behind counters while customers are making up their minds as to what kind of ribbon to buy or how many yards of stuff they will want. Buyers should be encouraged and helped to do all this thinking before they ask for the goods. A departmental store should have elaborate show-cases in which samples of all materials and finished articles can be seen and studied independently of the man behind the counter. Rapid methods of getting full information about all products are easy to devise when we are concerned with only a few comprehensive stores instead of with hundreds of shops. Quantities can be weighed and wrapped by machinery. Goods can be placed in containers and delivered cheaply by express vans when the thing is done on a system. As many as three dozen business vans at present visit a small street in the course of a single day. Three delivery vans in a day bringing everything for everybody should be quite sufficient.

Starting with a small self-supporting state, it would be possible within a few years to demonstrate the high standard of life obtainable by good organisation and modern methods. Do some of my hearers say, 'Oh, this was tried by Robert Owen years ago, and failed'? Men tried to fly before the Wright brothers, and failed. Robert Owen was right in some of his theories and would have succeeded better if he had had some of the advantages we have to-day. To say that we are not to try a properly organised system merely because some previous attempts have failed is to condemn the world for all time to the muddle in which it now finds itself. Having succeeded on a comparatively small scale, the region under sane control would be extended until it gradually embraced the whole world. The natural resources would be developed and each country would supply those commodities for which its climate and natural products made it most suitable. There should be only one monetary system common to the whole world, and one universal language taught in all the schools. Nationalism need not die, but there need no longer be a clash between nations since the wants of all would be bountifully supplied.

I know of dozens of young men of ability in this country who have nothing useful to do. Many of them are kicking their heels waiting for a job. I am sure that they would all volunteer to take up any work that might be organised to produce wealth for themselves. I suggest that the engineers and economists of this association should urge upon the Government the necessity of organising a wealth-producing community in which the voluntary work of thousands of young men might be directed to making things for themselves—houses, clothing, fuel, food, and most of the things they want. I have elsewhere [2] elaborated a scheme of the kind by which we could in a few years completely do away with unemployment and at the same time teach the world how things should be done.

One of the main things wrong with the inhabitants of the world, more serious than the inefficiency of their methods of providing themselves with material things, is the poverty of their outlook. The vast majority fail completely to look at life from the right point of view. They do not see its finest opportunities; they are almost blind to its greatest duties. The intellectual and spiritual sides of their nature are undeveloped. This is partly due to the exhaustion of effort in their struggle for existence, a struggle which ought to be lightened in the way I have indicated. But this is not the only cause of the poverty of outlook in the vast majority of mankind. It is in a great measure due to the inefficiency of their teachers and especially of their religious teachers. I had in the original draft of this address put down some remarks on what the engineer and scientist had to say upon religious teaching, for if they took a greater share in the management of the world, this most important subject should not be left out of account. This subject is, however, precluded from the discussions of this Association, so I am reluctantly constrained to strike out what I would like to say.

The education of the young is a duty that must be approached with great discretion.

Each child must be regarded as a reasonable entity looking out upon the world with interest and ready to absorb impressions from its surroundings. It is most important that the things that we put before it shall be of such a kind that, when the child applies its reason, it shall arrive at a correct result; for it is only in that way that the young mind gains confidence in its reasoning powers. It is a pity that in this country the first efforts in a child's education should be concerned with so unreasonable a thing as English spelling. The little mind applies the reasoning powers which nature has given it and finds that the answer is wrong. Over and over again it tries. Sometimes it is right, mostly it is wrong. Instead of the reasoning powers being strengthened they are undermined, and the majority of children learn to rely upon their memory or their guessing faculties rather than on their reason.

After twenty years' experience of the students who present themselves for evening classes, I assert that not more than one-fifth of the inhabitants

[2] Paper read before the Seacombe Forum, March 1930.

of this country will follow a simple logical argument, even when it is about a subject in which they are interested. The remainder will let their minds wander and will take a result on trust without even hoping to understand it. This I attribute in a great measure to the fact that in their early years their reasoning powers, so far from being encouraged, were actually wrecked on the snags of unreasonable studies.

Education should be directed much more than it is at present to the making of young people into happy and useful citizens. To this end the subject-matter of education should be concerned more with the things around us than with the things of the past. History, of course, should have a place in education, but it should be valued mainly for its bearing on the present. The curricula of schools have been very greatly improved during the last few years ; but there still remains a great deal to be done before we can say that we take the shortest and most reasonable way to learning. When that shortest and most reasonable road has been gained, it will be found that boys and girls are carried much further and made into much happier and more useful citizens.

Some of my hearers may wonder why I have not confined my presidential address to Section G of the British Association to the subject matter of Engineering. It is because at this stage of the world's misfortunes, with output falling and unemployment figures rising, the engineer has an important message to give. When he gives it in his technical journals it passes unheeded by the world at large. The position is analogous to that of a mains engineer, who, working in a roadway, sees an omnibus out of control careering down a steep hill. The passengers are giving frantic and futile advice to the driver who does not understand the mechanism. Shall the engineer go on with his job or shall he jump on board and apply his expert knowledge in bringing the omnibus under control ?

You ask for a constructive proposal. It is that the Government should found an experimental, voluntary, self-supporting colony under the auspices of engineers, scientists and economists. The object in view would be to ascertain how far it is possible with our present knowledge and the best methods of manufacture and distribution for a group of say 100,000 persons to maintain themselves and continually to increase their wealth when freed from the restraints and social errors of modern civilisation. Such an experiment might do more to enlighten the world as to the possibility of modern logical methods than an experiment carried out on a continent thousands of miles across, where unforeseen difficulties might easily defeat the best intentions. If you ask what differences there would be in the old world and the new colony from which so much is to be hoped, I will in partial answer draw two pictures. One is of a feeble man of sixty years working all day in a sewer because it is the only occupation he can find to earn his daily bread. Far worse than the unpleasantness of the task is the rankling injustice that he should be compelled to do this despised job for no more reward than a living wage, while others with easier tasks get greater rewards. The other picture is that of a young man of twenty-three years, who has chosen the task of sewerman in the spirit of those who went to the trenches in 1914. Sir Sewerman aided by modern appliances cheerfully puts in his three hours of unpleasant work and for the rest of the day disports himself and extends his education.

So with all the work of mankind. It can be done cheerfully when justice seasons its incidence.

SECTION H.—ANTHROPOLOGY.

THE PLACE OF ARCHÆOLOGY AS A SCIENCE, AND SOME PRACTICAL PROBLEMS IN ITS DEVELOPMENT

ADDRESS BY
DAVID RANDALL-MACIVER, M.A., D.Sc.,
PRESIDENT OF THE SECTION.

I PROPOSE to follow in another line of inquiry the example which has been set by our outgoing President. As he addressed us on the general theme of Anthropology I shall consider the general subject of Archæology, its place as a science, and the practical policy which we ought to pursue in view of its startling and wide development. It is a very happy and propitious moment for such a discussion inasmuch as there was never so wide and universal an interest in the subject. There is some danger indeed that archæology may be killed by kindness and the indiscriminating affection of its admirers ; and there is very great danger that archæologists themselves may be more or less gently suffocated by the overwhelming mass of accumulating material. We need to devise methods of organisation, to think out means of collaboration, and to subdivide the field of our activities so that they may be all related in a conscious scheme.

Like anthropology ours is a very young science, and like anthropology it has grown at the most astonishing rate. Archæology in the true sense is scarcely a hundred years old, for its birth may be placed about the middle of the last century, unless we are willing to give a rather artificial value to that false dawn which came with the occupation of Egypt by Napoleon. I should rather prefer to say that it begins just about 1850. Layard was excavating at Nineveh in 1845. Boucher de Perthes published his first work on stone implements in 1841 ; and the entire theory was made known in England in 1858, in the same year that Darwin and Wallace read 'On the Origin of Species.' Keller's work on lake-dwellings appeared in 1854. Lartet and Christy were doing their chief work in 1861, and Pigorini from 1862 onwards. Schliemann's excavations of Troy began in 1870.

Just as chemistry had its precursor in alchemy, so archæology had its natural forerunner in antiquarianism. The Antiquary was a recognised person as early as the sixteenth century, when Thomas Nash in his *Pierce Penniless* speaks of him as an 'honest man' and says that he has known 'many wise gentlemen of this mustie vocation.' In those days, as a recent President of the Society of Antiquaries has told us, he was chiefly busy with the promulgation of written texts, so that the official antiquary of Oxford University was the 'custos archivorum.' In the seventeenth century such a promising title as 'British Antiquities Revived' consisted of nothing more important than a mere work of genealogy; while in the eighteenth century the Society of Antiquaries was still principally engrossed in philosophical studies. It was, I suppose, the formation of Sir Hans Sloane's collection, and the eventual foundation of the British Museum, which initiated that study of the material remains of man's history that developed into true archæology in England.

The old-fashioned type of antiquary was, as so often happens, beginning to pass out of existence at the moment when his character was immortalised in fiction. I doubt whether any of the younger generation of our own time have ever known a real Jonathan Oldbuck. That whimsical and lovable old pedant was a very different being from his modern successor, who is generally one of the most sociable of people, and who is so sure of the popularity of his subject that he can venture to address immense audiences through the machinery of the British Broadcasting Corporation. Archæology is no longer regarded as a ' mustie vocation,' but is one of the daily interests and recreations of the whole world, learned and unlearned.

It no doubt adds something to the general interest that there is a very vague understanding of what archæology really means. I hope it may not seriously impair this interest if I begin by inquiring what we are really talking about when we begin to discuss this subject. Definitions may spoil our unanimity, but they are necessary for any real agreement. The ordinary man if questioned would probably tell us that Archæology is just busy with old things—any old things. Now this is not a bad answer, but it is not sufficiently definite. For the essential that really differentiates archæology from several more or less cognate sciences is that it deals with old things only in so far as they are the product of man's hand and brain.

The works of Nature are not included in this science; for the study of the ancient structure of the world belongs to geology, while the description of extinct animals and plants is the province of palæontology and palæobotany. Archæology receives an immense amount of assistance from these kindred sciences, but it is wholly distinct from them.

Inasmuch as it is a study of man and his works, archæology is very closely related to anthropology, and the two subjects have always been considered together in this Section of the British Association. What then, we may ask, is the precise character of this alliance? Each deals with man and nothing but man, but they deal with man from different points of view, so that the two sciences are supplementary to one another. Obviously anthropology is the wider of the two, for it treats not only of man's material works but also of his mental, moral and sociological development. Anthropology moreover totally disregards date and time, it simply studies primitive man wherever and whenever he is found; and primitive man may exist and does exist in the twentieth century A.D. as well as in many thousands of years before Christ; though he has become rarer in these later days and is not so widely distributed over the earth. Strictly speaking, both civilised and uncivilised man should fall equally within the range of anthropology, which claims to be nothing less than the study of all mankind in every relation. But the latest and more complex developments of civilisation which are manifest in our own day have been appropriated by younger and more specialised sciences such as sociology and psychology, so that except for an almost academic distinction it may be said that anthropology confines itself to *primitive* man. It has two distinct branches—the one which examines man simply as an animal, the other which studies him as a *rational* animal. With the first of these, termed physical anthropology, which is really a branch of zoology, our science has very little to do. It may accept and use its results occasionally as a background, but with the same detachment that it shows towards zoology or geology. For the interest of archæology is solely in those works which can only be produced by man when he has become more or less sapiens. Even ethnology, which is physical anthropology as applied to the developed races of man, has only a very slight and limited usefulness for the archæologist.

From those branches of anthropology, on the other hand, which reveal man in his religious, sociological and cultural relations, and those which study his arts and crafts, archæology derives the whole of its theoretical structure. How intimately the two subjects are related is shown by such a book as Sollas's *Ancient Hunters*, in which, if it were not for the headings of the chapters, the reader could hardly tell at any given moment whether it is an ancient or a modern people that is being described. Without anthropology, in fact, archæology would be blind of one eye and very short-sighted of the other. For the only possible subject of archæology is the *material* output of man, the visible products of his hands, whether these are shown in agriculture, building and other modifications of the surrounding world, or in those manufactures, arts and crafts by which man improves the conditions and amenities of his material existence. What man has been thinking or feeling, or just *why* he did any of the things that we find him doing, archæology can never directly ascertain. What it discovers is merely the bare fact ; it can never divine the essence of the fact, that which gives it all its meaning and its interest. For the whole interpretation of the inner meaning and rationale of man's life we are necessarily dependent either on anthropology or on history—that is to say, on records and observations of the thought, habits and behaviour of men who could be actually studied as living and thinking beings. Without the aid of these records archæology would indeed be a musty science ; but when it employs them it is able inferentially and by analogy to construct the whole of man's story from his earliest beginnings to the present day. And this reconstruction is not only a book, it is an illustrated picture-book, richer than mere anthropology and richer than mere history.

Of the two auxiliary sciences, anthropology and history, the former is generally more useful to us, just because it deals with the primitive, and ancient man is necessarily more or less primitive. Documentary history is very limited in its range ; it gives only a few glimpses of the life of ancient times, and covers only a very small section of the immense period over which archæology must range. Occasionally, however, it throws a vivid searchlight on times which are especially interesting to us as being comparatively near our own, and usefully supplements our anthropological knowledge by information as to what civilised people, as distinct from savages, thought, felt, and said. Its principal and indispensable function, however, is that of providing a time-scale, which cannot be obtained from any other source, even though its time-scale only covers a few thousand years. A few thousand years is only a small fraction of the time which is included in archæology. The material of this science goes back to the Tertiary period in geology, innumerable thousands of years before the first beginnings of writing or the first whisperings of tradition. It begins even earlier than zoological anthropology, for in the Chellean, not to speak of pre-Chellean, flints we have records of man's handiwork which antedate any actually known remains of man himself. For these immeasurably remote periods a very rough and inaccurate time-scale, which is, however, steadily being improved, has been provided by geology. It is not until about 3,500 years before Christ that this clumsy instrument can be replaced by a much finer one derived from inscriptions and documentary evidence. Then comes a stage of overlap when the interaction of historical tradition and archæological study is extraordinarily fertile. At this stage we are able to build on our most solid foundations, when archæology synchronises with written records or with the epics, sagas and genealogies which precede them. This, if we care to make this distinction, is the period of proto-history as distinct from pre-history. It is the time which is most familiar to the general public, and naturally the most attractive. For it illustrates the dawn of all those great civilisations, oriental and classical, which enter into the intellectual life and interests of all cultivated people. Egypt, Elam and Sumeria, the Crete of Minos, and the Troy and Mycenæ of Homer are some of the subjects of this period.

But archæology does not end where history begins ; it does not even end when written histories are numerous and fully documented. All through the classical periods of Greece and Rome, and all through the Middle Ages, history needs and receives the greatest assistance from archæology. Down to at least A.D. 1000 archæology is needed as much as documentary evidence for reconstructing the life of any people. It is not until written records of every kind are so minute in character and so abundant in quantity as to cover almost the whole field of life that archæology becomes superfluous. Then gradually it gives way, but does not wholly cease to exist until all ' old things ' have been replaced by new and modern things, which is almost the time of our own generation.

The ordinary man is rather apt to suppose that history is infallible and archæology is a study in which individual fancy may have free play. It is therefore well worth while to spend a few minutes in considering the relative trustworthiness of history and archæology. The modern historian has recently ceased to be contemptuous of archæological data, and some of the latest histories show a remarkably able handling of what I may call ' dumb documents.' Indeed, the methods of history and of archæology are analogous to one another, only the historian's documents are loquacious, whereas ours are tongue-tied. This does not mean, however, that the historian's material is intrinsically superior to the archæologist's ; verbosity is a different thing from veracity. Wholly apart from the essential impossibility, long ago remarked by Sir Walter Raleigh, of obtaining consistent accounts of the same occurrence even from two independent eye-witnesses, a great deal of documentary evidence is vitiated from the outset by its propagandist bias or basis. Personal vanity, envy, hatred, and malice, the desire to please great persons, the fear of offending dangerous powers—these and a thousand other motives enter in to deform the truth. Just as only a childish intelligence supposes that what is printed has any value merely because it is printed, so only a very purblind historian can maintain that a document has any scientific value merely because it is written. And if anyone feels disposed to challenge this statement, I will only ask him to remember his experiences between 1914 and 1919 if he took any part in the Great War. Without troubling about the deliberate and obvious propaganda, intended to deceive ourselves or the enemy for some immediate purpose, let him reflect on the character of the ordinary current documents whether of civilian or of military origin. Would he consider that they were scientifically accurate ? A slight but amusing illustration of my point may be drawn from the ration strength of a battalion. Of course everyone, from the commanding officer to the youngest private, was closely and personally interested in overestimating the figure so as to deceive, with the most laudable object of self-preservation, the officers who provided supplies. And yet a very eminent historian once indignantly asked if I would not unquestioningly accept the stated ration strength of a force, if a Latin author had been so thoughtful as to record it.

Now contrast with the lying or tendencious documents issued in this and in much more serious cases by battalions and brigades the complete objectivity of my ' dumb documents,' for instance the cap badges and regimental insignia found on the field of battle. These are perfectly trustworthy evidence, equally useful to an intelligence officer during the war or to an archæologist years after.

Passing from this recent material to that which has survived from ancient days, is it not evident that even the strongest motives of family pride can never induce a pre-Chellean flint to falsify its genealogy ? Again, the Hermes of Praxiteles will never open his mouth to tell us whether he is an original or a Roman copy. In brief, to leave a subject which it is tempting to expand at greater length, archæology is not precluded by its material from being just as scientific as history. Neither the one nor the other can claim to be rigorously exact, each is in much the same degree liable to misinterpret its data ; but I claim that at least the data of archæology have never been falsified from the start. The historian has perhaps one advantage, in having at his command certain fundamental documents which are supposed to be unimpeachable, such as charters, treaties, statutes, and—in very late times—textual reports of trials and speeches. Even these, however, find a fairly close analogy in the stratified deposits which the geologist guarantees to archæology and in the intact tombs which contain inscribed objects.

It must not, of course, be supposed that there is any disparagement to history in the emphasis which I have laid upon its subjective character. The ideals of history are far greater than its mere skeletal form, the bare record of events and dates, though it is principally this skeletal form which is valuable to archæology. The position of history is unique ; it appears to oscillate between science and art, but at its best and truest it must surely be art. Herodotus writes an epic, and Thucydides composes a tragedy; Gibbon displays a pageant, and Macaulay delivers an oration. We value them not for their scientific accuracy, which may or may not be unimpeachable, but for the beauty and philosophic truth of their artistic production.

Having now to some extent defined the place of archæology as a science, I will speak of the organisation of its material.

The organisation of archæology may be treated under three headings. First there is the collection of the material in the field and the recording of it. Secondly there is the housing, conservation and exhibition of this material in museums. Thirdly there is the comparative study of all such material, and the digesting and dissemination of the results in books of synthesis and popularisation. Each of these activities demands separate consideration.

The collection of material in the first instance is due to the work of the explorer. He may either travel through a country observing its visible features and monuments, or he may seek to discover new material by excavating what has been hidden underground, either deliberately in tombs and treasuries or accidentally by the accumulation of sand and soil over the deserted ruins of ancient buildings. At the present moment our chief attention is centred on excavation and our most sensational results are being obtained thereby. Recent excavations in Egypt, Mesopotamia, Greece and India are of vivid interest to every cultivated person. Now as one who excavated himself for a good many years and has had constant opportunities of studying all aspects of the excavator's problems, I have been able to form some very clear ideas as to the policy and general necessities of science in this regard. First there are one or two elementary axioms, which were once generally ignored, but are now so universally recognised that they need only be mentioned and emphasised as axioms. The most important of these is that no person who is not qualified by special knowledge and study should ever be allowed to excavate at all. And since individuals are not impartial judges of their own capacity, this comes to mean that no one must excavate unless he is endorsed by a scientific institution or at least by a committee of scientific men. This necessity is explicitly recognised almost everywhere, though I can remember some flagrant instances of the violation of the rule even in these last few years. It is a rule, however, which can admit of no exceptions. The days are long past when the looting of sites for the amusement or personal profit of a private individual could be tolerated, and no government with any pretensions to enlightenment will ever again allow it. But various countries which have only recently arrived at autonomy may need warning in this respect, and it would be well that public opinion should be fully alive to the danger. Powerful interests, both individual and political, are often enrolled against our science, and we may sometimes regret that there is no scientific League of Nations to which we might appeal.

If the right to excavate is only granted by the licence of government to a properly qualified individual, it ought to follow as a corollary that digging for antiquities even by the owner of an estate should be forbidden. Such a restriction would reduce the trade in antiquities, which is a survival of barbarism and utterly to be condemned, to a minimum. This is the true ideal, but in practice it proves impossible to execute ; science retires baffled before the conspiring avarice of the land-owner and the collector. Nevertheless a vigilant and determined government can do much to mitigate this evil, and it is to be noted that both Italy and Greece have been remarkably successful in their systems of close supervision and control of export.

A very intelligent and practical policy was long ago adopted by the Egyptian Department of Antiquities, which goes far to satisfy the smaller buyer though it cannot cope with the bigger gangster. The Cairo Museum maintains an official sale-room in which duplicates and objects of small value are sold to the tourist. These are officially guaranteed to be genuine, which is incidentally no small advantage in a country where forgeries are so frequent and sometimes so clever as to deceive even an expert. It would be very useful if this system were extended and adopted also in other lands. Even objects of real value might be placed in the sale-room when they are already abundant in the national collections. There are several European countries in which the store-rooms of the great museums are crowded with thousands of duplicates, that can never be exhibited or used and are practically waste material. If these were sold the result would produce large sums which could be used in financing new excavations ; knowledge would be usefully disseminated, and the destructiveness of private dealing might be a little restrained.

Now let us consider what happens and what ought to happen when a museum, a university, or a scientific body of any kind sends out its duly qualified explorer. Both this explorer and his employers have certain perfectly clear duties to discharge, and I suggest that on one side these are not sufficiently recognised. It is the explorer's business not only to furnish his home museum with collections of valuable specimens, but also to make the most complete study of all the conditions under which they are found and to publish this study in the fullest possible form. But here he is very often fettered by the unthinking or deliberately selfish egotism of his employers. A great deal of pressure is often brought to bear on the explorer to make him not only excavate the most lucrative sites, which may be quite legitimate, but neglect the less attractive and remunerative parts of his concession. This is so notorious that I need not quote instances. I prefer rather to recall the admirable public spirit shown by a great American institution, which ungrudgingly and uncomplainingly supported its representative through several years of expensive and quite unremunerative trenching which he judged to be necessary. And it is pleasant to relate that this generosity was rewarded by the eventual discovery of prizes which excelled their wildest dreams.

If it is the explorer's duty fully to study and record whatever he finds, it is a duty which is never neglected in these enlightened days by any scientist at all worthy of the name. But it is not quite so invariably a part of his creed that the privilege of exploration carries with it the implied promise to publish, and to publish quickly and fully. The record of British archæologists is very honourable in this respect, and there is hardly any important field work that has not been published or is not in process of publication. A great deal of credit for this happy state of things must be given to the doyen of British excavators, Sir Flinders Petrie, who has never failed, in spite of every obstacle, to furnish a published account of his field work within the shortest possible time of its completion. This example and the growing pressure of public opinion have been very effective in Great Britain, but several continental countries have fallen far short of our standard. It is sometimes the fault of the individual, sometimes of the institution. There are some men who direct workmen admirably, but seem to be seized with paralysis at any mention of publication. And there are many institutions which make no provision and take no thought for the publication of their material, once it has been safely hoarded in their exhibition rooms. Now let me be perfectly outspoken on this matter. That explorations should be made and left unpublished is a disaster, and if the explorer or his employers are responsible for this failure it is a crime. Nothing can take the place of publication. Notes, drawings, photographs and plans, however elaborate and careful, are of very limited usefulness except to the man who made them and who can alone interpret them. It is an error even to suppose that a literary executor can take over the material and produce a satisfactory result. If an archæologist does not bring out his material, or at least fully prepare it for publication, in his own lifetime, a great part of it is irretrievably lost to the world.

This being the case, the institution which obtains a site for excavation ought to guarantee the expenses of a reasonable publication and ought to bind its excavator by contract to publish. I may quote as an example my personal experience with an institution which appreciated its duties fully and exactly. In January of 1907 I accepted a contract with the University of Pennsylvania to conduct excavations in Egypt and the Northern Sudân. The term was fixed at five years, and the University stipulated that before the lapse of these five years I should have prepared for publication a full report of all the results. In accepting this provision I stipulated on my side that the University should publish every word that I might write and every illustration that I might deem necessary. No obstacles were allowed to stand in the way, and the contract was precisely fulfilled on both sides. I consider that such an undertaking ought to be given by every institution that sends its man into the field, and that this should be so fully recognised that the excavator need not even have to propose it.

There is still one more consideration in regard to the exploration of sites which is very little appreciated. The wisdom of one generation, even if it be our own, is inadequate to foresee all possible problems. Therefore, whenever the circumstances allow, a portion of every site should be left unexplored and reserved for future study. The advantages of this are manifest; let me quote only two examples. The results obtained at Pompeii within the last ten years have been so revolutionary that they have put all the old standard books out of date. If this city had been cleared at one sweep when first discovered all this knowledge would have been lost, owing to the imperfections of the methods then in use. The proper technique has only gradually been evolved. On the other hand, the frantic rush to explore all lake-dwellings in the third quarter of the last century barely left Vouga enough material for the studies which he has just completed. Had they been *all* destroyed by the first excavators the mistaken opinions launched seventy years ago would have been stereotyped for ever.

In some countries where the government is very weak it is unavoidable that cemeteries should be completely cleared before they are abandoned, otherwise the natives descend like vultures and sack whatever the archæologist has left. But in places where the police control can be more effective a portion of a cemetery might sometimes be left; and certainly a town, palace, fort, or other site which does not contain remarkable treasures, could be protected for a second generation to study. The new generation will have new points of view and problems to solve which the earlier explorers never suspected.

The second aspect of an archæologist's activities is museum work. Sometimes the same man who has formed a collection in the field will be placed in charge of it in a museum. This is a very happy arrangement and ensures that the most minute and intelligent attention will be given to everything that has been found. More often, however, the museum curator is a person who stays at home, and acts as the recipient and custodian of the collections that are brought to him.

How he treats these collections must be to a great extent determined by the circumstances and the accommodation at his disposal. Our greatest museums in England and on the Continent are in many instances so overcrowded, and so hampered by an excess of concentrated material, that it is useless to lay down ideal rules for them. The only hope for a really rational treatment of them is that they should be broken up into a number of smaller units; this may for the moment be impracticable, but should certainly be borne in mind as the ideal at which any really systematic policy would aim.

In countries like Italy, with its traditional liberality towards science and art, or America, which starts in at a later stage with great resources and no hampering accumulation from past years, a genuinely systematic arrangement is possible. From the point of view of an excavator many of the Italian museums are ideally arranged. The results of any given excavation are kept together in a single room, and each tomb and deposit is placed in a separate division of a case, carefully marked off from its neighbours. The effect of this is that a student can go into the museum at Florence or Bologna with the excavator's report in his hand, and study every paragraph with the objects in front of him. Even when the objects have been incompletely published I have been able to make a fairly systematic record of them from the mere contents of the cases thirty years after the work had been done. In the Egyptian department of the Metropolitan Museum at New York the deposits are not so rigidly kept in series—which is, indeed, difficult unless the available space is almost unlimited—but the same ideal has been borne in mind. The exhibition, therefore, can be used as an illustration of the actual excavation. Moreover, New York has gone far beyond any other institution in popularising its exhibition. Photographs illustrating the stages of the excavation, abundant and detached labels and descriptions of the objects, and *résumés* of periods and styles of work make the collection an illustrated picture-book which has an immediate appeal for the public.

Many of our own museums might follow this example with advantage. A recent Government Commission, as you are aware, has published its reports on the museums in England. Amongst other things it remarks on the discouraging truth that the public does not seem to want museums. The same might be said of many places on the Continent. Now as conditions are at present, I must confess to having a good deal of sneaking sympathy with the public. If a few institutions, like the British Museum and South Kensington, as well as a small number of enlightened provincial museums up and down the country, have published admirable handbooks, instituted popular lectures, and encouraged popular demonstrations by expert guides, yet these are only a very small minority. Whether in Great Britain or on the Continent the visitor to a museum, other than a gallery of pictures or sculpture, is merely left to drown in an uncharted sea of unintelligible cases. We can scarcely blame him if he objects to being drowned and rushes out into the fresh air. It is not the public but the management of the museum which is to blame. In America it would be quite untrue to say that the public does not want museums. On any holiday the Metropolitan in New York is crowded to overflowing by thousands of people, rich and poor, educated and uneducated, who show the most intelligent interest.

In order to popularise museums, however, a totally false start has been made in many places. With the mistaken idea that the ordinary man can appreciate art but cannot appreciate science, a number of institutions have been founded which are called Museums of Art and Science. The title might be allowed if it did not dictate the policy. But the policy has generally been to subordinate science, and presently almost to thrust it out of doors. The local magnate who has bought a few pictures for his own home, together with copies of the Apollo Belvedere and similar works which are supposed to be above criticism, declares to the committee of which he is chairman that the museum must not be filled up with old stones and pots and pans. And in the hope, very often unrealised, of a substantial legacy the committee obsequiously follows his lead. And very probably the director of the museum, who has been chosen for his talent as an art connoisseur, is very content with the policy of his committee. Now as far as the general public is concerned this is a sheer error of psychology. The ordinary man has no training and little aptitude for fine art, but he can understand workmanship, and he is interested in the things which come near either to his daily life, or to a life that he might have led some centuries ago. A well-illustrated and well-explained collection of ethnographical or archæological objects makes a definite appeal to him, and he responds wonderfully to the romance of ancient history or of primitive life.

This supposed union of science and art is simply hypocritical, and when science has insinuated itself into a collection under the disguise of art it is high time that the disguise should be thrown off. A scientific collection is not made for æsthetic purposes ; it need not be ugly, and if capably handled it will not be ugly, but its primary purpose is not æsthetic. The attempt to æstheticise an archæological collection is constantly being made, and always results in much damage to scientific interests and very little satisfaction to the æsthete. Let us be perfectly clear-sighted and frank about it. In itself archæology has nothing to do with art—at most it chronicles the *history* of art ; which is a very different thing, as every artist knows, from genuine æsthetic appreciation. The art-critics are perfectly justified in protesting, as they constantly protest, against the confusion of art-history with art-criticism. The individual archæologist may by the grace of heaven chance to be endowed, as a very few men are, with the real gift of æsthetic appreciation. But it is not directly evoked by his work, and there will be little opportunity as a rule for exercising it in the course of his work. The immense majority of the objects with which he deals have very slight æsthetic worth ; in so far as a man is purely archæologist æsthetic values do not exist for him. The archæologist works like a naturalist—it is his business to trace evolution, patterns, migration, and development ; and when he is tempted to discourse on æsthetic values his opinions are very seldom worth hearing. Except in very rare instances, therefore, the products of excavation and exploration should be treated as natural history collections, and not as more or less unsuccessful efforts at pure art. And we must remember that archæology has now happily become a popular subject. The man in the street is greatly interested in it. He delights in the pictures and the brief accounts which are published in the *Illustrated London News* ; he rushes to the exhibitions of antiquities excavated at Ur of the Chaldees, or in Egypt, or anywhere else. The reporters of the most up-to-date American newspapers will assure you that archæology is ' front-page news,' and it is printed with two-inch headlines in columns next to the exploits of the gangster and the gunman. This is fame—let us take advantage of it. It would be exceedingly foolish not to welcome this popularity and cultivate it by every possible means. Here is a study which does no harm to anyone, which any intelligent being can share, and which can add immensely to the amenity and happiness of the ordinary man's life.

I have now dealt with two aspects of an archæologist's work, the collection of material and the exhibition of it in museums. The third is the dissemination of knowledge by means of books. Some of these books must necessarily be technical ; others should be addressed less to specialists than to a cultivated public ; and a third class ought to be directly and deliberately popular in their aim.

First of all, the original scientific accounts of excavations can hardly be popular works, and need not be. They are written for the professional and make very dry reading. They are not essentially literary in form, and if a writer inserts some chapters of literary character these are only an added grace ; they are not essential at this first stage, but belong rather to the second. Lists, plans, schedules, catalogues and indexes are the fabric of which the excavator's reports ought to be composed. Their aim is to give a precise account of every feature of the exploration, and not until this has been done is there any occasion for general theories or estimates of the historical bearing of the discoveries. Books of this stage need be no more than mere chronicles ; it is probably best that they should not attempt to be more. An excavator need not be a literary man. If he has literary gifts he will have ample opportunity for using them in books of what I would call the second stage in the dissemination of archæological knowledge.

For if it is the absolute duty of the excavator to produce a perfectly dry, passionless record of his work for the sake of his professional brethren, this is only the first stage in the process of bringing knowledge into general currency. When the seed has been thus gathered and sown it has to be watered and cultivated. This is a task which may be undertaken by the original explorer or by others. Unquestionably the best results are obtained when the explorer himself, if he has any literary ability, undertakes the popularisation and exploitation of his own field work. No one else can so exactly estimate the finer values and all the different aspects of the discoveries which he has made. Indeed, any outside person will inevitably miss a great deal, and will probably view many details in a false perspective. Many of our best archæologists have achieved as much success in semi-popular writing as in exploration ; I need only mention Sir Aurel Stein as a conspicuous example.

I wish strongly to emphasise that such semi-popular works are a necessity if we are to have a wholesome circulation of general archæological knowledge. The multiplication of material has become so great that it is no longer possible for even the hardest working professional to master everything that is published in its primary form. It is doubly impossible if he is simultaneously doing any original work of his own. And yet, if he is to be anything better than a narrow specialist, he ought to know at least the outlines of what is being done for every period in every part of the world. Narrow specialisation is naturally and properly abhorrent to the British mind ; but it is not merely ungracious and undesirable in itself, it is positively damaging to the efficacy of an archæologist's own work. If he is shut up in a small compartment he becomes not merely a duller person, but a less efficient worker even in his own limited field. Cross-fertilisation and the production of new hybrids are indispensable conditions of a wholesome intellectual life.

In the chain which forms our organised knowledge of archæology I have spoken in order of the explorer, the museum worker, the author of technical books on exploration, and the author of semi-popular expositions of these technical books. All these aspects may be combined in one person, though generally the museum curator and the explorer will be distinct.

Separate from these, and with an extremely important function to fulfil in our Platonic state, is the writer of general synthetic works. He will probably be the occupant of some professorial chair, or a museum curator holding a post which allows sufficient leisure for writing, or occasionally an unofficial author who works in his own library and on his own resources. It is writers of this class who have manufactured our fine fabrics out of the raw material. It is they who have constructed those far-reaching syntheses which have made archæology a coherent science instead of a group of isolated and disparate phenomena. It would be invidious to enumerate the names of a long list of writers which begins with the great pioneers of the last generation, Sir Edward Tylor, Sir John Evans, Lord Avebury, and culminates in a perfect galaxy in our own generation. As I compare the archæology of even forty years ago with that of our own time, the new thing that is so striking is its sudden co-ordination. Even in the last years of the past century we were working departmentally. Magnificent explorations were being made, but they were in separate and apparently disconnected regions. Here and there an audacious prophet might hint at a trade route or a far-reaching connection, but the material was as yet insufficient to prove it.

Now suddenly the ancient world appears as a connected whole—it is a change like the shrinkage of the habitable globe due to steamship, railway, and aeroplane. We propose to connect Europe and the Mediterranean with the uttermost parts of Africa ; we speak freely of intercourse between the Sahara and the Russian steppes ; we do not hesitate to associate Mesopotamia not merely with Egypt but with India, and even perhaps with China. And within a less wide area countless links have been forged which unite one country with another, until the continents of Europe and Asia seem to be furrowed by numerous trade routes from the earliest times, and the Mediterranean is partitioned into well-defined spheres of commerce and empire.

Time has shrunk no less than space. Sir Arthur Keith, Prof. Elliot Smith and others have made fossil man a familiar pet, almost as close to us as the animals in the Zoo or Felix the cat. As for the Bronze Age, we move in it with as much security as the historian moves in the reign of Queen Elizabeth.

Now in constructing this type of synthesis the general writer is often carried far beyond the possibilities of strictly logical proof. This does not mean that his methods are to be condemned. I fully realise the wisdom of a colleague who said to me many years ago, when we were discussing first principles on the banks of the Nile, ' You must not break archæology on the syllogism.' It would be pedantry to ignore how much we owe to the poetic and far-seeing imagination of many a great archæologist, from Schliemann down to several of our own contemporaries. The picturesque prophecy of to-day may well be the scientific fact of to-morrow. So long as the author keeps his fancies and his facts distinct, he can remain perfectly scientific. But it is his duty to show clearly the grounds of his reasoning ; and this leads me to consider somewhat tentatively what are the types of logical reasoning which may be regarded as conditionally or unconditionally valid.

From such a vast and intricate subject I will select for discussion only two of the principal problems of archæology—namely, the application of a time-scale and the proof of the dissemination of a culture. First, then, as to the time-scale. A philosopher may attach little value to the mere arithmetical count of years, and a student will often work more freely if he thinks in culture periods rather than in centuries. But there is no doubt that the ordinary man demands not only ' facts,' but ' figures,' and it is a great temptation to supply the figures at any cost. A series of culture periods has been well established, so that there is a reliable system of what is called ' relative chronology ' from the earliest Stone Age down to the time of full documentary history. But it is a very different matter when we attempt to translate these culture periods into centuries and thousands of years. The estimates given by various geologists and palæontologists for everything behind the last stages of the Ice Age are immensely divergent from one another. I should not venture—it would be quite beyond my capacity—to criticise or discuss them. But when the stage of universal hunting has passed, and mankind has settled down to an agricultural and pastoral existence ; when the outlines of sea and land have become fixed in approximately the same forms which we know to-day, then we feel that pre-history is only a slight extension backward of what is generally recognised as simple history. It is a sketch of the early chapters in the story of empires, nations, and peoples, of whom several are known to us in written history or tradition. We naturally desire to know in terms of years and generations how far back we can trace the doings of the men who are our own ancestors or collateral forbears. Now here we must be clear-sighted enough to accept our inevitable limitations and avoid all sophistries and all claims, however specious, to know the unknowable. We are wholly dependent for our absolute chronology upon the dates recorded or obtained by immediate inference from ancient writings or traditions. The fragmentary relics of Mesopotamian and Egyptian official chronology furnish a time-scale, liable, as you know, to much uncertainty in minor details, but trustworthy in all its main lines. Whenever this time-scale can be applied, it is possible within quite narrow limits of variation to give precise figures as well as facts. Thus we can give a dating in years to all the products of Egyptian civilisation back to the beginning of the First Dynasty. And by direct inference we can apply this scale to many other parts of Europe and Asia, as Sir Arthur Evans has so successfully applied it to the dating of Cretan civilisation. Indeed, as archæological discovery proceeds in the coming years we may reasonably hope to arrive at a completely graduated scale of chronological dating in actual years for every part of the ancient world after 3500 B.C. But if it is asked what means we have for establishing a chronological as well as a typological scheme behind 3500 or possibly 4000 B.C., I answer unhesitatingly that we have none, and that unless earlier written records or traditions come to light it is probable that we shall never have any.

One very crude method of attempting to avoid this impasse is so illogical that I need spend little time in discussing it. Below the strata in which definitely dateable objects are found—whether at Knossos, Ur, Susa, Mohendjidaro or any other very ancient site—there are generally strata of a certain thickness in which other and obviously earlier forms occur. Now it is sometimes suggested, even by skilled explorers in their less discreet moments, that the mere thickness of these undated layers may give an indication of the length of time which it took to form them. And yet a very slight amount of reflection, not to speak of actual experience in the field, will show that this reasoning is as childish as it is simple. I have myself seen in Egypt deposits many feet deep which can nevertheless be proved by well-dated objects at the top and bottom to have been formed within a single century ; and I have also seen a concentrated stratum of not more than four feet which contained the products of many centuries closely pressed together. There are innumerable reasons for which the rate of deposit may vary almost indefinitely. To attempt therefore to estimate the rate of deposit in the prehistoric stratum from that which is observed in the historical layers above it is worse than illegitimate, it is sheer fantasy.

In a less crude, but not very different form, the same error appears in the attempt made by several justly admired writers to establish a chronological scale for the typological series preceding the historical in a country like Egypt. The system of sequence-dating based on typology is now familiar to all students. It was established for Egypt by Sir Flinders Petrie, and for Europe in general by Montelius. As a scheme of relative chronology it sometimes creaks a little, but on the whole it works well and has justified itself, though it may need occasional emendation. But the recurring attempts made by one author after another to translate this relative system into an absolute chronology of years have no logical justification whatsoever and only encourage self-deception. The argument is really based on an assumption which can easily be shown to be fallacious. This is the assumption that the rate of progress in civilisation is always uniform. If we know the rate of development in types which took place during the First and Second Dynasties and know also from inscriptions the length of these dynasties, then, it is argued, we have a yard-stick which can be applied to the period preceding the First and Second Dynasties. It is as though a policeman, having timed a speeding motor car over a measured mile, and found that it was going at sixty miles an hour, should appear before the magistrate and state that it was evident the defendant had been proceeding all day at sixty miles an hour. The falsity of the conception is evident as a mere matter of logic ; but it can also be shown by numerous examples in the well-known periods of mediæval and modern history. Would any historian, for instance, seriously maintain that the rate of intellectual and artistic achievement was exactly the same during the Dark Ages as in the Gothic time or the Renaissance ? Would anyone venture to argue that the industrial progress of the nineteenth century A.D. was no more rapid than that of the eighteenth, or that material development proceeded at the same rate in the reign of George I as in that of George V ? Merely to ask such questions is sufficient. I need not dwell on the long centuries of Byzantine or Chinese immobility, or on the static quality of much actual Egyptian art.

If, however, we must abandon such illegitimate methods, it is not quite impossible that properly directed ingenuity may find some others which will give a rough scale, less accurate indeed than the chronological, but nevertheless valuable. The recent success of Miss Caton-Thompson in settling the very difficult dating of Badarian culture by truly logical methods based on geology is very encouraging ; and thirty years ago I myself made a suggestion which I still think has some value. If, I suggested, we could discover the village corresponding to an ancient cemetery, and also ascertain the total number of burials in that cemetery, then we should be able by calculating the presumable death rate to arrive at a rough estimate of the number of generations. It is evident that several factors in this equation can never be established more than approximately, but it would be worth attempting if ever a suitable site could be found.

Next we may briefly consider the problem of the dissemination of cultures. This is one of the most interesting and important aspects of archæological study. In it are involved all questions of the migration and movements of peoples, their commerce and intercourse of all kinds, and the degree and extent of their reciprocal influence upon one another. It is really the cardinal problem of archæology, irresistibly attractive, and for that very reason offering peculiar temptations to hasty and premature generalisation.

Now the foundations of this particular study, in so far as they have been well and truly laid at all, have been laid not by archæology but by other sciences, those in fact which deal not with man himself but with the conditions necessary to his very existence. Geology, climatology, palæontology, palæo-botany have been the instruments of that great progress in synthetic theory which I have pointed out as the special achievement of the last thirty or forty years. Those who have worked out the details and the stages of the Ice Age and the rainy periods have shown us that various parts of the world were uninhabitable for a long time. It is obvious, for instance, that man cannot exist under a snow-field, so that it is useless to look for him north of 50 degrees of latitude until the Ice Age is well past. That already reduces our problem to much smaller dimensions, and teaches us to exclude large parts of the world from the possible area of man's earliest evolution. Conversely, large areas which to the modern view seem impossible homes for man are shown to have been eminently suitable for the life of the palæolithic hunter. The Sahara and the Gobi desert in their present condition cannot maintain the life of man or beast ; but the climatologist shows that there was a not very remote period when they were well-watered regions, covered with grass like the South African veldt, and teeming with large game. Thus he explains what otherwise might have remained an ambiguous problem for the archæologist, the finding of human implements of very early types in these apparently uninhabitable tracts.

The botanist next comes forward to tell us that the food plants on which a settled agricultural life depends can only be found in their wild state in certain closely defined areas. And he shows how changes of climate produce various types of afforestation which necessarily limit the movements and activities of a man who possesses only primitive tools. This type of reasoning has been exceedingly skilfully used, in particular by writers like Peake and Fleure, to restrict the range of choice and to give proportion, scale and limitation to the study of man's origin and movements. I regard this as one of the most solid achievements of recent years.

But when the archæologist proceeds by purely archæological methods to fill in the details on a background of which the outlines are thus immutably drawn by the other sciences, he is confronted with innumerable difficulties of method, and the logic of his procedure is not always well studied. In the first place we must necessarily rule out many types of reasoning which are so general and inconclusive that they can never carry any conviction. A little serious reflection must show that we necessarily know so little of the mental equipment of early man that it is often impossible to say what actions and habits are natural to all men as highly developed anthropoids, and what are so peculiar as to be specifically human and characteristic of one or another developed type of man.

As to many simple actions and habits there is simply no analogy which can teach us whether they are natural and inevitable to any human animal, or whether they presume so much specialised intelligence that they could only originate in some one place and time. I will choose a few instances.

That man should seek shelter from the elements is so obviously natural, and so like all other animals, that probably no one would argue that the living in caves or the construction of a primitive shelter, analogous to an animal's lair or a bird's nest, must presuppose any identity of race or origin. Or again, may not any animal pile up stones? And if so, at what exact stage does the piling up of stones become such a complex action that it can only be developed in one place? After all, stones will only hold together in certain shapes; the existence therefore of simple cairns in many parts of the world could be no valid evidence of a single mind at work. Let us go one step further and suppose that a shelter of stones has to be roofed. Is the laying of slabs, one overlapping the other so as to form a corbel, so intricate a device that it might not be invented in many places simultaneously? It seems a very primitive process, even if it has been developed with great skill in certain countries.

Again, let the form of shelter be the very primitive form of boughs or saplings placed in a circle and tied together at the top. If this simple trick is found amongst many peoples living thousands of miles apart, must we argue that they all learned it from the same source? Take again the wattle-hut: birds know how to weave a nest and to plaster it with mud—is *homo sapiens* less intellectual than the hedge sparrow?

This last example may carry us to another line of thought. It has sometimes been suggested that the discovery of the uses of burned clay, and consequently of baked pottery, may have been due to the accidental firing of a wattled hut. If so, it is difficult to maintain that the invention of pottery could only happen in one place, unless the use of fire was limited to one little spot on the earth.

Even with regard to burial customs, though many probably will disagree with me, I think it is unwarrantable to suppose that simple customs found half the distance of the globe apart must have a common origin. There are many methods of disposing of the dead, but they fall into two main classes: those which aim at preserving the body and those which aim at destroying it. Are all races which destroy, or even those which destroy by the same general methods of exposure or burning, necessarily derived from the same stock or necessarily learning from one another? It is not even convincing to say that races which preserve the body must have learned the idea from each other unless their methods are intricate and all the intricacies are identical.

These apparently elementary questions go to the root of the whole matter. Whatever answer an archæologist might give—and I personally would give no answer at all in such cases—he could not persuade by logical means any opponent who chose to disagree with him. He would be obliged when driven into a corner to say 'I am convinced' of this or that, but the conviction would express nothing more than his own temperament and psychology.

To apply logic at all then, we need to find our material in highly specialised products or habits of man. In short, it is only possible to reason convincingly when manufactures or arts and crafts have reached a high point of intricacy. Let us take examples from flint-working, man's earliest craft. It seems fair to say that the use of natural flints, perhaps even of pre-Chellean or rostro-carinate and other forms which involve the minimum of workmanship, might arise independently among various types of almost simian man. But when it comes to elaborate chipping, and when this chipping produces implements of identical and highly specialised forms, then it is indeed logical to argue that this process and these forms could only have been invented once and only in one region. Chellean flints already seem to me to be so distinctly a product of a highly specialised intelligence, which might have taken a hundred other forms, that it must inevitably be inferred that a single type of man originated these artefacts, even though they are found distributed over an immense area.

Still more it might be supposed that when one more degree of elaboration has been added, by the use of so peculiar a technique as pressing off flakes as well as chipping, the logical inference was still stronger. And if, further, this peculiar technique is combined with peculiar shapes, then the case seems to be almost irresistible. To accept this would entail some surprising consequences, linking, for instance, the Badarian culture of earliest Egypt with the Solutrean of Europe and perhaps with other even remoter places. Yet it is certainly good reasoning. It is curiously significant, however, of the difficulty of arriving at any certain conclusions that just as we might be ready to accept this theory of the Solutrean, with all its far-reaching consequences, Menghin comes forward with the assertion that the Solutrean style is the natural and inevitable product of the juxtaposition of a core-working and a flake-working industry.

In contrast to the doubts and uncertainties which beset all reasoning based on the manufactures and products of early man, it is a relief to turn to a field in which unquestionable logical certainty can be achieved. This is when we are able to study man's action in moving and displacing natural products. For when the natural distribution as known to geologists of rocks, ores, and other natural products, is artificially changed there can be no doubt that man has been at work. The direction of his movements can be traced, the motive of his action can be divined, and even the intensity of his action can be measured. Thus if a certain kind of flint is peculiar to Grand Pressigny in France and implements of that flint are found in Switzerland, there can be no doubt that Switzerland is trading with Pressigny. Similarly, if gold combined with antimony is known only to occur in Transylvania, it is a just, though a surprising, inference that the sceptre of a very early Egyptian king, living about 3000 B.C., which shows this unique combination of metals, is made of gold from Transylvania. To take a simple example from nearer home: if a number of stones in the circles of Stonehenge are of a type peculiar to Wales, they must have been transferred from Pembrokeshire to Salisbury Plain by man. In short, whenever the rare and precious stones used for ornament, the quarry stones used for building, or the peculiar metals and alloys used for jewellery and weapons can be shown to occur naturally only in one place and yet to be used in widely different areas, that is certain and positive evidence of trade and intercourse. The most perfect example of this kind is furnished by amber, which in one form of its composition is peculiar to the Baltic. It is found at hundreds of stations all across Europe, from Jutland to Italy and Greece—a fact which proves beyond all possible doubt the existence of a trade route, of which every step and deviation can be traced.

Raw materials, then, are better evidence than manufactures, especially in the earlier stages of man's life. When we are dealing with the works of man, logical processes of real value only begin to be applicable as handicrafts become more complicated and as the arts begin to emerge. Between art-styles, if we are sufficiently discriminating, it is possible to institute sound contrasts and comparisons. To take an extreme instance, we should no doubt recognise a Greek statue even if it were found in West Africa. Thus an unprincipled person knew that we should recognise an Egyptian faience figure if it were found in South Africa, and produced a very passable forgery from South Africa in that reasonable confidence. There are, of course, traps for the untrained, and there is such a thing as expert criticism even of the most primitive painting in the world. But if the criticism is sufficiently good it ought to be able to arrive at quite positive results. No two schools of art can possibly coincide in the united peculiarities of technique, convention and artistic style. I am confident, therefore, that in due time we shall have our palæolithic painters as neatly ticketed by schools as those of pre-Raphaelite Italy.

When therefore we find, as we very frequently find in all ages, either very highly specialised implements or very complex manufactures or highly stylised decorations, then we may and must concede that they originate from a single source. The hammer-axes of Troy and the Danube, the polygonal battle-axes so widely spread over Southern Russia and Northern Europe, the lunulæ of Irish gold, the decorated situlæ of Iron Age Italy, the painted vases of pre-Corinthian style, may stand as instances of highly specialised products which unquestionably denote commerce and reciprocal influence wherever they occur. To measure the intensity of the influence and the direction of the commerce is another and scarcely less difficult task, but the contact itself is beyond all doubt. No one has so ably and scientifically used evidence of this kind as Prof. Childe.

But we have to be on our guard against many cases in which the style is hardly developed enough to be a convincing criterion, or in which the style has become so confused owing to cross influences that it gives an ambiguous answer. Most of all does this occur in the sphere of pottery. There is no study that is more necessary to the archæologist, more fruitful in its potentialities or more fascinating to pursue than that of pottery. It is very often approached, however, with the utmost light-heartedness and with an absence of technical knowledge which can only provoke scepticism and irritation in a critical reader. How often have I read suggestions for pottery manufacture which any potter knows to be technically impossible! And how entirely subjective and arbitrary seem many of the assertions commonly made as to derivation and influence! There is more bad reasoning in regard to pottery than in regard to any other part of our subject.

Here and there however, though almost confined to the work of only a very small number of authors, there is some extraordinarily good reasoning. Dr. Frankfort in particular has shown that he is fully alive not only to all the subtleties and intricacies of the subject, but also to the peculiar traps which it constantly presents for the unwary. I will quote one admirable piece of reasoning which only a skilled technologist could have used. In pre-dynastic Egypt there occurs a very handsome and well-known class of pottery of which the body is red and the upper margin a lustrous black. In Anatolia and Cyprus a similar black-topped red pottery is found. It would be most natural to suppose, and it has been constantly assumed, that the Anatolian and Cypriote wares were derived from those of Egypt. But Frankfort shows that though the results are similar in the two wares the processes from which they were derived are radically different. The Egyptian school, of which we know the entire genealogy, is the result of evolution from a process of producing red ware ; the Anatolian and Cypriote arise out of a black ware production. In spite, therefore, of a very close fortuitous resemblance there is no dissemination from a single source even in this highly specialised type of pottery.

In dealing with pottery, especially in such early stages as the Neolithic and the Chalcolithic, there is the same danger of reasoning in too general terms that I have already pointed out in regard to primitive customs and habits. Limitations of opportunity and knowledge, similar climatic conditions, and even deep-lying similarities of temperament, may produce an apparent uniformity of type over a wide area without necessarily implying commerce or contact. It is generally agreed, for instance, that the entire margin of the Mediterranean, throughout all its length and breadth, was principally peopled by a uniform race called the Mediterranean race. It is also an observed fact that in the Neolithic and Bronze Ages a carboniferous black ware, so uniform in its general character that I and others have been content to call it simply ' Mediterranean black ware,' is found all over the same area. In the Iron Age it becomes specialised into finer products of great beauty, such as the bucchero especially associated with the Etruscans. Now it might naturally be argued that the uniformity of this black ware, coinciding as it does so nearly with the distribution of the Mediterranean race, was due to the uniformity of the race. This, however, does not necessarily follow, and the fact that black bucchero also appears as far away as Japan, without any intermediate links to connect it with the Mediterranean, shows that the inference would actually be false. The real explanation no doubt is that all these peoples are living at just the same stage of technical knowledge and limitation. They did not know the use of the kiln—they were obliged to burn their pottery in open bonfires. Wherever this is done the fire is smoky, and black smudges on the surface of the pot give it an unsightly appearance. The easiest way of remedying this trouble is to make an all-black ware on which the smoke-stains do not appear. This is the simple and rational explanation of the occurrence of the black carboniferous wares which occur almost literally from ' China to Peru.' Similarly in regard to form, primitive man is closely conditioned by the material which he has around him. The smaller vessels used during the

Neolithic stage are all imitations in clay of receptacles originally made in other materials. Goatskins, leather bags, gourds and baskets are some of the natural predecessors of pots. It is only to be expected therefore that the clay imitations of these will be found far and wide among people who may have had no racial connection or commercial intercourse of any kind. It is only occasionally that geographical conditions may intervene to prove that there is a real unity of culture underlying the superficial resemblances. There is, however, one happy instance of this. Gourds are indigenous in tropical and semi-tropical countries, but do not grow naturally in Europe. When, therefore, pots derived from gourd-forms are found in Moravia, it is a logical and necessary inference that the people who made them on the Danube came from a gourd-producing country like Asia Minor, or were in close commercial relation with it.

The same caution that is needed in reasoning about the technique and the form of very primitive pottery must also be used in regard to a great deal of the decoration. Pitting holes with the fingers, puncturing rudimentary designs with a stick or a bone, studding the surface with warts and bosses, even imitating the human face, are probably devices natural to any and every primitive man or woman. The production of simple patterns by tying a string on the wet clay or copying the impressions made by a net or a basket is equally natural and by no means distinctive of any one people.

In short, it is seldom possible to produce any convincing argument from pottery as to dissemination of culture or movements of peoples until the potter has so completely mastered his material and his implements that he, or more generally she, begins to invent freely and to form distinctive schools of design and ornament. This stage is reached by the advanced peoples of Egypt, the Near East, and the Aegean, in the Copper and Bronze Ages while Europe still lags far behind. And so it is natural that the best studies of pottery connections which have yet appeared, from the pens of such writers as J. L. Myres and Frankfort, deal with these more advanced regions. Into the complexities of their arguments I cannot here enter ; but I think it may be well to emphasise that the quality of their reasoning is put on a different plane from that of many other writers by the fact that it is based on actual technological knowledge. It is only too evident that many general writers on the theory of pottery have never seen a primitive potter at work, have never experimented with their own hands, and have seldom even read the very considerable though scattered literature produced by travellers who have accurately studied primitive methods among contemporary peoples.

In concluding this necessarily very brief *résumé* of the pottery question I should like to contrast two examples of reasoning, the one of which has led to useful and fruitful results while the other threatens to plunge us into confusion. All archæologists are agreed that the beakers which have such a wide distribution over Europe in the Bronze Age are derived from a single source, though they are not unanimous as to the centre of origin. Their arguments are based on a study of graduated evolution and a connected system of distribution which it would be too long to examine but which is generally recognised as valid. This unification of a single system all over the west and north of Europe, including Great Britain, has greatly assisted the study of the Bronze Age in those regions.

But contrast with this the attempts which are being made—not, I am glad to say, without many protests—to unify the schools of painted pottery so as to make a chain from Chalcolithic Sicily to China. The dates are hopelessly incompatible over large sections of this immense area, the civilisations have few if any points in common, and yet we are invited to unify them on the sole basis of paint being used. It is even asserted in so many words that it is improbable that the idea of applying paint to pottery should arise independently in different centres. It might be too dogmatic to say that this is utterly illogical, but it can certainly be said that it is quite unconvincing. The discovery of paint is in itself easy and inevitable, and once this medium is known it will naturally be used for anything and everything. To paint every object in sight, from his or her face to the furniture, the house, the shutters, the tables and chairs, is surely the natural impulse of every *homo sapiens*, whether male or female, from the earliest times to the present day. As for the fixing of the colour on the pottery by firing, that is no discovery at all, for the pottery has to be fired in any case, whether it is painted or not.

We need a systematic study of this entire subject of the reasoning that can and cannot be based on pottery. I have been able to touch on only a few points, and shall be more than satisfied if I may have stimulated someone to work the whole matter out more thoroughly. It cannot, however, be done without a wide experience and without a very thorough technological knowledge.

And this leads me to make in conclusion the only suggestion that I think need be made in regard to the training of the young archæologists of the coming generation. I do not believe that early specialisation in archæological training would be wholesome—indeed I think it would probably be rather harmful. As I mentally call over the roll of my most distinguished colleagues, some a little older and some a little younger than myself, I am struck with the remarkable diversity of their background and training. Several dozen potential professions and callings are represented among them. But this diversity has probably been a real source of strength. That classical scholars, historians, anthropologists, geologists, lawyers, engineers, artists and many other types of mind should focus from different angles on the same subjects has led to catholicity and breadth. For it is not so important that an archæologist should be an expert in one subject as that he should be widely and well educated. But with this premise once granted, I think that much time would be saved, and much efficiency would be added, if the student at the beginning of his archæological career were to superimpose a year or so of intensive technological training on his more general education. We all know the saying that a man does not really know about an object until he can make it. A technical training in primitive handicrafts such as pottery-making, flint-chipping, weaving, and the hammering, alloying and casting of metals, would give him an insight which no mere reading or even handling of finished specimens can give. We must all envy the rising generation its wonderful opportunities. I venture on this one small suggestion for its assistance.

CURRENT CONSTRUCTIVE THEORIES IN PSYCHOLOGY

ADDRESS BY
PROF. BEATRICE EDGELL, D.Litt.,
PRESIDENT OF THE SECTION.

I.

On August 29 there occurred the tercentenary of one who is often called 'the father of English psychology,' John Locke, 1632–1704.

His *Essay concerning Human Understanding* is primarily a theory of knowledge, not a system of psychology, but none the less there is much of psychological interest in the Essay, and it has had a profound influence on empirical psychology in the eighteenth and nineteenth centuries.

We may regard it as a misfortune that what he described as a 'historical plain method' should have been interpreted as a genetic study, and that his doctrine of simple and complex ideas should have been translated into a doctrine of psychological elements and compounds; but such has been the case. Historians trace a straight line of descent from the Essay of Locke to the *Analysis of the Phenomena of the Human Mind* by James Mill, and thus claim Locke as a founder of the Association school.

It may seem a far cry from 1632 to 1932, but I want to consider some of the differing constructive theories of learning and knowledge offered by the psychologists of to-day in the light of the unreconciled methods and principles which find expression in the Essay.

We find first and foremost in the Essay a confusion of logical and psychological analysis; secondly, we find a theory that attributes the union of discrete ideas to their accidental association in time, introduced as an afterthought to the theory that ideas are united by the perception of their connection or repugnancy.

To begin with the confusion of logical with psychological analysis. As Prof. Gibson has pointed out in his book *Locke's Theory of Knowledge*, at the time at which Locke was writing the distinction between the elements of knowledge attainable by logical analysis and the simple beginnings of knowledge attainable by genetic study was a distinction which it was well-nigh impossible for a writer to draw. Growth and development were conceptions which had a very different colouring from what they have for us to-day. They were, moreover, conceptions which had no literal application to knowledge. Knowledge for Locke was a structure whose validity could be tested by taking it to pieces. Just as a logical analysis of the ultimate items into which, say, a building could be resolved and an inquiry into the material out of which it arose might lead one to much the same catalogue of stones and beams, so a logical analysis of knowledge into its elements seemed to have the same issue as an inquiry into the beginnings of knowledge. That which is simple in its content is easily confused with that which is simple in its origin. It is this confusion which lays Book II of Locke's Essay open to much misunderstanding. Having in Book I denied that mind is possessed of ideas at birth, and having claimed that all knowledge is founded upon, and derived from, experience, Locke seems by his account of the 'simple ideas' of sensation and reflection and of the 'complex ideas' built upon them to be offering a psychological constructive theory of knowledge.

There is much of great psychological value in this second book: his frequent appeal to concrete illustrations, his references to children and animals, the famous citation of Molineux's problem whether a man whose sight was only restored to him in adult life would be able to distinguish by sight between a sphere and a cube. The book also contains his striking chapter on retention, vivid through its analogies but of paramount importance for psychology by reason of the statement added in the second edition: 'This laying up of our ideas in the repository of the memory signifies no more but this, that the mind has a power in many cases to revive perceptions which it has once had with this additional perception annexed to them, that it has had them before, and in this sense it is that our ideas are said to be in our memories, when indeed they are actually nowhere; but only there is an ability in the mind when it will to revive them again, and as it were paint them anew on itself, though some with more, some with less difficulty; some more lively, and others more obscurely' (II. x. 2). Here there is a glimpse of a conception which might have done much to correct the atomism encouraged by the 'blank paper' and 'cabinet' metaphors in other passages.

When mind is compared with an empty cabinet which is furnished by the simple ideas of sensation and reflection, simple ideas are being treated as the psychological origin of knowledge. When, on the other hand, Locke tells us that simple ideas are unanalysable, are not distinguishable into different ideas, and are those in which men agree when they clear away verbal misunderstanding, we have simple ideas as the materials of knowledge in the logical sense. If we look at the simple ideas listed together, we find the same confusion: the items 'colour,' 'sound,' 'pleasure,' 'pain' might be interpreted as psychologically simple, but what of the items 'existence,' 'unity,' 'power,' 'succession'?

We are told of the idea of unity, 'Amongst all the ideas we have, as there is none suggested to the mind by more ways, so there is none more simple, than that of unity, or one: it has no shadow of variety or composition in it: every idea our senses are employed about, every idea in our understandings, every thought of our minds, brings this idea along with it.' The simplicity of 'one' or 'unity' lies in its content rather than its origin. It may be logically implied by every single idea, but this does not explain how we come to reach the idea of unity. Similar difficulties are found in Locke's account of succession, duration and space. Prof. Ward wrote, 'Locke hopelessly confuses time as perceived and time as conceived.' I would prefer to say he confuses the psychological and logical analysis of the idea.

In his account of complex ideas he starts with what purports to be a psychological account of how they are formed—viz. the operations of compounding by putting together several simple ideas, and of abstracting by 'separating them from all other ideas that accompany them in their real existence.' These operations are set side by side with the operations of comparison and seeing relations. Locke holds that such operations are not present in animals. The complex ideas of animals are apparently combinations of simple ideas given to, not made by, the animal. 'They take in and retain together several combinations of simple ideas, as possibly the shape, smell and voice of his master make up the complex idea a dog has of him, or rather are so many distinct marks whereby he knows him; yet I do not think they do of themselves ever compound them, and make complex ideas' (II. xi. 7). These operations of mind in building complex ideas are never brought into clear relation with the operation which constitutes knowledge—viz. 'perception of the connection of and agreement, or disagreement and repugnancy, of any of our ideas.' Cutting across his attempted psychological account of how complex ideas come to be formed, Locke gives a logical classification of complex ideas according to the nature of their object or reference: there are ideas of modes, of substances, and of relations. In this we have another example of the confusion of the psychological and the logical standpoint, or shall one say of transition from one to the other without any realisation of the change in outlook?

No orthodox psychologist from the time of Wundt onward would have admitted for a moment that his acceptance of sensations as psychological simple elements was due to logical analysis. He would have declared that it was due rather to the analysis of physiological events, viz. the simple stimulation of a sensory receptor and the resultant excitation of the central nervous system.

I question whether any psychologist who sets out from simple sensations is really determined by a search for what is primitive in experience. That we do not experience simple sensations as such is, of course, admitted on all hands; when treated as elements they are often said to be reached by 'hypothetical' analysis. What I want to suggest is that such analysis is the outcome of logic, not psychology. The method implies that perceptual knowledge is a structure, the logical analysis of which will yield the bricks out of which it is made. This is a teaching derived from Locke's Essay. The use to which the Association school put Locke's theory of association rests on this doctrine. The theory is given in a section added to the fourth edition of the Essay, and was put forward as a theory to explain strange aversions and likings, prejudices and errors. It is never put on a level with the synthetic processes of knowledge wherein there is perception of a relationship between ideas. Association is thus primarily a way of uniting items which are discrete and have no intrinsic connection with one another.

Gestalt psychology to-day is never tired of proclaiming itself as a revolt from Associationism. Even if we believe that Associationism in pure psychology is dead, how far may it nevertheless be true that Gestalt is fighting a present-day attitude of mind which had its historical foundation in Locke's confusion of logical analysis and an inquiry into psychological genesis ?

Gestalt psychology would claim that no constructive explanation can be satisfactory which sets out from such elements as sensory events or reflex responses, and attempts to build up the experienced phenomena of human awareness and behaviour by the synthetic method. Perceptual awareness of a situation and responsive behaviour must on their view be taken *in toto*. The explanation of why just ' this ' is perceived rather than ' that ' must be sought in the physical constitution of the immediate environment and in the total condition of the organism. The school sets itself the task of studying the conditions in the stimulating situation which determine the perception of this pattern rather than that. It is always the pattern or configuration as a whole which has to be explained. Much experimental work has been done and valuable information obtained, particularly in the field of visual perception.

Whereas for the ' orthodox ' school—if there is still a school capable of claiming this adjective—' meaning ' in the form of memory images, actual or potential, comes in as an ingredient in the complex perception of an *x*, for Gestalt meaning may lie in the nature of the sensory pattern or total organisation. To take an example, size or shape perceived in indirect vision is not ' apparent ' size or shape modified by the memory of ' real ' size and shape ; the size or shape actually perceived is due to the sensory pattern of the whole field.

Leaving aside such characters of perceived objects as form, size, colour, brightness, and considering the characters derived from past experience of effects upon the percipient, a wider interpretation of ' meaning ' is required. For example, ' these red berries ' are recognised as poisonous. ' Poisonous ' is not due to the sensory pattern in the sense in which the particular shade of red is. Intra-organic conditions are stressed in such a case. We have a theory of memory traces. ' Traces of past experiences are neither an indifferent continuum nor a mosaic of independent points ; rather they must be pictures of past organisation.' [1] We must presume that the behaviour response wherein lay the gist of being noxious is part of the berry organisation. It is ' organisation ' which for Gestalt replaces the conception of association. The so-called association of contiguity is never mere collocation in time or space. It is always an instance of organisation. ' Organisation is not at all an aggregation of indifferent material. . . . If association is a consequence of organisation, it must also depend upon the mutually relative properties of what is or shall be organisated.' [2]

When we turn to the question, How do organisations arise ? we may not be wholly satisfied with the answers at present forthcoming. There are the sensory organisations or patterns the conditions of which are being experimentally investigated. Here the relative importance of the environmental and the intra-organic factors stands in need of elucidation. Descriptive terms such as ' closure,' ' nearness,' ' pregnancy,' ' symmetry '

[1] Köhler, *Gestalt Psychology*, p. 211. [2] *Ibid.* p. 226.

summarise the present formulations of experimental findings. There are also the organisations said to be created intentionally. Here the 'self' and 'attitudes' are called in as explanatory concepts, and with them we pass over into a speculative region of tensions and dynamic relations in the brain field, a somewhat misty region in our present state of knowledge.

The contemporary representatives of Locke's doctrine of association are, of course, the Behaviourists. According to this school, man is born with certain native responses to definite conditions in his environment: his unconditioned reflexes. He 'learns' or acquires new responses when an original response is extended to a different situation or when an original situation is made to evoke a different response. This acquirement is the result of 'conditioning.' All conditioning depends upon the temporal arrangement of the factors in the stimulating situation and upon the structure of the animal's nervous system. Conditioning is a scientific formulation of the facts noticed by Locke as association. 'Custom settles habits of thinking in the understanding, as well as of determining in the will, and of motions in the body: all which seems to be but trains of motions in the animal spirits, which, once set agoing, continue in the same steps they have been used to; which, by often treading, are worn into a smooth path, and the motion in it becomes easy, and as it were natural . . . and are therefore called so, *though at first they had no other original but the accidental connection of two ideas*, which either the strength of the first impression, or future indulgence so united, that they always kept company together in that man's mind as if they were but one idea' (Essay, II, xxxiii, § 6 and 7). In the language of Behaviourism such a man is 'conditioned' to respond to the second idea as he originally did to the first. As in Associationism the complex phenomena of mind were constructed from the simple ones by association, so in Behaviourism all the complex phenomena of human behaviour are constructed from the simple units of reflex responses by conditioning. To quote from a recent article by Pavlov: 'The theory of reflexes divides this general activity of the organism into separate activities, connecting them with internal as well as external influences, and then unites them anew, one to another, which brings us to a more and more clear understanding of the total activity of the organism, as well as of the interaction of the organism with surrounding conditions.'[3] Thus might James Mill have described the aim of his *Analysis of the Phenomena of the Human Mind.* Behaviourism presents us with a tidy system wherein everything hangs together. The whole of man's thought (speech) and conduct is theoretically capable of being explained deductively from his original reflexes subject to conditioning.

There are other contemporary schools wherein association figures as a great principle of linkage, but in each of them some condition over and above bare sequence is recognised. In the psychology of Prof. McDougall association by bare contiguity has a place, but he also lays great stress on the learning that implies a thread of purposive interest. The 'a,' 'b' and 'c' that are associated together are members of what Prof. Stout terms a 'conative unity.' This interest would be an essential feature in the

[3] *Psy. Review,* 1932, p. 103.

experience acquired in working out any instinctive tendency. Membership of a purposive whole is in principle a radical departure from association by temporal contiguity.

In psycho-analysis there is again great emphasis on association and its opposite, dissociation. The old forms of association, contiguity and similarity, are retained and much use is made of them in explaining transference, trains of ideas, complexes, but the operation of association links appears to be completely controlled by instinctive and emotional dispositions. The machinery of association is the same as in the older doctrines, but the levers are operated by forces which lie quite outside the ken of association psychology.

Association figures also in the motor-theory of consciousness, and here it would seem to be more after the old pattern. All association is between movement systems. Contiguity and similarity must be interpreted as contiguity and similarity between the systems of incipient and overt movements involved in the associated ideas.

We have said that Locke left his afterthought, his union of ideas by association, unreconciled with, or unrelated to, his account of knowing. Knowledge is the perception of the connection of and agreement, or disagreement and repugnancy, of any of our ideas. In Book IV he gives us a classification of the kinds of connections and repugnancies we thus perceive: identity, relation, co-existence or necessary connection, real existence. It would be out of place to go into the details of each class. What is at once apparent is that in all varieties of knowing the knower is perceiving some kind of relation between his ideas. They are synthesised or united in virtue of a perceived agreement or repugnancy.

If we turn to contemporary psychology we may compare this doctrine with the principles of cognition laid down by Prof. Spearman. Prof. Spearman calls his qualitative principles of cognition 'noegenetic.' He claims that they and they alone are generative of new items in the field of cognition. Familiar as these principles may be, I will venture to quote the second and the third. The second is the principle of the eduction of relations: 'The mentally presenting of any two or more characters (simple or complex) tends to evoke immediately a knowing of relation between them.' The third is the principle of the eduction of correlates: 'The presenting of any character together with any relation tends to evoke immediately a knowing of the correlate character.' These two principles make the knowing of relations the basic fact of cognition. They are the key to intelligence. Prof. Spearman would agree with Gestalt psychologists in stressing organisation. He differs from them by regarding organisation as dependent upon perceiving characters as related. All organisation or synthesis depends ultimately upon cognised relations. He thus denies sensory organisations as simple data. By his second principle he necessarily repudiates association in the Lockian sense. Although he keeps the names of the old laws of association, contiguity and similarity, he states explicitly that 'quasi-mechanical reproductive adherence has its source in the noetic coherence.'[4] In principle reproduction by association and the eduction of correlates are akin. The

[4] *Nature of Intelligence*, p. 146.

distinction is that in reproduction the relata have already been related in past experience, the organisation is old, whereas in eduction of correlates the educed correlate is new. It is this aspect of his third principle in creating new knowledge that Prof. Spearman wishes to stress, and it is just this stress that differentiates his principle from tha of relative suggestion advocated by Thomas Brown in his *Philosophy of the Human Mind*, 1820. Whether such a distinction of 'old' and 'new' is one that can be drawn in any absolute sense is a question that need not be raised in this connection.

Locke left us with unreconciled methods and principles, and in connecting these with differing schools in contemporary psychology I may seem to be emphasising divergencies of doctrine. Indeed, I may seem to be giving support to the gibe that to-day there is no psychology, only a collection of psychologies. By many this is thought to be a sure sign of decadence. At first sight there is much in the present situation which may give rise to a sense of disappointment to those of us who belong to the older generation. The present century opened full of hope—psychology was emerging as a new science. It was being recognised as something distinct both from philosophy and from physiology. It was rapidly developing a technique of its own. All was 'set fair' for the growth of the 'new' psychology. It is true there were schools in a very limited sense. There was Leipzig, Göttingen, Paris, Harvard, Cornell, etc., but the lines of cleavage represented, say, at the Paris Congress of 1900 were but deep furrows in a common experimental field. To-day the schools appear to be separated by unbridged gulfs. Yet it is little more than fifty years since Wundt opened his laboratory in Leipzig, and fifty years is a brief interval in historical retrospect. Is the present division of theory really a bad sign? Does it indicate the petering out of the spirit which animated the workers from 1879 to 1900, or is it a sign of vigour? I believe there are good grounds for believing the latter alternative. Prof. Woodworth, in his book *Contemporary Schools of Psychology*, declares, 'all the schools are emphasising something that demands emphasis and serve a useful function in the progress of psychology.' The methods and principles which find a place in Locke's Essay may demand for their reconciliation, not resolution but increase of knowledge to enable us to mark out their respective spheres.

II.

If Prof. Woodworth is right, we need reject no 'psychology' as false, but rather consider how far its particular teaching serves to explain certain aspects of complex human phenomena. It is as a concrete exemplification of this view that I wish to use data from my recent studies of memory.

Experiments A.

Last year I had the honour of laying before this Section the results of some experiments on recall. The material used was pictorial, British Museum postcards depicting the occupations and pastimes of the months, copies from a sixteenth-century Flemish MS. Six of these cards were shown serially to individual subjects, each card being exposed for thirty minutes. Immediately after the presentation the subjects were asked to write a full report of the cards. Without warning they were asked a month later to report all that they could then recall of the pictures; a third report was called for at the end of another month, and finally, in some cases, a fourth report was written after the lapse of a period varying from a year to nineteen months. The results of these experiments showed that certain pictures had been uniformly well remembered and others ill. The question arose how far this might be due to the position of the cards in the series, rather than to the intrinsic character of the cards. The reports also suggested problems about the influence of one recall upon another.

Further experiments have been made with the same material. Eleven new subjects took part, and the range of their scores for immediate recall show them to be a group comparable to that of the previous experiment. Some of the hypotheses suggested a year ago receive further support.

Position in Series and Intrinsic Character.

In the experiments of the present year the pictures which had been worst remembered were put in the positions occupied by the pictures yielding the best scores, and *vice versa.* To be first in the series would seem undoubtedly to be advantageous. The best score now as number 1 attaches to a card which only possessed a fair record previously as number 4. There is also something to be gained by being last in a series. As last picture old number 2 has now a fair score. It previously had a very low one.

But position will not explain everything. Old number 5 which was put in the position of good number 3 remains very low in score. Number 3, though assigned the position of old low-scoring number 2, still yields a high score. Old number 1 is not so high now that it occupies the fourth place, but it still obtains a good score.

One may contrast the two cards that retain their former respective high and low scores. I hazarded the suggestion last year that this was due to their intrinsic character, and in particular to the spatial organisation. In present number 2, foreground, middle distance and background make a single whole—each contributes to one scene. In present number 3 there are three scenes unrelated, whether viewed in terms of perceptual organisation or in terms of meaning.

This year's reports contain evidence of the same confusions as last year's. In meaning there is a relation between 'Chopping Logs' and 'Felling Trees.' The right side of number 3, representing the latter activity, is imported into number 1, where log-chopping is in the centre of the picture. The hut of number 1 and the hut of number 5 are interchanged; each has a feature of similar appearance—viz. a wooden upright supporting the roof. The principles of Gestalt psychology as well as the doctrine of meaning may be evoked to explain the data.

The recall of the picture wherein 'pig killing' is the central episode may find its right explanation in the emotional value of the scene, and here psycho-analytic theories may be in place. What is recalled and what is forgotten both suggest the importance of emotional factors.

Repetition.

In the experiments of last year there was one case of two recalls only, an immediate recall and a delayed recall after an interval of ten months. The second recall by this subject was much poorer than that of a comparable subject who gave four recalls, the last after ar interval of fourteen months. To test further this influence of recall on recall the subjects of the present experiments were divided into two groups. Six gave four recalls—the fourth after an interval of four months, and five gave two recalls only—an immediate recall and the second after five months. The scores of this group are consistently lower in this last recall than those of the former group. Repetition of recital fixes recall. The same phraseology is used, the same errors are repeated from recall to recall. Subjects remember not only the original but their own reports of the original. This taken by itself is a testimony to habit memory.

The distortions and changes in the nature of the objects and scenes depicted in the originals raised questions about the nature of memory traces. There were reports that bore out the Gestalt view of traces of organisation. There were reports wherein memory was conceptual in character. It is knowledge *about* the scene. There were other reports which suggested that if the writer saw imagery she created this in terms of her knowledge about the object or scene. Other reports suggested the presence of the orthodox memory image, a sensory presentation on the model of the original sensory pattern. The same features are shown in reports of this year's group.

Experiments B.

A new set of experiments was undertaken with the aim of testing the influence of conceptual knowledge about an object on the recall of a sense-given particular and the influence of one sense-given particular on the recall of another belonging to the same class.

For these experiments two parallel sets of cards were used. Set X consisted of five variants of each of five simple objects—a lamp, a slipper, a book, a candlestick with candle, and a teapot. The objects were drawn in outline in black ink and coloured with chalk. Set Y consisted of five variants of five shapes. These variants were obtained by drawing the shadows of the same piece of cardboard placed in different positions in relation to a light.[5]

One variant of each object (or shape) constituted a series. Three shades of yellow, of blue, of green, and of red chalk were used for the drawings, and no two drawings in any series were alike in both colour and

[5] This method was adopted by Stevanovic in his 'Experiments on the Mental Processes involved in Judgment' (*British Journal of Psychology*. Monograph Supplement 12). The material for these experiments is a duplicate of material being used for a different purpose in other experiments, and I wish to express my thanks to Miss A. M. Jenkin for kindly allowing me to use her material and for making the duplicates.

shade. While the variants in Set X are members of the same class, in that they are obviously lamps, slippers, etc., the variants of Set Y have the same fundamental relationships of form. The character of the outline is determined by the one original.

Six subjects took part in the experiments with Set X, and four of them continued with Set Y. The five cards constituting a series were shown serially to the individual subjects under the same conditions as in the picture experiments. The order of objects or shapes was kept constant and an immediate recall was asked for. The subject was required to draw a reproduction of what she had seen on a card of similar size, and was provided with a box of chalks containing the full range of hues and shades. In addition to her drawing, the subject wrote any introspective report or comment that she wished. *After* giving this immediate recall of the series seen at that sitting the subject was asked for a delayed recall of the series seen a week earlier.

It would be unsuitable to give a detailed report of these experiments. I want here to confine myself to presenting a table of the objects and shapes which were reproduced best and worst, and to noting salient points about the recalls.

Each reproduction was scored for accuracy in colour, shade, and form (including orientation). Marking for size was tried but abandoned ; a drawing that was too large because of an addition or too small because of an omission involved debiting the same error twice. Drawing the object or shape consistently smaller than the original was in one case an individual characteristic. One mark was given for correct colour (half for hue, half for shade) and one mark or a fraction, according to the proportion of the whole form correctly reproduced. The tables (pp. 179–80) give the results. Roman numerals indicate the series and Arabic the objects and shapes.

The number of persons taking part in the experiment is so small that quantitative results have no great significance. Taking the five series together, the object and the shape which secures the highest average score in immediate recall is the one that stands first. Position would again seem to be a determining factor in recall. If the objects and shapes marked *b* and *w*—best and worst—in the delayed recall are compared with those marked in the two recalls taken together, it will be seen that there is close agreement.

The fifth variant of the second object—viz. slipper—is slightly better on joint scores than the fifth variant of the third object, book, which had the best average in immediate recall. The fifth variant of the fifth object, teapot, is the worst in both immediate and delayed recall. It has gained nothing from its end position, though the last cards of the series have a high average score.

When these best and worst scores are analysed into the mark given for colour and that given for form, colour and form contribute equally to the score of the book in immediate recall, form more than colour to the score of the slipper.

Colour and form are responsible for the low score of the fifth teapot, and colour for the low score of the fourth candlestick. The first best

TABLE I.

Set X. Average Scores. Max. for I.R. and for D.R. 2·00.

Object :	1st (Lamp).			2nd (Slipper).			3rd (Book).			4th (Candlestick).			5th (Teapot).		
—	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.
I	1·61	1·04	2·65	1·72	1·32	3·04	1·56	1·18	2·74	1·21 *w* 2	0·80	2·01	1·31	1·01	2·32
II	1·56	0·64	2·20	1·33	0·93	2·26	1·70	0·82	2·52	1·42	0·69	2·11	1·22	0·65	1·87
III	1·97 *b* 2	0·79	2·76	1·44	0·84	2·28	1·58	0·41	1·99	1·73	0·50	2·23	1·58	0·68	2·26
IV	1·85	0·91	2·76	1·71	0·97	2·68	1·76	1·21	2·97	1·27	0·44 *w* 2	1·71 *w* 2	1·79	1·31 *b* 2	3·10
V	1·81	1·29	3·10	1·71	1·52 *b* 1	3·23 *b* 1	2·00 *b* 1	1·20	3·20 *b* 2	1·25	1·10	2·35	1·19 *w* 1	0·39 *w* 1	1·58 *w* 1
Totals	8·80	4·67	13·47	7·91	5·58	13·49	8·60	4·82	13·42	6·88	3·53	10·41	7·09	4·04	11·13

TABLE II.

Set Y. Average Scores. Max. for I.R. and for D.R. 2·00.

Shape:	1st.			2nd.			3rd.			4th.			5th.		
—	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.	I.R.	D.R.	Sum.
I	1·71 *b* 1	0·63	2·34	1·54	1·12	2·66	1·46	1·06	2·52	1·13	0·81	1·94	1·00	0·44	1·44
II	1·21	—	1·21 *w* 2	1·51	0·38	1·89	0·90 *w* 2	0·31	1·21 *w* 2	1·56	1·13	2·69 *b* 2	1·62	0·19	1·81
III	1·69	0·25	1·94	1·25	0·69	1·94	1·21	0·53	1·74	1·38	—	1·38	0·56 *w* 1	—	0·56 *w* 1
IV	1·00	0·31	1·31	1·12	0·44	1·56	1·19	0·37	1·56	1·15	0·44	1·59	1·69 *b* 2	0·37	2·06
V	1·56	0·75	2·31	1·37	0·69	2·06	1·50	1·06	2·56	1·69 *b* 2	1·32 *b* 1	3·01 *b* 1	1·56	1·13 *b* 2	2·69 *b* 2
Totals	7·17	1·94	9·11	6·79	3·32	10·11	6·26	3·33	9·59	6·91	3·70	10·61	6·43	2·13	8·56

shape on immediate recall has only a moderate score on delayed recall. The shape which is one of the second best in immediate recall is first in delayed recall and on joint score. The worst shape in immediate recall is lost altogether in delayed recall. The second worst receives a low score. These constitute the two worst on joint score.

Analysing for colour and form, one finds that colour and form are both contributory to the high score of the best shapes in immediate and delayed recall, and to the second best in delayed and joint recall. The low scores in immediate and in joint recall are due more to form than to colour.

Coming to the qualitative consideration of the actual recalls, one may take the two sets separately.

Set X.

A study of the reproductions shows very clearly the influence of 'knowledge about.' In Set X no one ever reproduced anything but an object of the appropriate class—a lamp, a slipper. I attribute the low scores of the teapot V and candlestick IV to their commonplace character; they are reproduced just as *a* teapot and *a* candlestick, and the particularising features are lost. As one subject writes, 'The teapot was, I think, ordinary shape.' The best recalled slipper V and book V have distinctive characteristics, although each is a familiar example of its class.

Knowledge *that* the object is so and so is frequent even when the reproduction is wrong in form, colour, or orientation, or all three. There may be knowledge *that* the slipper was a mule, *that* the lamp was angular, *that* the book was lying down, without ability to recall the particular object with its sensory features. There may be an imaged object, but the image is not a recreation of the original pattern.

As an illustration of reasoning out a memory recall based on 'knowledge about,' the following is worth quoting in full. It relates to lamp II.

> 'I find very great difficulty in seeing or drawing this. I remember that it consisted of two balanced arrangements of planes. There was a triangular shape in both large masses, but how the other lines fitted on to this I can't tell. The above was written after my first attempt to draw. When I returned to this I saw it wouldn't do, because I couldn't get depth in. So I started again, building up the two blocks (one small, one large, in each) as I thought they must go if there was to be depth. I was pleased when I saw this gave me a triangle on top because I feel sure there was one. But now that I look at it, I don't think it was this shape. It was more like the shape of my original wrong start. Also I now don't feel certain whether the smaller blocks were on top of the bigger blocks or *vice versa*. I'll colour in what I have drawn and see if it helps me to see whether it looks like the original. Done. It looks very unlike it. I shall put the outlines in, in pencil. Done. This makes it a bit better, but I've got it too symmetrical. The bottom was less large than the top, and the whole didn't seem to go in such a straight line. I think there were other surfaces bounded by lines, but I can't see

> how they would fit on to the shapes. As I was writing this I saw I'd left out the third side of the bottom triangle. I stopped and put it in. I shall try some lines down the sides to see if these make the figure look at all more as it should. They are not right. I give this one up.'

The influence of the object of the day on the delayed recall of the series of the previous week is evident in the errors of form, of colour, and of orientation.

There are many instances of remembering form or colour through 'association.'

> 'When I saw the book I immediately tasted olives.'
>
> 'I remembered the sandal because it had reminded me so much of sand in colour and purpose.' 'I liked the lamp; the stand reminded me of a gallé vase (*sic*) I had once seen converted into a lamp.'

As with the more elaborate pictures, one finds evidence in the reports of what I should term genuine memory images, re-creations of the original sensory pattern.

> 'I had a visual image and started to draw. At first I left no place for the band between shade and bottom. I saw this was wrong as I drew the bottom coming up to meet the shade without any band, and so corrected it. As I did so I had a distinct visual image of this band, seeing black lines on it and the handle.'
>
> 'The slipper—I could not remember anything about it at all, so could not draw it. I could see my own page of writing quite clearly, and knew whereabouts on the page I had mentioned the shoe.'

Set Y.

Conceptual knowledge of the shape had to be gained from the experiments themselves before it could be used as an aid to recall, and was in fact only gained by two of the four subjects. The scores are lower than in Set X, and each subject refers to the difficulty of the task.

> 'There is nothing definite that I can get hold of about these except the colour. They are so complicated. The objects were much easier, as one could remember them by thinking of shoes, etc., like one has really seen.'

The best scores for shapes are for V 4 and II 4, shapes which all four subjects likened to an animal and a bird respectively. V 5 scores principally through colour, but its form is also well remembered and its symmetry is noted. The worst shapes are those that are most indefinite and suggest no analogies. Colour rather than form is responsible for the low score of IV 1.

As in Set X, the influence of the perceived variant of the day on delayed recall is seen in the errors of form, colour and orientation.

All subjects try to see the shapes as like something.

> 'The designs seem much easier when I can connect them with something else.'

This does not aid memory in the direct way in which association may aid the recall of the objects. If an analogy is seen for the variants of the first series, the subject tries to apply this as a controlling concept to the following series, and here it may have misleading results and cause confusion. The second shape in the first series was seen as 'a slipper' by everyone (possibly the fact that in Set X the second object was a slipper contributed to this interpretation). 'Slipperness' is not very appropriate for an accurate recall of the later variants of this shape. The first shape of the first series was seen as a picture hook and a chicken's head, with misleading results in each case. Reproductions are worked out in terms of the analogy.

> 'I feel my drawing has become too much simply like a slipper.' 'How did the horse one go?' 'Which is the bird one?'

The subjects who got hold of the concept of the shape reproduced shapes correct in general features, but sometimes wrong in orientation or in colour, and sometimes unlike the original when this is regarded as a sensory whole.

As in Set X, there is evidence of simple memory images. Thus one subject writes:

> 'I tried to think of the shape. I remembered angles one side, curves the opposite—I couldn't remember which. Suddenly I had a visual image of the two corners I've made.'

Both here and in the following there is a combination of knowledge '*that* so and so is so and so' and a memory of the sense particular.

> 'The blue one. I've a visual image of this, not definite; also I remember that there were three projections on the right, the centre one largest, the lowest one curved.'

To return to my purpose in referring to these studies: To explain what I find I need to draw on explanatory principles typical of each of the current schools. If I stress position in series and the influence of repetition on recall, I am using factors which would find their place in Behaviourism. Indeed, if I stress the influence of the present sensory pattern on the subsequent delayed recall, I may be using a factor which could fall under the conception of conditioning. Much of what I have said about the intrinsic characteristics of the pictures, objects and shapes which are best recalled is explicable in terms of organised sensory wholes, and some of these organisations seem to be simple data. On the other hand, many of the reproductions depend upon seeing relations, particularly the relation of likeness. 'Gestalt theories and noegenetic principles both have their place.' There is also evidence that likes and dislikes play their part, and that emotional factors influence forgetting and recall. If I separate form from colour in assessing the recall of the objects and shapes, am I confusing logical with psychological analysis and following the old view of elements? In a certain sense, 'yes.' But if colour and form can be ill-mated in reproduction, must they not be psychologically as well as logically different aspects of recall? If such recall is image creation under the influence of knowledge *that*, such changes need not surprise us. The logical analysis of experience involved in conceptual thinking furnishes us with simple ideas of form, colour, size, etc., simple ideas in Locke's 'logical' meaning. These can enter into conceptual knowledge about objects, but they can also control image constructions built on the lines of perceptual patterns. Such image constructions are not in any literal sense reproductions of a particular sensory organisation and should not be explained by a theory of traces. The attempt to so explain *all* images entangles those which have their origin in the logically simple,—conceptual knowledge, with those which have their origin in the psychologically simple,—sensory experience. Greatly as memory is controlled by concepts, there are the cases which I feel I can only regard as re-creations of the original sensory pattern, genuine memory images. The painting anew on the mind seems directly conditioned by the original sensory experience. It is not an image constructed under the influence of knowledge *that*.

Inadequate as this sketch is, I trust it may serve to support the claim that it is important to consider all the constructive hypotheses that are to be found in present-day psychology while continuing patient experimental work. We cannot perhaps go forward with the confident belief of the early pioneers that the solution of many problems lies close at hand, but we can possess their spirit of adventure and their enthusiasm for progress.

When we compare the constructive theories of psychology with those which light up physical science to-day, without envy and without shame we may echo Locke's words in his Epistle to the Reader: 'The commonwealth of learning is not at this time without master-builders, whose mighty designs, in advancing the sciences, will leave lasting monuments to the admiration of posterity: but everyone must not hope to be a Boyle or a Sydenham; and in an age that produces such masters as the great Huygenius and the incomparable Mr. Newton, with some others of that strain, it is ambition enough to be employed as an under-labourer in clearing the ground a little, and removing some of the rubbish that lies in the way to knowledge.'

SECTION K.—BOTANY.

THE GROWING TREE

ADDRESS BY

PROF. J. H. PRIESTLEY, D.S.O., B.Sc.,

PRESIDENT OF THE SECTION.

CONTENTS.

TREES do not form a special botanical category; they are often regarded as the special study of the forester rather than of the botanist, and they seem never to have formed the special subject of a presidential address in this Section. In 1894, however, when Prof. I. Bayley Balfour presided over Section D, upon the last occasion on which that Section included botanists as well as zoologists, forestry was the subject of his address.

In making this his theme before a gathering of biologists, he laid emphasis upon the fact that the 'utilitarian side gave the first impetus to the scientific study of botany,' and that botany still had, in agriculture and forestry, its contribution to make in the service of mankind. He laid stress upon this because he felt that a recognition of its practical significance would vitalise botanical teaching, which was 'inclined to elaborate the minute detail of a part at the expense of its relation to the whole organism, and discuss the technique of a function more in the light of an illustration of certain chemical and physical changes than as a vital phenomenon of importance to the plant and its surroundings.' This tendency, Bayley Balfour argued, must be counteracted 'if botany is in the future to be aught else than an academic study, as it was of old an elegant accomplishment.' He sees the roots of the trouble in the failure of botanists, so far, 'to see the lines through which the subject touches the national life.' Bayley Balfour would possibly, therefore, have felt some sympathy with this effort to show that a study of the growing tree throws fresh light upon its form, structure and vital functions, and gives new meaning to the practices of the forester and horticulturist, whilst the details of structure which attract the attention of the worker in wood are also seen in new perspective.

The Habit of Growth of the Tree.

The tree is characterised essentially by prolonged vegetative growth and delayed reproduction. Green leaves add to the substance of a plant by their activity, whilst flower and fruit production exhaust it, so that during this prolonged period of vegetative activity the tree gains annually in substance. It is a further characteristic of the tree that each growing season sees this substance added as an increment of radial growth upon a woody branch system which increases no more in length. Each year also, emerging from the buds in which they lie concealed during the dormant season, the growing points of the shoot form new extension shoots bearing new leaves, although after flowering commences some of these growing points also form flowers.

At first sight the extension growth of the shoots from the buds, and the formation of wood and bast on all the rest of the woody axis, seem two independent processes, but recent studies in the Leeds laboratories have convinced me that the key to the interpretation of the behaviour of the growing tree is to be found in the fact that these two processes are inseparably and causally connected. This statement must first be justified, and then it is hoped to show that, regarded from this angle, problems of form, structure and function connected with the growing tree reveal an entirely new significance.

Apical Growth and Radial Growth.—Two great classes of plants, the Dicotyledons and the Gymnosperms, are characterised by growth processes which continue to thicken the axis of the shoot after it has extended in length. In these two groups are found the two characteristic tree groups, the hardwoods in the Dicotyledons, the softwoods in the Gymnosperms. To each great group also belong plants which are not trees, the Dicotyledons in particular being predominantly herbaceous, but throughout both groups the axis increases in thickness, after it is first formed, by the continued growth of an internal cylinder of cells known as the cambium. This cambium consists of cells which grow and divide, as did the cells of the shoot apex which were thus responsible for the original growth of the shoot axis, and the cambium cells prove to be very closely related to the growing (meristematic) cells of the apex.

At the shoot apex two processes can be seen to follow one another in close succession. In this region the crowded leaf primordia, with the youngest nearest to the apex, are evidence that surface growth is in excess. Growth is here proceeding in a beautifully ordered manner, throughout a mass of similar meristematic cells. The shape of each cell is being determined by the mutual pressure their expanding semi-fluid contents exert upon each other, their plastic walls yielding readily to pressure, whilst cell expansion is due to the increase in amount of living protoplasm. The cells remain small because after a certain increase in size each cell divides into two new cells which behave in the same way. Just below the apex the leaf primordia are being dispersed along the shoot axis, as they increase rapidly in size, because here cell expansion by vacuolation is taking place, mainly in a longitudinal direction, in association with a series of cell divisions in which the new cell walls are formed at right angles to the length of the shoot axis. At this stage of cell growth, cell extension is rapid and largely due to the intake of water. The cell wall resists this rapid extension, so that neighbouring cells are no longer in mutual contact over their whole surface. Their walls separate from one another at all angles of contact, so that an intercellular space system now develops. This is at first full of sap but rapidly fills with air—a change that must exert a profound influence upon the further progress of growth in this tissue. In all probability the great longitudinal extension of the shoot tissues, which are composed of such vacuolating, dividing cells, is attributable to the properties of the cellulose wall, which resists expansion in some directions more than in others.

Before shoot extension begins, the leaf primordia are crowded at the apex, with no indications of internodes between them. When cell extension and vacuolation, with continued cell division, lead to the development of the internode, all the cells of the leaf primordium and axis do not vacuolate simultaneously. In the median plane of the flattened primordium and in continuity with this, in the axis, in a region between vacuolating cortex and pith, the cells remain meristematic, continue to increase in size by increase in protoplasm and remain in contact with each other over their whole surface so that intercellular spaces are absent. These meristem cells are therefore behaving just like the apical meristematic cells, but they are now embedded in vacuolating dividing tissues which are extending mainly in a longitudinal direction. As a result their plastic walls are drawn out in a longitudinal direction, and we distinguish as procambium this strand of meristematic tissue in the leaf primordium together with its prolongation into a hollow cylinder or network in the extending internode. This procambium is however nothing but meristem such as is present in the surface of the shoot apex, which is still left as meristem when neighbouring cells vacuolate.

But other changes are visible in the procambial tissue almost immediately. The outermost cells begin to vacuolate and differentiate into protophloem elements with thickening of wall and ultimate loss of contents, the change being initiated from below upwards in continuity with the differentiated sieve-tubes of the vascular strands below. Then another change is noticed at the base of the leaf primordium; on the inner (adaxial) side of the procambial strand cells begin to vacuolate and differentiate into lignified xylem elements, but even earlier the growth and division of the elongated meristem cells in the centre of the strand has taken a new form. These elongated cells at first expanded mainly in length, with the natural result that they subsequently divided by a transverse wall. These cells now grow more rapidly than can be allowed for in the longitudinal extension of the system as a whole. As a result they increase in size in the radial and tangential directions and new cell divisions occur repeatedly in which the new cell walls are tangential in the axis and parallel to the flattened surfaces of the leaf primordium. These repeated tangential divisions in elongated meristematic cells are characteristic of the cambium, and their occurrence marks the change from procambium to cambium. The new cells formed by such divisions lie in radial files which are visible at a very early stage of shoot extension. Evidently, even during extension growth of the shoot, the meristematic cells of the cambium are growing more rapidly than the vacuolating dividing cells around them. The vacuolating cells cease to divide altogether as the intercellular space system around them fills permanently with air; but the meristematic cells of the cambium lie between the differentiating vascular elements, from which supplies of sap still reach them along walls which are in close contact, or between which small intercellular spaces are only just developing. In the fully extended axis, therefore, the growth and division of the cambium cells still continues, the new walls being mainly in the tangential direction; from the inner cells of the radial files thus formed, new xylem elements are differentiated, from the outer cells new phloem elements.

The tree is the outcome of the maintenance of this radial growth in the axis long after the leaf in which it was initiated has fallen, but it is essential to realise that this radial increase by cambial activity is in direct continuity with the normal meristematic growth of the shoot apex, and is initiated always, at successively higher levels in the extending shoot apex, at the base of each new leaf primordium. This fact is quite definite, and whilst the protophloem on the outside of the procambial strand always differentiates forwards into the shoot apex as an extension from previously differentiated elements below, cambial activity and xylem differentiation begin afresh at the base of each new leaf primordium and extend from thence downwards as the growth of the vacuolating and dividing tissue around them produces the axial extension we know as the internode. In each developing internode, therefore, cambial activity and xylem differentiation are most developed at the top of the internode, at the point of leaf insertion, and from thence diminish in amount downwards.

So long as the internode is extending in length, the vascular elements differentiating from the cambium are pulled out during differentiation and are characterised as protoxylem and protophloem. It has only recently been realised that in many plants much, if not all, of this protoxylem differentiates from cells cut off in regular radial rows from the cambium, so that it is ' secondary ' in origin. After extension has ceased, the vascular elements, metaxylem and metaphloem, differentiate, without undergoing further extension, from the elongated cells cut off by tangential division from the cambium.

This process of radial growth continues in the axis as long as the leaf is active, being renewed in successive years when the leaf is evergreen ; but when the leaf dies the process does not necessarily stop. Higher on the axis are now developing new leaves ; new impulses to cambial activity and vascular differentiation are travelling basipetally downwards through the newly extending internodes, and these impulses do not cease to be effective at the base of an internode. On the contrary, they continue downwards into the fully extended internodes below, so that the cambial activity and proto-vascular elements of the upper internode are in direct and causal relation with the cambial activity and meta-vascular elements of the internodes below, and, so long as new leaves are growing at the apex, radial growth of the vascular tissues continues on the fully extended axis below. It is the essential feature of the tree habit of growth that this radial growth of the vascular system does not cease at the base of the current year's shoot, but continues as a similar impetus to new radial growth, from the base of the growing bud down over the surface of the wood throughout the permanent woody axis of the tree.

Basipetal Cambial Activity from the Buds.—So long ago as 1862 Th. Hartig pointed out, in the willow, that the new cambial activity on the dormant woody twig began at the base of the buds and worked from thence basipetally downwards, and that this original direction of growth continued in a willow cutting even when the twig was inverted. The significance of this observation does not appear to have been realised at the time, and the fact was rediscovered recently and attention drawn to it by several workers. Using ordinary anatomical methods, it is a very tedious task to determine where cambial activity is renewed in the spring, and it is not surprising that statements upon the subject are very contradictory. During the last few years detailed studies of two species, one hardwood and one softwood, by two Leeds workers, Mr. G. Cockerham and Dr. W. Wight, have shown that in both the first inception of cambial activity on the woody axis is to be found at the base of the buds, and from thence cambial activity and vascular differentiation spread basipetally downwards throughout the tree. Many thousands of sections had to be examined to establish these facts. Fortunately in the present year a new and simple method of following the renewal of cambial activity has been found, which has rapidly extended the range of our observations.

In the resting condition the cambium cells on the surface of the old wood seem to be relatively firm in texture. They are then very granular in appearance with somewhat thick walls, and are bound firmly between the surfaces of the wood and bast, so that the bark will not 'slip.' The first sign of renewal of cambial activity is a change in the consistency of the cambial cells. Their contents become much more transparent and apparently semi-fluid, and the bark now 'slips' easily upon the surface of the wood, separating from it at this plastic cambium layer. But if the bark is peeled off a little later, after a few divisions in the cambial cells have taken place, then the separation still takes place at the cambium layer, and as most of the newly formed cells have usually been cut off to the inside of the cambium, these now lie in a thin film on the firm surface of the old wood. These new cells have thin walls and fluid contents and can readily be stripped off the surface of the old wood. In this manner long strips of tissue newly formed from the cambium, in which protoplasmic streaming has frequently been seen and in which early stages of vascular differentiation are readily visible, can be stripped from the surface of the old wood with the greatest ease. By the use of this method it has been possible to follow the resumption of cambial activity in a number of species of both hardwoods and softwoods.

The results will be presented in detail elsewhere, but the general result is a complete confirmation of the conclusion that the renewal of cambial activity upon the surface of the old wood depends upon the commencement of growth in the buds. Such cambial activity always begins beneath the buds and spreads from thence basipetally downwards. In the softwoods the basipetal spread of cambial activity is extremely rapid. In some hardwoods, as oak, ash, sweet chestnut and elm, it is also extremely rapid, but in others, as in sycamore and horse chestnut and many of the Rosaceæ, the downward spread of cambial activity is much slower. In birch, beech and alder again, the buds have burst and the leaves emerged before there is any sign of cambial activity spreading down the twigs; but as the extension growth begins in the new shoots, cambial activity appears on the woody shoots beneath the buds and spreads from thence relatively rapidly down the tree. The varied details of this process have proved exceedingly interesting, and there is no doubt that the new method has much to tell us of the characteristics of radial growth in different trees. The ring-porous type of wood characteristic of oak, ash and elm is evidently connected with the rapid and early spread of cambial activity and vascular differentiation down the axis, whilst the diffuse-porous type of wood of beech links with its later basipetal spread of cambial activity. At the moment however, we must be content to emphasise the significance of the general conclusion that the resumption of radial growth of the trees is almost completely dependent upon the commencement of growth in the buds. With this clue to their interpretation, the problems of form, structure and function presented by the tree are seen in quite a new light.

I. Form.

We can only indicate, by discussing one or two examples, how tree form is dominated by this causal link between bud development and radial growth. One familiar horticultural operation demonstrates the point beautifully. When a branch is pruned it is the invariable rule that the cut is made just above a bud, not just below one. As a result no piece of stem is left projecting beyond the uppermost bud on the pruned branch. The reason is that practical experience has shown that any such projecting length of stem, above the influence of any bud, makes no further growth but withers or rots into an unsightly ' snag '—clear evidence that cambial activity from the buds is only basipetal and that it cannot recommence in a region of the woody axis which has no living bud above it. All forestry practice is really based upon this fundamental fact. When growth starts in the tree, the buds in the light are moving first, and if their growth is sufficiently vigorous, buds on lower branches shaded by neighbouring trees may never resume growth. Such lower branches fail to make any radial growth also and lose their supplies of water and food to the vigorously growing regions of the crown and trunk. It is the tacit recognition of this fact that underlies the system of close planting to obtain straight-shafted timber—a system which meets a rather different problem in the different branching habits shown by softwood as compared with hardwood trees.

Branching in Softwood and Hardwood Trees.—In the softwoods, as in *Abies*, *Picea*, or young pines, the branching habit of the tree is usually singularly regular, a whorl of branches starting each year from buds left in the axils of some of the uppermost leaves on the shoot of the previous year. In the spring, growth activity begins in all the apical buds of leader and branches at about the same time. In the leader and the youngest branches radial growth is thus stimulated and progresses down the stem very rapidly and at about the same rate ; but in older branches, and progressively as the branches grow older, the downward propagation of cambial activity becomes slower and slower. As a result, when in the main stem radial growth is already well advanced—because differentiation of new wood, when once begun, proceeds very rapidly—the bases of the lower branches joining the stem still show no signs of radial growth. The new wood formed on the main stem runs downwards in a loop closely encircling the previous year's wood of the branch, which runs radially inward through it, the two tissues having no continuity at all. Later, when new wood formation begins at the base of the branch the new wood is continuous with the downward running elements of the new layer of wood still forming on the axis. Still lower on the main axis, especially when shaded by neighbouring trees, branches will be found in which the radial growth of the branch does not recommence because the apical bud does not grow. These lower branches lose their sap to the growing trunk. Around the dry wood of such branch-bases flows increment after increment of the wood formed on the main axis. But the branch is usually set at an angle to the main stem ; each new layer of wood is forming from above downwards, and expanding outwards with irresistible force against the dried and brittle base of the branch, lifting up the dead bark which clothes it, throwing this into folds around the base of the branch to which the bark is firmly fixed, and ultimately straining the dry tissue so much that the branch is broken off. New increments of wood still flow around the base of the broken stump of wood until they cover it over completely.

All that is now left as external evidence of the presence of the branch is the scar where the bark has healed over the stump, and the folds in the bark around this scar where the bark has been thrust outwards against the base of the stem. But within the wood of the trunk, below the scar, the branch stump is left to form a loose knot when planks are cut from this region because of the way the wood of the branch has simply been gripped in the flanks of the vertically running fibres of the wood of the main stem. Still further within the tree the branch wood has more continuity with the wood of the trunk, but still remains a tapering, radially directed cone with its fibres, in the main, running radially inwards, distinct from the downwardly running fibres of the main axis. This is particularly clearly shown when the wood of the main axis rots away leaving the tapering branch end pointing into the hollow centre of the trunk.

In the hardwood, the beginnings of radial growth similarly wait upon apical growth, but the branching is less mathematical in its regularity and there is no constant succession of longer and larger branches regularly spaced along the axis. Usually radial growth is proceeding at the same time on main stem and branch stem and a continuous layer of wood is laid down smoothly on all sides of the branch-base, in closest continuity with the wood of the main axis. Here again however, if light does not reach them, lateral branches lower on the tree will fail to make any extension growth ; radial growth will then also fail in them and these branches will dry and die. Then successive increments of wood upon the main axis will thrust against the bark where it is held tight around the bases of the dead dry branches, and thus ultimately strip the lower part of the trunk of such branches, the stumps of which will promptly be buried under the new layers of wood, with only the branch scars and their attendant folds in the bark as evidence of their presence. When these stumps are brought to light as knots in planks they will usually be very firm because of the different manner in which wood of branch and main axis made union, and because under high forest conditions the lateral branches die and fall off young, leaving no dead stub of wood to be buried in the wood of the main axis. Only when older branches have been cut off by the forester in such a manner as to leave projecting stumps are these likely to be buried and reappear as loose knots in the planks cut from the trees.

Although the hardwood has not the mathematical regularity of branching characteristic of the softwood, its branch system is usually built up upon an ordered plan. The case of poplar may be described as an interesting example in which, as in oaks, the natural abscission of branches contributes to the rapid simplification of the branch system.

The vigorous vegetative seasonal shoot of a poplar bears many buds, of which the terminal one normally makes very vigorous growth the following season. The next few buds remain dormant. Then follow a group of buds which grow out into vegetative shoots, the uppermost of these usually being the stronger and the lower ones progressively weaker until again buds are reached which remain dormant. Cambial activity in these various shoots shows some proportionality to their vigour of growth ; in the strong lateral shoots the basipetal impetus to cambial activity moves strongly down to the base of the shoot and on to the main stem, so that the shoot is subsequently firmly bound to the main axis by differentiated and lignified vascular elements common to them both. In weakly growing shoots basipetal cambial activity is weak and carries over little, if at all, into the main stem, to which this shoot has as a result but little lignified vascular attachment. Then as the parent axis enlarges under the vigorous impulse to radial growth reaching it from the vigorous terminal shoot and contributed to by the more vigorous branches above, the weaker lateral twigs, as they continue to make little or no lateral growth, are forced off by a perfectly natural process of abscission which leaves a clean scar on the surface of the parent axis. These twigs thus gradually disappear from below upwards, leaving in the leafy crown a scaffold of stronger branches.

Later in life, probably after thirty or forty years of vegetative growth, flowering begins on lateral shoots in which only the apical bud continues a relatively weak vegetative growth. The buds immediately below this, and all other buds except perhaps a few of the most basal ones, develop flowers, and these flower-producing buds contribute nothing to the cambial activity of the axis ; in fact, as they draw food from it they probably diminish the vigour with which the basipetal impulse to cambial activity travels down the stem from the terminal bud. Such shoots usually make a most inadequate vascular connection with the axis that bears them. The parenchyma amongst the woody tissue is in excess and contributes to a swollen base which, strained by the girth expansion of the more vigorous axis it joins, is abscissed after some years of flowering, even though the branch thus abscissed is fifteen to twenty years old. In some species of poplars and oaks, in England, the ground beneath the trees is thus carpeted each autumn with a crop of still fresh, sappy branches, self-pruned from the distal branch system, the rounded bases of the abscissed branches and the cup-shaped scars on the branches that bore them bearing witness to the natural manner in which they have separated.

II. Structure. Cambial Growth and Vascular Differentiation in Softwood and Hardwood.

It is clear that the branch system of the tree is mainly determined by the close relation that exists between shoot growth and radial growth. Only when the bud is still making extension growth and producing new leaves will the woody stem beneath it increase in thickness and remain a functional member of the woody crown. The slender twig still shows evidence, in contour and leaf scars, of the series of nodes and internodes laid down during shoot extension, but in later years the smooth addition of each new radial increment, spreading basipetally downwards from new leafy shoots above and independent of any local influence, gradually obliterates all trace of node and internode, whilst the repeated cracking of the bark as the stem thickens may make it impossible to trace the original leaf scars. This region of the woody shoot now forms an integral portion of the woody axis, but the texture of the wood is still determined by growth characteristics of the cambium which are linked in the closest manner with its origin at the shoot apex, and which are strikingly different in softwoods and hardwoods.

Conifer and Dicotyledon have very different types of shoot apex. The Conifer bears narrow leaf primordia, many often growing simultaneously at the apex (the seedling often has many cotyledons), and most of the subsequent growth of leaf and subtending segment of the axis is in a vertical direction. The Dicotyledon usually has few primordia sharing the growing apex, with a broader leaf primordium, and the seedling has two cotyledons. The subsequent growth of the primordium, whilst mainly longitudinal, also includes considerable tangential expansion. With these differences may be connected the contrast between the long narrow cambium initials of the Conifer (Fig. 1), which thoroughly deserve Bailey's term of 'fusiform,' and the shorter Dicotyledon initials which are often not fusiform but more, as Fig. 2 shows, like elongated meristem cells which have retained their original polygonal faces. These characteristic forms of the cambial cells have a very distinct bearing upon the differences in the elements cut off from them—differences which affect the grain of the timber and which are well known to all workers in wood, who distinguish sharply between the properties of the softwoods with their uniform grain and freedom from vessels, and the more varied hardwoods with vessels, fibres, etc., variously distributed throughout their texture.

We will now briefly examine the relation of these structural features to their formation from the cambium, as this tissue resumes activity when growth recommences in the buds.

Cambium and Vascular Differentiation in the Softwood.—In tangential longitudinal view, ends of adjacent fusiform initials never lie at the same level. Evidently as the cambial cylinder grows in size and the initials in the periphery increase in number, new initials do not arise by longitudinal radial division. Tangential divisions do not add to the number of cells in the periphery, and the only other divisions that have been seen are transverse divisions, when the two new cells are separated by a somewhat oblique cross wall. This wall rapidly assumes a more oblique or vertical position, so that it is usually assumed that the two daughter initials have glided past one another by 'sliding growth.' In view of the plastic walls and liquid contents of these meristematic initials it is difficult to understand how they readjust their relative positions by sliding past one another, whilst such a process is also difficult to reconcile with the presence of plasma connections and pits on the radial walls of the vascular elements differentiated from the cambium. Further, if the alteration in the relative position of any two cambial initials with time is followed in the only possible way—viz. by studying the relative displacement of the radial files of tracheids in the woody axis—then such sliding growth does not appear to be a necessary assumption. The tracheids in any radial file, traced outwards through the wood, grow longer but undergo little or no vertical displacement, so that the cambium initial that has been present all along on the outer tangential face of this file has grown longer but

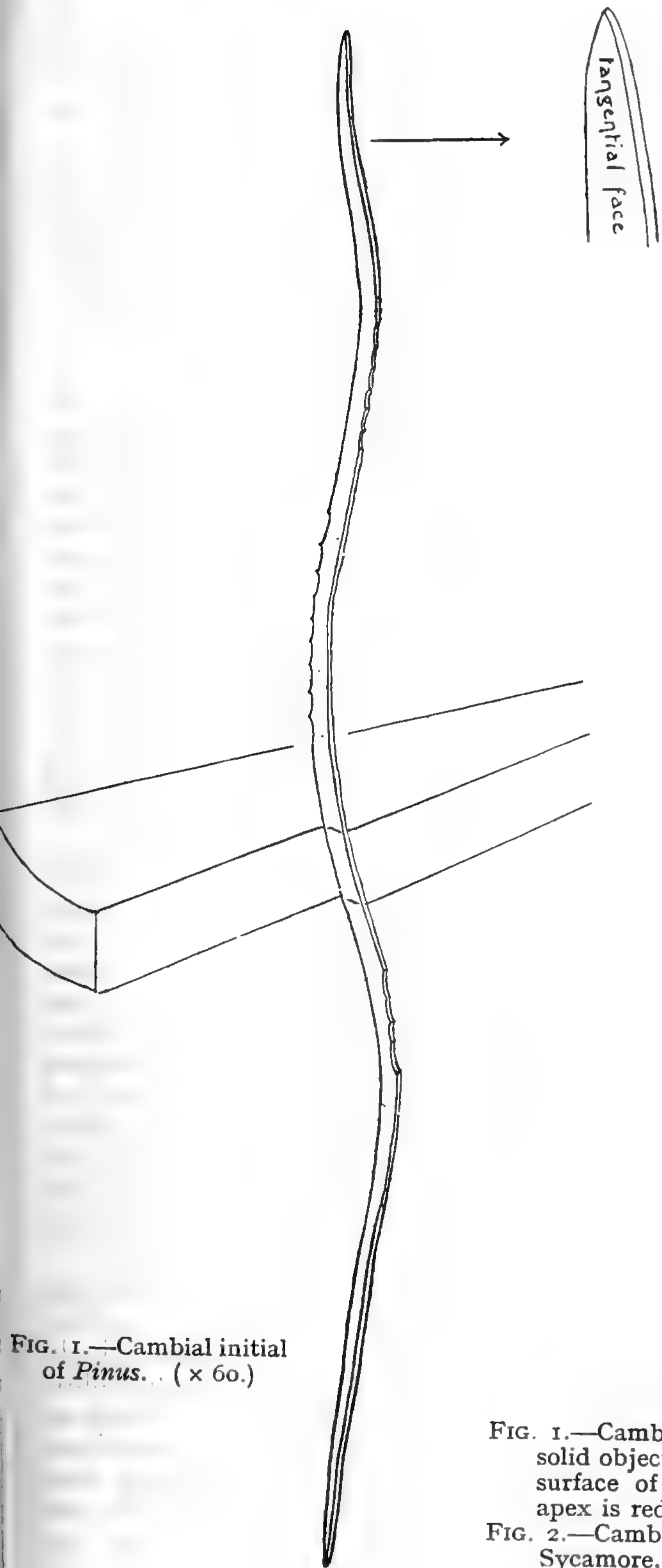


Fig. 1.—Cambial initial of *Pinus*. (× 60.)

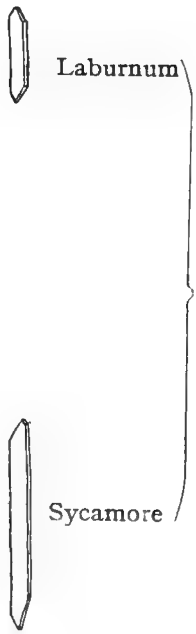


Fig. 2. (× 60.)

Fig. 1.—Cambium initial of *Pinus* drawn as a solid object. (× 60.) Its position on the surface of the wood is indicated. The apex is redrawn upon a larger scale.

Fig. 2.—Cambium initial of Laburnum and Sycamore. (× 60.)

has not shifted upwards or downwards as a whole. When the file of tracheids doubles, through the transverse division in the cambium initial, the new files of tracheids are at first nearly superimposed vertically, but as the two initials grow in length, the cross wall between them becomes more tilted, especially in the tangential direction, so that the two files of tracheids cut off from them come to lie more nearly side by side. The readjustments in relative position of the two daughter initials, on the face of the files of tracheids, may take place without slip, in view of the liquid nature of the cell contents and the plastic nature of their walls, which allows of a relatively rapid extension of the new 'three-ply' cellulose-pectin-cellulose division wall as it moves into a more vertical position.

Reasons have been given elsewhere for thinking that these relatively minor readjustments of position in the cambial cells, as the cambium cylinder grows wider, thus take place by 'symplastic' movement of the common framework of walls of the fusiform initials, which thus continue to grow and spread tangentially between the rays. The latter act as fixed points because they are formed of vacuolated cells which extend through to the differentiated vascular tissues on either side. When growth in the cambium is renewed in the spring, if the impetus to growth and tangential expansion reaches one point first at any level in the cambium cylinder and spreads from thence gradually round the cylinder, this plastic wall framework of the initials will tend to undergo an oblique displacement as a whole. The result, when the new pattern is repeated in the wood, will be the production of 'twisted fibre' or 'spiral grain.' This is a phenomenon that frequently thrusts itself upon the attention of the forester and worker in wood.

In the early summer quite a number of tracheids in the same radial file are in course of differentiation, and the radial expansion of these vacuolating elements must exert a very considerable pressure upon the plastic meristematic cambium initials outside them, which thus remain radially compressed and seem to become even more elongated in the young tree each year as the vigour of radial growth increases. This radial pressure was very vividly brought home to us when we were stripping the young differentiating tissue off the old wood. When a thick layer of differentiating tracheids was present, as the knife scraped these tissues a fine spray rose from their surface to a height of more than a foot. This phenomenon has only been noticed with the softwoods, and supplies the clearest evidence of the pressure under which the liquid contents may be held in the vacuolating tissues.

Cambium and Vascular Differentiation in the Hardwood.—Bailey has pointed out that the cambia of the Dicotyledons may be grouped in different categories in which, as the initial becomes less elongated, the specialised development of wide vessel segments and elongated fibres becomes more pronounced. The shorter cambium initial shows an obvious correlation with the broader leaf primordium and diminished longitudinal extension of the original meristem cells. In very short cambial cells division walls, which are originally nearly transverse, will not be pulled out into an oblique or nearly vertical position by the subsequent elongation of the cambium initial but will remain nearly transverse. As a result, when the cambial initials are short, it is impossible for their number to increase at any one level in the cambium cylinder in the manner described for the softwood cambium. Instead, the cambium cells increase in mass in a tangential direction and are then divided by a radial longitudinal wall. When this process has been in progress for some time the cambium naturally has a ' stratified ' appearance, when viewed in longitudinal tangential section, as the ends of the cells derived from one another will all be at the same level. Bailey has pointed out that such stratified cambia are characteristic of hardwoods with relatively short cambial initials, and that they are associated with a marked contrast between the length of the vessel segments and the fibres in the wood differentiating from the products of cambial activity.

In many hardwoods the cambium initials are not so short, new division walls which are originally nearly transverse do subsequently become oblique, and so the number of initials in the cambial cylinder multiplies without radial longitudinal division and the cambium does not become stratified. None the less, even these initials are shorter on the average than those found in the softwoods, and, in the products formed from the cambium on the inner and outer surfaces, as the result of the usual tangential divisions, the differentiating elements begin with walls at top and bottom which are relatively transverse. There are a few rare exceptions. For example, in *Drimys* and *Trochodendron*, genera of the Southern Hemisphere, the fusiform initials average more than four millimetres in length, no walls appear to be specially transverse and no vessels are subsequently differentiated.

In almost all other hardwood genera the original fusiform initials are comparatively short, the elements differentiating from them have walls that, even if oblique, are relatively transverse, and when these elements begin to vacuolate, the collapse of this wall leads to the formation of a vessel. For when vacuolation commences, as the cell expands transversely, expansion of a cell just below follows immediately and the transverse walls between them, thus violently stretched, suddenly perforate, so that the contents of the two cells coalesce. This happens with great rapidity throughout a long chain of cells, and the common tracheal element thus formed, which may be very long indeed, ultimately thickens and lignifies its wall, loses most of its protoplasmic contents and becomes a vessel.

It is very frequently assumed that these perforating cross walls are gradually digested, but this assumption becomes untenable when the differentiating tissues are examined by the new method. Very long strips can readily be peeled off the surface of the old wood in spring in which these differentiating vessels can be traced for long distances. It then becomes clear that the vacuolation which expands a series of vessel segments takes place with extraordinary rapidity in cells whose walls are in a very thin ' primary ' stage. Even in these preparations, in which the course of the differentiating vessel can be followed, stages in perforation are very difficult to find. There can be no doubt that the process occurs absolutely suddenly, in a long series of cells that lie more or less vertically beneath one another, and that it is associated with a very rapid expansion in the size of the future vessel segments. The walls of these elements subsequently thicken and lignify. Unfortunately the polarising microscope can only tell us about the structure of the thickened wall, and no cross walls are thickened before perforation. In *Fraxinus* it has been possible to examine cross walls with comparatively small perforations and with a thickened rim. The arrangement of the cellulose micelles in this thickened region certainly suggests that if they were arranged similarly in the original primary wall they would offer minimum resistance to perforation.

It is interesting to examine more closely the magnitudes involved in the expansion of a hardwood vessel segment as compared with a softwood tracheid. The softwood fusiform initials are so much longer that their volume exceeds that of a hardwood initial, but this volume relation may be reversed during differentiation. Details of the calculations are omitted, but it is estimated that in Scots pine an average cambium cell of length 3·2 mm. has a volume of about 0·00014 cubic mm. In wych elm the cambium cells are about 0·2 mm. long with a volume of about 0·000013 cubic mm. The expansion of the tracheid in the pine is almost entirely radial and a spring tracheid may expand to about 7·5 times its original radial diameter, so that its new volume is of the order of 0·00105 cubic mm. The vessel segment of the wych elm expands to a roughly circular structure. Quite an average diameter for such a segment would be 0·1 mm., which gives a vessel segment of length 0·2 mm. a volume of 0·0016 cubic mm. Such an average vessel segment may have a volume of the same order of magnitude as a softwood tracheid, but compared with the cell from which it was derived, it has attained its new dimensions by an enormously greater transverse expansion, in this case some 120 times as compared with 7·5 times.

It seems natural to link this greater expansion with the early collapse of the transverse wall. The collapse of this wall is associated with the fact that a number of cells vertically beneath one another vacuolate almost simultaneously. Possibly the stretching of the wall accelerates the vacuolation of the element immediately beneath in each case, so that the impetus to vacuolate spreads more rapidly downwards beneath a differentiating vessel. This would help to explain the other characteristic that distinguishes differentiation in a hardwood from the process in a softwood. In the hardwood the cells formed from the cambium at the same time, and therefore lying in the same tangential plane, do not vacuolate simultaneously. Some vacuolate before others, and these are always the cells which lie beneath differentiating vessel segments above. But the result is that their expansion can take place at the expense of the plastic elements around them, which are compressed into more elongated elements, and may later differentiate into fibres, or in some cases they vacuolate as they are compressed, as in the oak, where the vessel is surrounded by curiously contorted tracheids.

In this argument we see the vessel as a natural consequence of the vacuolation of tissue elements which have transverse walls, and the fibre as the natural corollary of the rapid basipetal spread of this tendency to expand in the files of elements which will form the vessels. The fibres are often compressed to a length several times that of the original cambium initials. It is concluded, from the evidence as to correspondence of pits, that these future fibre elements deform under compression in a symplastic manner, their walls changing position as a common framework. As the cambial activity begins in the leaf trace and proceeds thence basipetally downwards, vessel segments are also added in succession basipetally and the compression of the tissue between the vacuolated vessels and rays also takes place in the same basipetal sequence. Thus a wedge of expanding differentiating tissue spreads downwards, on the surface of the old wood, inside the growing and dividing cambium, which is carried outwards upon this living and expanding framework without undergoing much direct radial pressure and without an appreciable increase, as a rule, in the length of the individual cambial initials.

In this manner the surface of the wood is clothed throughout its length with a new layer of wood, which originates and spreads from the base of the extending foliage shoots, and which consists of thin walled wood elements in which vessels are relatively numerous. But when the leaves are fully expanded and are busily engaged in photosynthesis, a good proportion of the new tissue formed from the cambium is phloem, whilst the new wood elements have much thicker walls and the vessels are not so prominent. This rhythm of structural differentiation builds up the annual ring which, in temperate climes, where foliar expansion all takes place at a definite season, forms such a characteristic feature of the annual increment of wood. This growth and differentiation of new secondary tissues, in such close connection with leaf expansion and physiological activity, cannot fail to have a great influence upon the growth and functional activity of the new leaf system. Curiously enough, although the attention of many observers has been attracted by the problems presented by the maintenance of the water supply to the leaves at the top of a tall tree, and by the removal of the products of photosynthesis from the leaves for the nourishment of the rest of the tree, including the root system, these problems are usually considered as if detached from the phenomena of growth in the tree. We have noticed already that if the buds on the lower branches fail to grow, cambial activity also fails in these branches, which thereupon dry, losing their water, if not their food supplies, to the regions in the tree which are still growing. It is clear that any interpretation of water and food movement in the tree must be inadequate which neglects to consider these problems in relation to growth and differentiation, and these problems will now be briefly reconsidered from this standpoint.

III. Function. The Movement of Water and Solutes in the Tree.

Water Movement at Bud-break.—The opening of the buds in spring must be associated with the movement of water into their tissues. In an English spring this might mean the movement of water from the soil through the activity of the root system, but in Rhodesia for instance, where the spring foliage expands in early August over a dry soil in rainless weather, the essential water movement must be from the branch to the bud. Sachs long ago drew attention to a simple experiment which suggests that such a movement of water will take place with rising temperature. In spring, when a woody branch is either dipped in hot water or placed in a vacuum, the expansion of air in the tracheæ will drive water freely to the cut surfaces of the wood, especially of the youngest sap wood. In the intact tree, therefore, a rise of temperature will drive water to the ends of the tracheal system of the youngest sap wood which are to be found, as a result of their method of differentiation, either at the leaf scars or in the tracheal systems of the buds. At the leaf scars these ends are blocked, so that all this water movement following upon rise of temperature must find its goal in the buds which now resume their growth.

But, as Pringsheim has emphasised, when such a growth centre resumes activity it is capable apparently of drawing water from any other portion of the plant, and is the last to suffer from lack of water when supplies are deficient. Thus even when the older leaves are wilted the growing point may continue active and leaf primordia expand in size through the vacuolation and division of their cells. The mechanism drawing water to such a growing point requires further elucidation, but a contributory cause is almost certainly the osmotic system provided by the differentiating vascular elements. In the bud in spring, between dormant cambial cell and fully differentiated xylem element, are always left elements which are not fully differentiated, whilst throughout the woody axis the dormant cambium usually lies directly against fully differentiated and lignified wood. As the water enters the buds in spring the first visible change is the swelling of these partly differentiated elements between cambium and wood, and water is obviously attracted by the osmotic forces within them. The shoot meristem as a whole now recommences growth, and cambial activity spreads downwards to the base of the bud and into the dormant cambium lying upon the surface of last year's wood. But as the cambium thus awakens into life, this layer and the newly formed tissues arising from it must be withdrawing water from the woody tissues within. This will be true of both hardwood and softwood, but it is particularly clear in the case of vessel differentiation in the hardwood.

In the leafy shoot of the hardwood are found differentiated, lignified vessels, with cross walls all perforated and no protoplasmic contents, so that if they contain sap under pressure it will flow out through the permeable lignified wall into the surrounding tissues. Traced downwards this vessel system is in direct continuity, in the tissues growing upon the surface of the old wood, with a vessel system which still contains protoplasm and in which water is accumulating under osmotic pressure sufficient to force outwards the still plastic walls. This liquid, thus accumulating under pressure, becomes continuous suddenly (with the collapse of the cross walls and the coalescence of the liquid contents of the originally separate cells) with the liquid in the vessel in the leafy shoot, from which it is separated at most by a very occasional unperforated but permeable wall. Naturally, then, the water withdrawn from the old wood at the lower end of the system, by the differentiating elements which are there being added to the vessel system, is driven forward under pressure into the distal end of the tracheal system, where it is slowly released into the still growing tissues of the leafy shoot.

The facts of anatomy and development are the clearest evidence that each differentiating vessel, common to both leafy shoot and woody axis, must thus transfer water from the woody axis to the growing shoot. The growth of the bud, especially the vigorous cell expansion in the growing tissues, is clear evidence that water is thus moving from the woody axis to the young shoot. The following considerations support the view that this water movement takes place under the impulse of a mechanism that is actuated by the growth and differentiation which begins in the bud itself and spreads from thence to the axis.

Occasionally so much sap is driven into the vascular system of the young developing leaves that they 'weep' from the tips of the veins; the sap flows out of the veins, injecting the intercellular spaces in which it accumulates until it flows out through the stomata on the teeth near the termination of the veins. Such 'weeping' is often spoken of as caused by root pressure, as it certainly is in the case of seedlings, but in the tree the connection with root pressure is very indirect. So long as root activity throughout the winter has accumulated sufficient water in the old wood, weeping may occur from the buds. It can be demonstrated in buds on twigs removed from the tree provided they are kept in warm saturated air. Th. Hartig has pointed out, in *Carpinus Betulus* particularly, a tree which shows both 'bleeding' from the cut stump and 'weeping' from buds in the intact tree, that the two processes do not synchronise. In a particular season, 'bleeding' from a cut stump began on February 22, but no buds were observed to 'weep' until March 17. 'Bleeding' occurred from 9 A.M. till midday each day, but 'weeping' began in the afternoon, was strongest at night and ceased about one hour after sunrise. The sap flow from the veins of the leaves in the buds, therefore, does not synchronise with the time of highest sap pressure, derived from root activity.

Many points about bud development in the tree become much clearer when it is recognised that the movement of sap in these developing tissues depends so directly upon processes originating in the bud itself. All buds on the tree do not start into activity at the same moment; well-developed buds in full sunlight open first, and as they draw off the supplies of water from the wood immediately adjacent we can understand why it is (1) that the buds immediately below the vigorously growing terminal bud of a poplar shoot remain dormant (p. 192), and (2) that the lower shaded branches on which the buds do not commence growth so soon, may never start into growth at all, unless the upper, vigorously growing buds are cut off by man or by a frost; and that such branches, if the buds do not commence growth, lose water to the differentiating tissues in the main axis.

It is not easy to obtain further experimental proof of the presence of the osmotic systems connected with each developing bud, because they are so closely connected with processes of growth and differentiation and cease to operate if the experimental procedure prevents further growth. When the young bud is cut across, liquid can be seen to well out from the veins, but it is impossible to collect drops of this liquid which are not mixtures of sap from both wood and phloem. The sap in this differentiating wood is certainly much more concentrated than any recorded concentrations for the tracheal sap, but it must be remembered that all analyses have been made upon extracts which are drawn mainly from fully differentiated tracheæ. Observers who have tried to distinguish between the sap from the outer and inner tracheæ have always found that the sap from the outer and younger contains more solutes. In all cases where sap is collected from differentiating tracheæ but little can be obtained, because when these elements are cut open and the sap released the processes of growth and differentiation come to an abrupt end; the osmotic system thereupon soon ceases to function and no more sap collects. It is possible to collect small supplies of sap from the new tissues differentiating over the surface of the old wood in spring, and such samples in both hardwoods and softwoods have shown themselves more concentrated than a 0·25 M cane sugar solution when tested by Bargers's method. In a drop from the differentiating tissues of the plane, the reducing substances after inversion, determined by the method of Hagedoorn and Jensen, were equivalent to about 2·6 per cent. sucrose.

Water Movement into the Expanding Foliage.—As the tracheal elements absorb water, as they differentiate in and beneath the bud, naturally their liquid contents are under pressure and are leaking outwards into the leaf tissues; but as the foliage expands, evaporation from the larger surface rapidly removes any excess of water, and 'weeping' cannot be detected long after sunrise even in young leaves. But evaporation will still continue during the day, so that the living cells of the leaf tend to withdraw water from the tracheæ faster than it enters, with the result that the liquid contents of the tracheæ are soon under tension. It is surprising how soon this condition of tension can be detected in the tracheal system of the expanding bud. If the bud is cut across under indian ink, which contains a fine suspension of carbon particles, and the cut surfaces washed under running water, many of the tracheæ will be seen to be injected with the ink. The injected tracheæ will be found to be protoxylem elements of medium age. Older collapsed elements are not injected, and younger elements, still differentiating and containing liquid contents under pressure, are also not injected. In a young bud, a freshly cut surface, whilst showing ink in some injected vessels, will also show liquid welling from the bundles for a time because of the excess liquid still accumulating in the elements which were differentiating when the bud was cut across.

The same phenomenon can be demonstrated in the case of the tracheæ differentiating from the base of the bud over the surface of the old wood, the hardwood being naturally a more suitable subject for such experiments.

Phloem and bark can be easily removed, these tissues coming away at the plastic cambium layer without any damage to the differentiating vessels within. These vessels, and the older wood within, can now be pierced with a sharp knife through a drop of indian ink placed on the surface of the cambium. The newly differentiating vessels are full of liquid at first and do not inject at all when so cut; very often instead sap flows freely from them, though they never give off a fine spray when punctured, as the differentiating tracheæ of the softwoods sometimes do. While they are thus found full of liquid, the vessels of the old wood immediately beneath them will be found to inject freely, which may be due to the withdrawal of water from these vessels by the differentiating elements forming outside them. This suggestion is supported by observations on the ash, in which the vessels are extraordinarily long, so that when they are cut open they cease to function throughout a great length of the tree. Beneath the surface of such punctured differentiating vessels the old wood has often subsequently failed to inject, whilst beneath undamaged differentiating vessels on either side it injected very freely.

A little later in the year (by June 1 this year in Leeds), the differentiated lignified vessels in the newly forming ring of wood inject freely, and from then onwards, as von Höhnel first pointed out, this evidence of a state of tension in the contents spreads gradually inwards, the vessels of progressively older and inner rings of sap wood injecting as the summer progresses.

The Contents of the Wood.—Nowadays it is usually assumed that the tracheal elements remain full of water although their contents are under tension. In this case, each day that water loss from the tree by evaporation exceeds water entry by absorption, the tension must mount in the tracheal system and should reach extraordinarily high values. This possibility must now be more closely examined. In the first place it is clear that the structure of the tracheal system is such that air will not readily enter to displace the water, although air at approximately atmospheric pressure is present in the intercellular spaces that form a continuous system along the flanks of the rays, and which are in immediate contact with the tracheæ and in communication, through the cambium, with the intercellular system outside and with the outside air.

Air.—The only pores in the water-saturated wall of any element of the wood, including the hardwood vessel, through which gas might enter are the minute holes in the thin primary walls that run across the pits, which were originally filled by the plasmodesma strands. In the softwood Bailey has recently demonstrated the passage of gas and fine suspensions through these pores, and concludes that in *Larix laricina* they vary in diameter from 3μ to $0 \cdot 5\mu$. The smaller pores here would need pressures of $5 \cdot 8$ atmospheres on either side of the wall in order to drive air through to displace water. Bailey actually drove air into the tracheids of *Larix* by using pressures below 3 atmospheres. In the hardwood the pores in the pits are certainly smaller: A. Meyer estimated their diameter at $0 \cdot 15\mu$, whilst Renner estimates them at less than $0 \cdot 5\mu$. In actual experiment we have failed to displace the liquid contents of closed hardwood vessels by air, using pressures of 15 atmospheres.

The displacement of water by air entering through these pores would not in any case be easy, and when it is remembered how they arise it will be seen to be practically impossible. The pores were filled originally by protoplasmic connections. These are found only connecting adjacent protoplasts, and only persist as pores in thin-walled pit areas where the original wood elements have not been displaced relatively during development.

The pores, then, do *not open on to intercellular spaces* and are not in communication with the air of the intercellular system unless considerable splitting apart of the primary walls of adjacent tracheal elements has occurred ; such splitting only occurs, if at all, in dry heart wood in which the water movements are relatively unimportant. We may conclude then that the liquid contents of the tracheal elements may be under tension without the slightest likelihood of air being drawn in from the intercellular system of the wood to displace the liquid.

Water.—But the tension upon the water contents of the tracheal elements must increase very rapidly if the water cannot be displaced by gas. When the water in a trachea is in tension, at points where the wall faces upon an air space the water will be withdrawn into the wall until the menisci are very concave and only a thin film of water, no longer free to move, covers the internal (inter-micellar) surfaces. This is not only true of the wall where it faces upon an air space, but the water in all the wall must be in equilibrium with this and will be withdrawn into the trachea until only a thin film is left. In the cohesion theory of the ascent of sap the high tension which must develop in the contents, if the tracheæ remain full of sap, is held accountable for the upward movement of water in the tree. But this tension must isolate the liquid contents of the trachea, because the walls between this trachea and its neighbours will only have a water content in equilibrium with the walls bordering air spaces, and the movement of water across such walls, under the difference of tension developed between the tracheal contents, will be very slow indeed. Indeed, as Schwendener and Nägeli pointed out many years ago, when tensions develop the liquid contents of the tracheæ are immobilised, with the result that the rate of evaporation from the mesophyll is cut down.

Water Vapour.—Nevertheless, though the rate of evaporation falls on a sunny day with the water in the tracheæ immobilised, if they all remain full of water the tensions developing in the tracheæ near the leaves would be very high indeed.

Experimental evidence however, such as was supplied originally by von Höhnel and Scheit, suggests that water vapour replaces water in many tracheal elements. As soon as a bubble of water vapour forms in any trachea, its water will be immediately free to move and dispersed into the surrounding tracheæ in which tension will be released, and thus water remains available for the tracheæ supplying the evaporating leaf without a great rise in the tension of their contents.

The presence of tracheal elements containing water vapour may be beautifully demonstrated in the trunk of *Fraxinus excelsior*, in spring, when the newly formed vessels lie just below the cambium. These vessels are very long; they have been traced, without a cross wall, for more than 25 ft., and they often have a diameter approximating to 0·1 mm., so that they are readily seen with the naked eye. If the cambium is exposed and the vessels are then cut open under indian ink or coloured oil, the liquid can be seen to enter, moving both upwards and downwards in the tracheæ with an astonishing speed, often more than 1 ft. in three seconds. In this way vessels will rapidly fill often to a length of more than 10 ft. from the point of injection. As the liquid enters, there is no marked change in diameter of the vessel such as would suggest a great release of tension, and, if the vessel had been originally full of water, it is very difficult to explain where this water has been accommodated when it is so rapidly displaced, particularly as vessel after vessel can be injected, the liquid entering at practically the same speed. But that the vessel originally contains water under tension seems to be completely negatived by a simple modification of this experiment. In most trees the vessels are much shorter, and many closed vessels in isolated branches, stripped of all leafy shoots, can be injected when they are cut open under suitable liquids. These injection experiments, carried out extensively in a different form by von Höhnel, seem to admit of no other interpretation than that, in many of the tracheal elements, as the leaf surface expands, water vapour displaces water.

Sap Wood and Heart Wood.—Water vapour displaces water in the wood beneath the opening buds both in the old wood and in the new ring of wood in direct communication with the leaves; and during the summer water vapour continues to displace water in the tracheæ of the older wood throughout the axis, but is found first in the outer rings and then appears progressively further inwards. In the autumn water absorption exceeds evaporation even during the day, and the tracheæ will begin once more to fill with water, save that if any air has accumulated from the water as the result of release from solution with rising temperatures, this air cannot be driven out but is only slowly redissolved. In the older rings of wood, where the tracheal content has fluctuated between water and vapour over many seasons, air has gradually accumulated, in some trees to a very considerable extent. This older wood is then often structurally modified, so that it is distinguished as heart wood from the relatively air-free sap wood, and the accumulation of air in the tracheæ may prove to be causally connected with these structural changes. Such heart wood gives buoyancy to logs floating down streams to the lumber mill, because the air within the tracheæ is not readily displaced, but it probably plays little part in the movement of water in the living tree, which takes place mainly through the sap wood.

The Ascent of Sap.—Through the complex tracheal system of the sap wood the water supply is maintained to the foliage of even the tallest trees, and the facts reviewed in the previous section are relevant in this connection, though they do not in themselves supply a complete explanation of the mechanism by which this movement is brought about.

The first movement of water into the bud seems to be brought about by osmotic systems consisting of differentiating tracheæ developing in the bud itself and then extending downwards from the bud over the surface of the old wood. Then these new tracheal systems, as they lose water to the expanded foliage faster than it can be supplied, are able gradually to draw upon the water in the old wood through its displacement by water vapour, thus mitigating the tensions developing in the water columns in tracheæ which remain full of water. Up till the end of the growing season, the water content of the wood shows that many tracheal elements in the sap wood remain full of water, and during the autumn and winter the tensions in these columns, as well probably as in the living parenchymatous elements interspersed throughout the wood, may play a part in filling the remaining tracheal elements once more with water instead of water vapour.

The problem is a difficult one—a tracheal system would obviously fill again with water to any height to which water could be driven by the pressures available in the root supply system, but at heights beyond this it is not at present clear how the tracheal elements are once more refilled.

The present discussion of the problem, however, should serve to emphasise a consideration that is too little regarded at the present day. Water movement through the tree is associated with the growth of the tree ; the mechanism of movement is inseparable from the processes of growth and differentiation, and the movement is *not* equivalent to the passive flow of a liquid along a pipe driven either by a pressure below or a tension developing above.

Within the tracheal sheet laid down in the current season, which alone has direct continuity with the leaves, is an inner core of sap wood which acts as a reservoir of water of which the contents fluctuate daily and with the seasons, under the influence of a supply and demand determined by the activities of the growing tissues of root and shoot.

The Movement of Organic Solutes.—Finally we would suggest that the movement of solutes throughout the tree similarly cannot be adequately interpreted unless the growth processes of the tree are borne in mind. The movement of inorganic solutes will not be considered ; the available data are too few, but one consideration is emphasised in relation to the organic substances which are manufactured by the leaves during their season of activity. Undoubtedly these substances are mainly transferred downwards from the leafy shoot to branches, trunk and roots, where they are stored. Both the path of transfer and the mechanism of movement are controversial subjects which cannot be fully examined here. There is very general agreement that the phloem plays a rôle in this movement, and much discussion centres around the problem as to how so much material can move through a tissue containing elements of such peculiar and characteristic structure as the sieve tubes. The data supplied by Ramann and Bauer show that the gain in dry weight of stem and root system takes place relatively late in the growing season. The point it is desired to emphasise is that this gain in dry weight appears to synchronise with a vigorous basipetal growth and differentiation of the phloem, which, like the earlier differentiation of spring wood, begins in the leafy shoot and spreads from thence downwards over the axis. The successive enlargement and division of cells that lie below one another in the cambial cylinder, which must take place during this new formation of phloem, represents in itself a very considerable downward movement of food.

The following very approximate calculation may be presented in this connection. In *Fraxinus excelsior* the structure of the phloem makes it practicable to remove it over small areas in fairly smooth tangential sheets. The fresh weight of a square centimetre of such a sheet, separated from the tree in April and containing the phloem formed in the two previous growing seasons, proved to be about 0·046 gram; the dry weight 0·018 gram. This phloem was taken from a small tree perhaps twenty to thirty years old, from the short main trunk which possessed about 14,000 sq. cm. of surface. The dry weight added to this trunk by the formation of phloem during one season's growth would then be of the order of $\frac{14,000 \times 0{\cdot}018}{2} = 126$ grams. Ramann and Bauer found that the increment of dry weight in the stem in one growing season, in 100 two-year-old ash trees, was about 2,437 grams, so that a single tree gained about 24 grams. In the older tree the increment of weight would be much greater, but when it is remembered that to the gain of weight due to the formation of phloem in the trunk has to be added that due to the new phloem on all the branches together with the formation of the thick-walled summer wood throughout the stem, then it would appear that a large proportion of the downward movement of organic solutes is effected during the actual growth and differentiation of these tissues, in which case the mechanism of movement would be closely linked with the basipetal mode of growth of the cambium.

So long as the cambium is still growing and differentiation proceeding, the downward movement of organic material in the tree must be closely connected with these growth processes, and no mechanism of transfer which is independent of them can accurately represent the processes at work. It may be that subsequently, in fully differentiated sieve tube, companion cell, etc., translocation of food still takes place, but on the other hand, the structural features of the adult sieve tube may rather be analogous to those features in a dry river bed which supply evidence that it was once a channel along which a rapid current flowed.

This brief review of some of the many problems presented by the form, structure and function of the growing tree has been presented, so far as possible, upon very general lines in an attempt to show that the issues thus raised, if primarily botanical, yet make a very wide appeal to our interests. A more detailed discussion of most of these problems will be found in a series of papers [1] in which citations of literature are given. It is hoped that this general statement has shown that the study of the

[1] 'Studies in the Physiology of Cambial Activity,' *New Phytologist*, **29**, 1930.

growing tree, whilst full of intriguing problems for the student of science, will not be without interest and profit to the forester and to all interested in growing trees. Furthermore, when we contemplate the texture of the wooden materials fashioned to our service, which surround us on every hand, it may add to our pleasure in them if we can link their structure and their properties with the story of the way in which they came into being during the life of the tree.

SECTION L.—EDUCATIONAL SCIENCE.

THE ADVANCEMENT OF SCIENCE IN SCHOOLS—ITS MAGNITUDE, DIRECTION AND SENSE

ADDRESS BY

W. MAYHOWE HELLER,

PRESIDENT OF THE SECTION.

The Function of Section L.—Some doubt exists as to the proper function of this Section of the Association. The group of men who, thirty-one years ago, threw themselves earnestly into the work of the Section were in the main interested in the teaching of science in schools of all grades. For some years our activities centred round the place in education of school science and its aims and methods.

Strong committees of investigation were appointed, and in a few years valuable reports were published which have influenced profoundly the teaching of science in many English-speaking countries. Joint meetings to discuss with specialists of other sections the school-handling of their subjects were frequent. It is clear that in these early years the 'Old Guard'—many of whom are still working with us—viewed the work of the Section as subject to these limitations and did not contemplate that still far-off objective—a Science of Education. In this latter direction we have made some progress: small-scale experiments under favourable conditions have discovered some truths. The valuable results of such experiments receive a narrow publicity, are seldom adequately or permanently recorded, and in a few years are forgotten and no longer available for the serious student of education. Too often these researches are interrupted by changes in the school staff or terminated by the growing pressure of external examination. As in other branches of science, we need a learned Education Society in whose transactions will be recorded permanently the results of original work and experiment in education. The annual reports of this Section for the past thirty years contain a wonderful record of investigation and thoughtful opinion which in its present form is inaccessible to any but the most determined inquirer. The time is ripe for the establishment of a clearing-house of educational effort such as was suggested at last year's meeting by Prof. Clarke in his advocacy of an Imperial Institute of Education.

Need for Experiment.—Before we can cultivate a Science of Education we need more experiment deliberately conceived, skilfully conducted, accurately interpreted, and intelligently utilised; for such experiments a soil cleaned of the weeds which to-day choke the growth of education is necessary.

In recent years the Section has spread its net more widely over the too-placid seas of educational discussion, and although we have landed some queer fish, we have on the whole made valuable hauls.

I do not propose in this address, as have many of my distinguished predecessors in office, to venture far into the field of general educational philosophy, but think it better to place on record the impressions and convictions that remain from a long contact with teaching, inspection and administrative problems. Nothing more is possible; the worker in education can seldom conduct true experiments—he can only attempt remedies for existing evils, and this he must do often under conditions that he cannot control.

Has School Science advanced?—I make no apologies for plagiarising the title of the Association for my address, but it seemed to demand a sub-title, and, believing that science and its method is the most needed force in education to-day, I have adopted for my purpose the characteristics of a force—magnitude, direction and sense. In case my use of the word 'sense' may be regarded as frivolous, I may say I give to it no uncommon meaning.

From the earliest times scientific thinkers, almost without exception, have tilted with little effect against the academic and traditional training given in the schools of their time. The astounding developments of the last hundred years have moved the mass centre of human knowledge towards natural science and away from literary teaching. Has the centre of effort of our schools changed correspondingly, and is the magnitude, direction and common sense of the effort satisfactory under the new conditions?

We have, I think, recognised honestly this new distribution of the weight of knowledge, and during the past half-century have provided gradually a machinery through which these new educative forces may act. We must test, from time to time, the efficiency of our machine, and if we find it low, must reconsider its design and trace the causes of transmission losses.

Our Faith in Science Teaching.—We have urged the advancement of science in schools in the belief that training in its methods should produce habits of cautious and judicial approach to the problems that confront us, and would give us courage and self-reliance in attacking them. We believe that natural knowledge must inspire a reverence for the Creator only to be obtained by direct contacts, and that our ability to use this knowledge wisely adds greatly to our general efficiency and power for good.

The outstanding value of a scientific training should be the development of a power of diagnosis, a quality essential to the majority of occupations. Consider for a moment how constantly a critical diagnostic faculty must be employed by the successful farmer, doctor, schoolmaster, housewife, architect, motor-mechanic or plumber; yet how frequently failure and inefficiency in these trades and professions is due to an inability to apply scientific method to thought.

Evidence of Progress.—What evidence have we that forty years of science teaching have produced the results for which we have hoped and striven ? Notwithstanding the fact that seven million of our population will invest hard-earned half-sovereigns in a sweepstake upon a horse race in which 'the unexpected always happens,' I believe there are many signs of improvement in general intelligence and vocational keenness. Boys, and especially girls, are entering employments and facing with success responsibilities unthinkable at their ages in Victorian days. The soundest critics of the schoolmaster and his work are the pupils he has taught. Although a few boys, and more girls, say they hated science at school, the great majority in after life regard the subject with profound respect and regret the lack of fuller opportunity for its study.

Admittedly the magnitude of science teaching in the schools is considerable ; how much is emerging in useful form ? Are we satisfied with the understanding of the commonest occurrences displayed by the man in the street and the woman in her home ? Is not their childlike simplicity about such matters rather disturbing ? To what percentage do such ideas as the burning of a fire, the nutrition of the body or the growth of a plant mean anything ?

Among the general practitioners in the scientific occupations mentioned above do we not often detect lacunæ of fundamental knowledge that would disgrace the average schoolboy ? We have yet to give the lie to Mr. Baldwin's recent epigram that 'the only permanent thing in life is human stupidity.'

The schoolmaster of grammarian bent still looks askance at our efforts ; he cannot visualise our wider and more distant objective. With the ends he has in view we agree, but we cannot regard them as all-sufficient, nor consider his methods the most direct for the achievement of his own purposes. But the old antagonism between traditional and modern studies is breaking down. In his presidential address to the Science Masters' Association this year, Dr. Cyril Norwood, Headmaster of Harrow, stated the case for science in the schools with cogency and sincerity ; his skilful diagnosis of the demands that life makes upon the product of our schools shows that a classical education is no barrier to scientific and courageous thinking.

The provision for science instruction in secondary and other schools for pupils over fourteen years of age appears to be fairly general and satisfactory.

Science in the Elementary School.—In the elementary schools little substantial progress has been made ; here more than elsewhere the child is dependent upon the school for his educational equipment for life ; if he does not get some introduction to natural knowledge at school, he will find few opportunities later. Sound science teaching must not remain the prerogative of the child over fourteen years of age. In recent years I have had the opportunity, as an examiner, of assessing the value of the science instruction given in the elementary schools of most of the larger centres of population in the United Kingdom. Although I was dealing probably with selected cases the results were wholly depressing, and consultation with the teachers into whose hands successful candidates passed confirmed the poor impression I had formed of the quality and nature of the teaching.

Twenty-four years ago, we said in a report of this Section that 'the child's time should be about equally divided between practical manipulative work and the ordinary lessons in reading, writing and reckoning.' In such practical work is included science, handwork and drawing.

We have not taken science seriously in elementary education ; we must regard it as of the same fundamental importance as the three R's : the first subject of instruction should be the study of our immediate environment. It is a serious reflection upon our system that our school output is incapable of thinking about its commonest experiences.

Once we believe that natural knowledge should hold a foremost place in the curriculum for both boys and girls the difficulties of reform are not great. The teachers are competent, or can be made so, and the cost of the simple equipment necessary is less than for other practical subjects.

I could not speak so confidently if I had not conducted large-scale experiments in both England and Ireland. That both these experiments were subject to serious interruptions does not in the least affect their value. What has been done, can be done, and I am sure will be done again. I take this opportunity of expressing my appreciation of the fine work done by thousands of teachers who have proved beyond cavil that purposeful science teaching is both possible and effective in elementary schools, large and small.

'*Nature Study.*'—The case for handwork has been won with incalculable advantage to the people ; the cause of science, with its even greater possibilities for the creation of alert minds and power of initiative, has yet to be fought. Some confusion exists as to the use of the terms 'Nature Study' and 'Science.' It is important that they should be properly defined for school purposes, and the distinction between them, if it exists, should be made quite clear. 'Nature Study' is an excellent term in that it expresses both the subject and the method, and, used as in America, would cover all elementary science up to the standard of the school certificate. In this country it is generally used to cover junior biological studies, but too often connotes aimless and incompetent teaching devoid of all experimental illustration. Natural knowledge, whether it relates to dead or living matter, is science, and I plead for courage to use the word wherever instruction is purposeful and methodical.

Methods of Instruction.

Aims of Science Teaching.—In educational discussion we hear vastly more about methods of instruction than we do about its purpose. We find a subject, 'Methods of Teaching,' presided over by a professor of Methodology ; there is no professor of aims and purpose. A method is merely a means of reaching an end already definitely enunciated ; any method that achieves its purpose successfully is a good one. Take care of your purpose and the methods will take care of themselves. We need, therefore, far less dogmatism about methods and far more emphatic definition of our objectives.

The aims of science teaching are admittedly the aims of all sound education; it must provide the pupil with that knowledge and those mental and personal characteristics that the demands of employment and leisure will make upon him. In this broad sense education must be directly or indirectly vocational, but does not imply any neglect of mental and æsthetic development. I refrain from the use of the term 'cultural,' as I have yet to discover the meaning of this password to respectability. On the one hand, one finds subjects labelled cultural which, pursued to the extent that the average boy follows them, produce little or no effect upon his adult life and thought; on the other hand, subject-matter which leads to an understanding of and a reverence for the wonders of the creation is often classed as non-cultural.

Every teacher of practical subjects knows of boys, failures in the class-room, who have first gained scholastic self-respect in the laboratory or workshop—a vital turning-point in their school career. To assert that practical studies do not constitute a powerful factor in the formation of character implies an ignorance both of school and of life.

The old grammar-school tradition, much of which we still inherit, provided an education which, for the few who profited by it, was more vocational than cultural; the majority left school half-way through the course with an equipment little better than the three R's.

We have scattered the same scholastic seed upon soil of all kinds in the blind hope that it will germinate and mature. We have paid little attention to the soil or to the variety of crops that are necessary.

Need for Vocational Outlook.—We must not constrain every boy into a course of study culminating at eighteen or nineteen years, and allow 90 per cent. to drop out at various points along the route without heed to their requirements at the point of departure. We must cater for the boy and the girl leaving school at fourteen, at fifteen, and at sixteen, and must endeavour to place them in a position to face with success the employment and the problems that will confront them. The last year or so of school life must have a frankly vocational trend.

We must envisage the demands of the office and the shop, the factory and the workshop, the building trades and transport services on land and sea, the farmer and the fisherman, domestic service and home duties; even the messenger boy and other blind-alley employments should not be forgotten.

At this final stage of the child's schooling, whatever the age may be, the teacher's work is as much concerned with character-building as with instruction; he must lead his pupils from the sheltered irresponsibility of school life to the habits of self-reliant and conscientious work that the world will demand of him.

No common school examination could direct usefully the varied types of training necessary, and inevitably it would divert attention from the more essential aspects of the teacher's work.

Natural Knowledge.—Natural knowledge renders possible aims and therefore methods applicable in only a limited degree to other subjects of the school curriculum. Our younger pupil comes to us with a considerable knowledge of his native language, but with a great store of natural knowledge gained through his own observations and experience in the best school of all. These two subjects stand apart, and in early years should provide the natural foundation upon which the fabric of his education is based. In this mass of unorganised knowledge there is abundant material about which he can be led to think and in which he is already interested.

Too often this foundation of the known is completely ignored; his lessons deal exclusively with ideas foreign to his experience; consequently he is bored exceedingly and makes invidious comparisons between the schoolroom and the world-school outside.

The young pupil is immediately responsive to any lesson upon a subject within the range of his experience; he is keen to display his own knowledge and to bombard one with questions in order to extend it. The lack-lustre eye of the grammar or arithmetic lesson sparkles into life and interest when in the science or nature lesson he is allowed to air his own views. Nothing is more astonishing than the power of logical thinking young people display, if they are allowed to grow up intellectually and their spontaneity is not curbed. Cannot we introduce into the class-room something of the atmosphere of the intelligent home, where children show knowledge and judgment years in advance of their school performances?

Concentration upon method and routine without reference to the end in view leads to dogmatism and stereotypes teaching. We can detect this blind obedience to traditional method in every subject of the school curriculum. Once a teaching method loses its directing purpose it becomes a dull-edged and inefficient tool.

Didactic Method.—Among science teachers I find three schools of thought:

(*a*) Those who don't think and advocate nothing.
(*b*) Those who advocate didactic method.
(*c*) Those who advocate natural method.

With group (*a*) I am not concerned, except to hope that their numbers are few and that they realise that they have mistaken their vocation. Group (*b*) is large but admittedly honest. The didactic teacher has an end in view, and hence we must accept his procedure as a method. His aim is to produce a pupil with a word knowledge of a subject that can be put on paper by a certain date, and can, by constant practice, carry out certain routine operations. He believes that these results are a true measure of the mental if not the character growth of his pupils. I have known many such for whom I have great respect; they play the school game—as they see it—efficiently, and believe that from hard work alone will result all that education can achieve. Others advocate didactic teaching from other considerations. Headmasters have their difficulties; some, with no great belief in studies other than literary, are forced unwillingly to include science in the curriculum; the time-table is upset by the small size and long duration of practical classes; the periods demanded by the science master are badly needed for more Latin. Why waste so much time breaking test-tubes? Of what use are balances and thermometers for boys who will only need a gentleman's knowledge of the sciences?

Every young teacher, no matter what his training, tends to revert to the methods practised upon himself at school. If a science teacher, he may find himself confronted with the demand for an annual list of successes, no time for preparation, and a starved laboratory; under such circumstances the text-book and didactic instruction becomes a substitute for real teaching.

Natural Method.—I have used the term natural method in contradistinction to didactic instruction. It is the method employed by every teacher worthy of the name in much of his daily practice. As far as the schoolroom will permit, it approaches the method by which we acquire knowledge in the world outside, and is applicable wherever we have a foundation of knowledge or experience upon which to build. It is natural method because its aim is to cultivate and satisfy the natural curiosity in young people about the happenings in the wonderful world in which they find themselves. It implies that children are encouraged to think for themselves, to express themselves, and are given ample opportunity to do so. Their irresponsible activities are gradually and carefully directed to inquiries into definite problems *within their powers of comprehension.* Lessons are conversational and argumentative, but need not exclude didactic statements where such are necessary to add interest and to make progress. The teacher is the leader, not the driver; upon his direction, wide knowledge and inspiration success depends.

By these platitudes I run the risk of wearying you; these principles in theory are almost universally accepted; in practice we find them to a large extent ignored to-day.

Heuristic Method.—You will say that natural method as here defined is but thinly disguised Heuristic Method first suggested by Prof. Meiklejohn in connection with the teaching of English. I have avoided the term because it has in these countries become associated with much intemperate controversy and destructive criticism. Its opponents have set up their own definition in the most absurd terms, and its exponents have sometimes allowed the method to submerge its aim.

Heuristic Method as defined by Prof. Armstrong in the many valuable constructive schemes of work which he has published from time to time has passed beyond the stage of controversy. It is accepted as an essential component of science teaching by thoughtful teachers in every country to which my inquiries have extended. Is there, in fact, any alternative method? Although applicable to many subjects, it is so specially adaptable to natural knowledge that it has become associated almost exclusively with science teaching.

Prof. H. E. Armstrong.—One name beyond others stands out as its advocate wherever science is taught—Prof. Henry E. Armstrong—originator of this Section of the Association. To his advocacy of training in scientific method the advancement of science in schools owes whatever progress has been made. His trenchant criticism has been supplemented by copious constructive suggestion. Therein he stands, almost alone, among the small band of scientific men who, during the past fifty years, have helped us to put purpose and method into our work. Like other great reformers, the full appreciation of his tireless efforts may not be reached even in his long lifetime.

General Science essential.—There is one implication in my definition of natural method as applied to science teaching : our subject must be General Science. We cannot work in the corners of knowledge fenced in by present-day examinations ; we must be free to trample down half a dozen of these fences in one and the same lesson.

In this great open field we can start almost anywhere ; it will depend upon the special interests of the teacher, or even of his pupils, and upon the environment of the school. Personally I find 'Air, burning, breathing,' a good starting-point ; it involves physics, chemistry, physiology and hygiene. In a girls' school a two years' course can be centred round the theme ' How the body keeps warm ' ; it provides a sound and adequate basis of fundamental general science.

Text-books.—Purposeful method in general science should dominate instruction up to sixteen years of age—that is, the teaching should be broad in scope, and fundamental and experimental in character. Subject-matter incapable of inquiry, illustration or verification should be introduced only where its utility is outstanding. During the later part of this period I see no objection to text-books properly used—that is, for reference after instruction and practical work. Science masters are more prone to the disease of book-making than other teachers, and I am not sure whether the mass of text-books available is a blessing or an evil ; their multiplicity and success is a proof that the great majority are misused. Publishers and authors alike are interested in sales to individual pupils. Text-books used otherwise than for reference tend to stereotype instruction and to check investigation and initiative. I am glad to say I know of no one book that provides a natural and rational course of instruction.

The Influence of External Examinations.

Examinations and Method.—It is impossible to discuss methods of teaching without reference to the constraints that preparation for examinations places upon them. In early reports of this Section we deplored the stultifying effects of external examinations upon the purpose and methods of the teachers' work. After twenty-five years this yoke appears to hang as heavily as ever upon the shoulders of our teachers, who accept patiently the burden as part of a pre-ordained scheme of things. In the years that need the greatest concentration upon those aspects of training that no ordinary examination attempts to test, this evil spirit has obtained a strangle-hold upon the efforts of both teacher and pupil.

Influence upon Teaching.—I am unconvinced that external examination produces much voluntary stimulus to effort with the ordinary pupil of sixteen years of age. It is a very powerful stimulus to the teacher and urges him to methods which repress initiative and destroy imagination. His reputation is at stake. No matter that the syllabus is extensive and without appeal to the average pupil, it must be covered ; no matter that his class is over-large and badly graded, he must deliver to the examination-room pupils capable of answering questions which an intensive study of past papers indicates as likely to be set. No wonder, then, he looks upon argumentative teaching as waste of time, and fails to show the bearing of his subject upon the events of every day. He has no time to digress to related subjects outside the four walls of his syllabus. Some teachers can resist the temptations that examinations offer, and, treating the syllabus as a useful servant, can obtain good results without sacrificing the broader aims of education.

The Public Demand for Examinations.—The public, with reason, demands some guarantee that a pupil leaving school has made satisfactory progress in a curriculum approved by an expert. It does not, unfortunately, seek information as to the more important results of school training—character, physical fitness, and practical skill—which written examination is unable to assess.

The shackles of examination are in the main self-imposed ; no efficient school will suffer in reputation because it elects to play the game in an amateur spirit and refuses to enter a league of rival competitors. Many public and secondary schools retain their freedom, or at least keep the dangers of examination in check, but hundreds of others appear to exist solely to promote the well-being of semi-official boards and examiners. The assessment of the progress of pupils is primarily the duty of the expert school staff, who are in daily contact with them. Periodical examinations by the teachers themselves provide valuable information as to the success of their own efforts, and as to the special difficulties of individual pupils. The tendency of these great examining bodies to mould many schools in the same pattern and to relieve the teachers of one of their important functions is a matter for grave consideration.

It is argued that the influence of preparation for examination is confined to the last year of school life. In practice we find this is not so. In some cases the purpose of instruction is distorted for several years prior to the examination, or, on the other hand, we find low-pressure teaching in the earlier years and consequent over-pressure as the examination approaches. Examinations, disastrous in their influence upon scientific and practical studies, are probably less harmful with linguistic and mathematical subjects, but with these must discourage free teaching and experiment.

Internal examination strictly upon what has been taught, supplemented by the other information that any well-conducted school can supply, should meet every demand that parent and employer can make.

The quantitative testing by written examination of selected candidates is no measure of the value of the work of a school as a whole, which can only be ascertained by the guarantee of the teaching staff, supplemented by adequate extern inspection. Constructive and sufficient inspection in close co-operation with the teaching staffs can provide every safeguard that the public may demand. Teachers and inspectors alike must assume wider responsibilities and we must trust them both.

The elementary and central schools have hitherto led a healthy educational life, but the virus of examination is beginning to enter their blood. The disease must be checked, and the schools must be isolated from the contagion which has become endemic in the majority of secondary schools.

The problem of external examination and its attendant evils is not insoluble, but it must be faced with courage and understanding. It is much less exacting to work for examinations than to strive for high ideals by thought and purpose. The teacher who needs an examination to direct his work and keep him at it is in no sense an educator. The majority of science teachers, at any rate, would welcome freedom from the thraldom that is destructive of all that is best in their art and renders much of their effort anything but a labour of love. The present position has been reached along a path of least resistance—always a dangerous route to follow.

Practical Examinations.—The efficiency of instruction in science cannot be tested by written examinations alone ; practical tests, properly conducted, are as reliable and more searching, and, moreover, tend to direct methods of instruction into the right channels. The failure of examining bodies to deal with practical and manual instruction is a potent cause of the non-advancement of science in our schools. The reason is not far to seek ; such examinations are troublesome and expensive and demand much expert man-power. These difficulties are shirked, and possibly are insuperable, but the teaching suffers accordingly.

The testing of practical work involves : (*a*) observation of methods of work ; (*b*) oral questions to test understanding of the problem ; and (*c*) evaluation of the results obtained. Such tests are impossible in the absence of an expert examiner, who should base his tests upon the course covered by the candidates, but should also test resourcefulness and the ability to carry out definite instructions.

In Irish secondary and central schools we have found no great difficulty in ensuring uniformity of marking by different examiners and have every confidence in the assessments made.

Scope of Instruction.

Science in the Junior School.—In a good infant school you will probably find thoughtful and skilful instruction, natural and scientific in its method. It is to be deplored that when the infant emerges into the standards the break in methods of instruction is often sudden and complete ; the passage of this barrier should be made more smooth by the co-operation of teachers working on either side of it.

The Lower Standards.—In the standards of the Junior School instruction in science is known as ' Nature Study '—a title which may cover much excellent work or cloak a multitude of sins. The old object-lesson, described in one of our early reports as ' the laborious elucidation of the obvious,' still persists, but has to a great extent been replaced by lessons on plant specimens examined individually by pupils. A lesson that centres round a single object is apt to be narrow : objects should be used to illustrate a topic or subject of instruction, and these subject lessons should be connected in short series and so lay some foundation for the work of the Senior School. The tendency to specialise on natural history topics to the exclusion of many phenomena more within the experience of young people is to be regretted ; they love to see things happening, and happening quickly. Little experiments on burning and breathing, how water boils, where the sugar goes to in a cup of tea, and a dozen other things about air and water, arouse enthusiasm and set them thinking hard. Some simple equipment of apparatus is necessary for such lessons and for plant experiments.

Animal Studies.—Compilers of syllabuses write glibly—'Animal studies: birds, fishes, insects, etc.' I do not think that animal studies are to any great extent practicable under ordinary school conditions ; the treatment is generally encyclopædic, does not set children thinking, and the facts are soon forgotten.

Need for Explanatory Syllabuses.—Teachers in junior standards need simple explanatory syllabuses of natural studies arranged seasonally and in good sequence that will provide a volume of fundamental and applicable knowledge. We need more constructive help from our biological friends than we have yet received as to details of instruction and which will recognise fully the conditions under which the average teacher works.

Teaching at this stage demands more inspiration than at later periods. Sound knowledge is needed for a full appreciation of the wonder and beauty of familiar things. The teacher must be able to think upon the same plane as his pupils ; he must neither be above their heads nor treat them as babies incapable of thought.

Nowhere can one learn the possibilities of science teaching as under the untrammelled conditions of these early years. Almost my whole faith in the teaching of science has come from my experiences in elementary schools rather than from contact with pupils of more advanced age.

The outlook and work of university professors, inspectors and secondary teachers, in their respective spheres, would greatly benefit if they were compelled to spend a post-graduate period in elementary schools, for here more than elsewhere can the art of teaching be learnt and practised.

In considering the scope of science instruction beyond the primary stage it will be convenient to divide the subsequent school life into three two-year periods: 12 to 14 years, 14 to 16 years, and 16 to 18 years.

Science the Same in all Schools.—There is no reason to suppose that for pupils of the same age, whether in elementary, central or secondary schools, there need be any marked difference in the subject-matter of instruction or in the manner of teaching it. The size of classes and the school equipment may modify the methods but not the purpose of instruction.

Period 12 *to* 14 *Years.*—In the first of these periods—12 to 14 years—our general science syllabus may be: 'Earth, air, fire, water, the sky, the green plant, and ourselves.' Under these broad headings the more fundamental ideas of physics, chemistry, geology, botany and hygiene can be taught. The experienced teacher will delight in drafting his own scheme of lessons on a syllabus of such universal scope, but the young student fresh from training will be in difficulties. To help him it is necessary to prepare a working syllabus in such explanatory detail that it amounts to notes of lessons. Theorists will hold up their hands in horror at such a suggestion, but I know from long experience that it is the only road to success. By working conscientiously through such a scheme the inexperienced teacher gains a grasp of the purpose and method of the course that he can obtain in no other way. For the preparation of these teaching syllabuses we need the co-operation of teachers and inspectors of long and thoughtful experience.

Demonstration lessons play an important part: they give purpose and meaning to individual work, but alone can never give the reality to words that comes from personal contact with things and phenomena. Provision for individual practical work is essential in every type of school; central and secondary schools are provided with satisfactory laboratories, and committees spend large sums upon manual and art instruction in higher schools, but plead poverty when the most modest demands are made for practical instruction in elementary schools in which the need is more urgent. Some elementary schools have—and all should have—a work-room fitted with flat-topped tables and provided with a gas and water supply.

Period 14 *to* 16 *Years*.—At no period of school life does the pupil react more to his treatment than between the ages of fourteen and sixteen years. His interests become keener and more serious, and his powers of initiative and judgment develop if not suppressed by an unyielding school regime. Both in the central and secondary school the course in science should be of a general character, but not necessarily the same in all schools or in all groups of the same school. A more systematic treatment of elementary physics, chemistry, electricity, biology and hygiene will necessitate revision of much done in the previous two years; it will not be possible to deal with more than fundamentals, and no attempt should be made to force instruction up to the present standards demanded by school certificate examinations in specific subjects. Instruction should be essentially practical, demonstration lessons bearing the same relation to practical work as in the earlier period.

Conditions of Practical Work.—The teacher should give many qualitative demonstrations not necessary for individual repetition; the laboratory exercises should lead to definite observational or quantitative results, and should be performed always with the eye on the clock, for quick work implies concentration and success. Laboratory work in groups of two or even more pupils is responsible for the formation of desultory and inaccurate habits of work, and is tolerated in no other form of practical instruction. Over-large classes, poor equipment, and lack of laboratory preparation lead to low-pressure work, waste of time and small achievement.

The organisation and supervision of laboratory work makes severe demands upon the science teacher; a practical class of more than twenty pupils cannot be *taught* by one teacher, and the normal school groups are usually divided or, alternatively, a second teacher called in. If the science master is to devote his whole energies to the problems of instruction he must have at his disposal the services of a laboratory assistant; valuable time is often wasted in mere fetching and carrying and by the difficulties arising from a poor equipment. Breakages must occur, and the bill for renewals is often a measure of the efficiency of instruction, but headmasters look askance at these demands and wonder whether the game is worth the candle.

Where a vocational outlook is possible emphasis should be laid upon the appropriate branches of the full course. For others whose future employment makes little demand for applied science, instruction will be mainly directed to the investigation of common occurrences and the problems of healthy living.

Value of Revision.—The adoption of a non-departmental scheme of general science has one great advantage: it necessitates the repetition and expansion of the same ideas in successive years. Few pupils really grasp a new idea at the first presentation, nor does the immediate and frequent repetition of the same lesson do more than secure a word memory which is not lasting. A new approach to the same idea, after a considerable interval, and by a more mature treatment, is invaluable, and much of the admitted ineffectiveness of school science is probably due to the neglect or ignorance of this fact.

It is urged as an objection to general science that it is not examinable. Could any stronger argument for its adoption be offered? There can be no doubt that external examination would affect the teaching of general science even more disastrously than it has affected that of specific subjects.

Senior Work in Secondary Schools.—If instruction up to sixteen years of age has been broad, thorough and practical, the nature of science studies in the last two years will be determined by the necessities of future occupation or employment. Reading and practical work will go hand-in-hand, the teacher's principal function being to direct and organise both. A real but elementary knowledge of the interdependence of the various branches of science is of greater value to the young student than a specialised book knowledge beyond his years.

The engineer, the doctor, the agricultural expert, the chemist and the schoolmaster require a much wider knowledge of science than they commonly possess, and these years should tend to counteract the narrowing influences of university and professional training.

The false standards of university scholarship examinations have influenced adversely the science in senior forms of secondary schools. The schoolmaster who has been through it knows what his pupils require in order to profit by university courses; his opinions should carry great weight in determining the nature and standard of these examinations, which should test practically and theoretically a broad and thorough knowledge of general science.

Science in Girls' Schools.—Domestic duties call for more initiative, executive ability, power of organisation and common sense than do the ordinary vocations followed by boys on leaving school. The woman in the home is confronted daily with problems the solution of which demands trained intelligence and considerable knowledge of science. A training in methods of inquiry in relation to the materials and phenomena of home-life should do much to create an alert interest in common domestic experiences. Until fourteen years of age the same course of general science is just as useful for girls as for boys ; but later there should in most cases be a different objective. The academic science syllabuses followed with success in boys' schools make little appeal to girls ; to meet this difficulty in Irish secondary schools we substituted a course of Everyday Science, with special emphasis upon domestic experience and hygiene ; while providing a good general foundation, it is less quantitative than the course for boys, and has proved an unqualified success.

In girls' schools there is need for better correlation between the teaching given in the laboratory and the kitchen ; the subject taught in both is really one and the same, yet too often the science teacher and the teacher of housecrafts ignore the educational existence of each other. I believe we shall not get the best out of either of these aspects of domestic science until both are taught by one and the same person. In classes for adults there is some justification in treating the subject purely as a craft dominated by rules and recipes, but in schools we should direct the instruction towards the development of scientific habits and reasoned action. Less advance in the purpose and methods of instruction has been made in this most adaptable of subjects than in other practical studies.

Training Schools of Domestic Science.—The remedy lies with the training schools. Training in Domestic Science not only ensures quick and congenial employment but provides the best possible preparation for married life. The leakage from the profession is doubtless great, but we need not regret the cost of training to the State or to the individual, since it provides for the future homes of the nation intelligent and skilful management combined with an ability to teach. Some training in the art of teaching young children should form part of the equipment of every woman ; it is at least as important as a knowledge of domestic arts and household management, and is an aspect of girls' education which has not yet received serious attention. There can be little doubt that the training schools are accepting students immature both in age and educational attainments, and are in consequence compelled to undertake much instruction which could have been given in the secondary school.

A sound knowledge of general science and considerable experience of the domestic arts should be an essential condition for admission to a training school, which could then devote itself more intensively to professional training, and so prevent the present tendency to undue prolongation of the training period. The instruction in science should concentrate upon the bearing of scientific method upon teaching and of science upon domestic experience. The preparation of dishes does not supply the most suitable material for practice in the teacher's art, it is too dogmatic ; there should in addition be lessons on science and hygiene argumentatively treated. Learned lectures upon subjects beyond the comprehension of the students should be avoided, as they create the feeling that science is an unpractical and ornamental fringe to training. In the kitchen as well as in the laboratory it is important to develop an experimental attitude of mind; the fear of spoiling food should not be allowed to prevent definite inquiries into the nature of the materials and processes of the kitchen.

Training in Science of the General Subjects Teacher.

Years ago I inspected a country school in the South of Ireland; the teacher—an elderly man—assured me his pupils were 'mad on science'; the school was full of devices for making instruction real and exciting; senior pupils had preserved the keenness often found only among the juniors, and would argue with one about anything. On leaving, I asked the teacher why he had succeeded when others failed. With a twinkle in his eye, he replied: 'I dunno, sir, but perhaps it is I wasn't trained.'

On the whole the training colleges for elementary teachers have done their work well: their product is reasonably well fitted to gain experience from their teaching. That is all we can expect.

The teacher of the primary or higher primary school is usually a class-teacher, responsible for some or all subjects of the curriculum; he has to contend with difficulties not found in the secondary school, but, on the other hand, his methods and his inclinations are free from the constraints of examinations.

The teacher, whether in elementary or secondary school, must have grasped the method of science, and requires the same skill in the presentation of subject-matter to young pupils. A training college staff in touch with the problems of real teaching can do this work more effectively than university lecturers.

The studies in general science followed in the training colleges should be fundamental but of necessity more limited in scope and degree than those attempted by the secondary teacher; they should revise, from the teacher's standpoint, the work done by the student when at school, but must also fill up the many gaps that remain.

With students of this age it is not desirable to divorce training in teaching methods from instruction in subject-matter; both can be dealt with simultaneously and without loss of time; constant reference should be made to the difficulties and experiences of class teaching. Every specialist in a training college should be his own professor of method. Although this might lead to a conflict of pedagogical advice, it would leave the student more inclined to form his own judgments and would encourage his own critical powers: we do not want all our teachers cast from the same mould.

In the training colleges as in the schools instruction should be more akin to discussion than lecturing. The final qualifying tests, theoretical, practical and pedagogical, should be conducted by inspectors and teachers who have been in close touch with the work.

The laboratory training must be intensive and individual in order that students may acquire the resource that their future work will demand of them. In order to face the difficulties that poor equipment imposes they require a good training in laboratory arts and an ability to make use of the simplest means of illustration.

The Making of the Science Teacher.

Over-specialisation.—It would be of interest to ascertain the proportion of science graduates who ultimately become science masters and who intended originally to adopt that profession. The number is probably small, and explains the complaint that many young graduates, possessing a diploma in education, are unable to deal with junior science classes, and fail to interest and to get down to the level of their pupils. Due to their narrow specialisation, they are unable, or unwilling, to undertake even elementary instruction in a broad course of general science. The preference given in school appointments to men with high degrees further ensures specialisation. There is something wrong when it requires three different specialists to teach a boy of sixteen the modicum of science with which he leaves school. There is no such specialisation in literary, language or mathematical studies. This haphazard preparation of the science teacher for his life's work explains the failure of general science to obtain any firm footing in the schools, and also the large number of candidates for the school certificate examination who receive an education in science so narrow as to be of little service to them in life.

In Irish secondary schools there is no alternative to general science for the first school certificate; specialisation is only allowed for the higher certificates taken at about eighteen years of age; but we find difficulty in obtaining teachers of all-round training and broad sympathies.

To remedy these defects we recently organised an intensive course of general science for a group of selected graduates. The instruction in elementary physical and biological science was given partly by inspectors and partly by the students themselves under direction. We quickly discovered the necessity for our experiment, and found that elementary work, such as would be covered in the first university year, was half-known and its importance little appreciated; practical work was slow and inaccurate, and there was little evidence of an understanding of scientific method or of an ability to undertake an experiment to answer a specific question. The material was good and the students responded admirably to a rather stern disciplinary training. The results of the course, as far as we can at present assess them, were very satisfactory.

Vocational Training for Science Teachers.—It would seem that science teachers should be trained for their work in life as deliberately as candidates for other professions. The universities have not yet seriously faced this problem, but years ago the Royal Colleges of Science did offer courses designed for this purpose, which, though not ideal, produced a large number of very sound teachers. Such a course should provide a very thorough foundation in physics, chemistry, botany, animal physiology, geology and physiography. Emphasis should be laid upon the meaning of scientific method as exemplified by the work of the great pioneers, ancient and modern. The course should preserve a professional outlook throughout and every effort be made to break down artificial barriers between subjects.

If science teaching does not influence the pupils' methods of thought, if it does not develop the habit of forming careful judgments, it has failed completely in its purpose, and little defence can be made for it. To produce such results the training of the teacher must provide deliberately a practical and scientific discipline. In addition to the acquirement of knowledge he must learn to play the game of science, proficiency in which examinations make little attempt to test ; bookish erudition and a brilliant degree alone give no guarantee that he is scientifically minded.

Training in Theory of Education.—The prospective secondary teacher spends a post-graduate year attending lectures in the history of education and psychology associated with some practice in teaching. Many of us are disappointed and surprised at the poor results this year of professional studies provides ; any good results appear to come from the amount and quality of the teaching experience rather than from the lectures on theory. The historical and philosophical treatment of education contributes admittedly to the intellectual growth of the student, but in effect is non-vocational and does not produce practical and resourceful teachers.

Such theoretical training would be more effective after some years of thoughtful experience ; the student would then be in a position to compare theory with the results of his own practice. Where they agreed it would greatly strengthen his own faith ; where conflict occurred he would seek the cause.

At the Winnipeg meeting of this Section Prof. Hugo Münsterberg, the leading experimental psychologist of his time, said : 'I would as soon give a student a manual of physiological chemistry and expect her to prepare me a good dinner, as I would give her a course in psychology and expect her to teach.'

If the art of teaching is to develop into a science it will do so along inductive lines, and truth must be sought by purposeful observation and experiment in the class-room. We must concentrate less upon deductive methods and didactic rules and more upon a product equipped to gain knowledge from experience and conscious that success in his art can be achieved only by his own thoughtful investigations.

An ability to conceive, carry out and utilise an experiment should form an essential part of the training of every teacher, since the problems of teaching are the same in all subjects. Some of the most truly scientific teaching may be found in elementary schools given by teachers of no academic training and whose knowledge of science is dangerously superficial ; they have a missionary interest in their work, and with freedom develop a natural method.

Why then is professional training in its present form not producing the results expected ? Fresh from the intensive grinding for his degree, the candidate-teacher enters his professional year with unchanged outlook —another essential examination to pass. With no experience to give reality to the lectures he attends, he thinks far more of the diploma he is seeking than of the demands of his future career.

Other countries have recognised the need of a break between academic studies and professional training, and delay the latter until experience and greater maturity serve to make it effective. The Danes, both in their Folk Schools and in the training of their teachers, recognise the need for some experience of the world before embarking upon studies that demand a serious outlook upon life.

An Unorthodox Experiment.—Recently a new Irish Education Act found us insufficiently supplied with the types of teacher necessary to implement it. We needed teachers of general subjects, building trades, metal work, motor-car engineering, rural and general science, and domestic economy. We selected our candidates for these groups with care, the average age being about twenty-five, and importance was attached to the quality of their previous work and experience ; few had previously taught. The groups were placed under teachers of experience who dealt with the technical training and the problems of teaching simultaneously. Teaching methods were confined to the subject-matter of the group, and consisted mainly of discussions and criticism lessons and a little class experience. The duration of the courses was less than a year. I was present at all the final teaching tests and was astonished at the excellent standards reached. These teachers are now at work throughout the country, and with few exceptions have fulfilled our expectations. Many have been called upon to undertake teaching duties not contemplated originally, and they have not failed.

Some conclusions are indicated from this unorthodox experiment. In the making of a teacher his maturity and serious contacts with life are of great importance ; concentration upon the teaching of specific lessons is more effective than the discussion of theoretical principles ; and, lastly, the skill acquired in the teaching of one subject is available for wider application.

Section L in York, 1906.—My distinguished predecessor, Sir Michael Sadler, in this chair and in this city twenty-six years ago surveyed, with very great ability, the whole field of English education at that time. He dealt at some length with many of the questions to which I have referred, but especially to the need for more vocational purpose in school work. At that time he saw signs of a first general appreciation of education definitely for life, and showed how educational problems must be interwoven with social problems. He said : ' In planning a course of education for anyone you must keep the actual needs of his or her future life-work steadily in view. The schools must prepare the children for citizenship and for individual efficiency in this or that type of future calling, and must dovetail educational discipline into the practical tasks of life.' And again : ' Schools are at present too little concerned in the question how each individual pupil is likely to earn his living.' He appreciated that, with the expansion of the public school downwards and the elementary school upwards, the old middle-class grammar school must disappear, and that the two remaining types would attract such a variety of pupils that it would be difficult to have a clear-cut vocational purpose.

The traditional ruts into which education moved, the concentration upon book-learning, the neglect of handwork, and our wastefulness of the more ordinary kinds of intellectual material he regarded as the besetting weaknesses of his time.

Much of the progress that Sadler foretold has gone apace, but though he deplored our 'worship of examinations' as destructive of teaching and learning alike, he could not foresee the extent to which machine-made examination would stultify the good that should have resulted from the fusion of the old class education grades.

Conclusions.—Within the limits of this address, and of your patience, I cannot refer to many aspects of science teaching of considerable importance: for example, the place of scientific thinking in adult education, and the marked decline of the amateur interest in science, are problems not within the scope of this paper.

During the generation which represents the life of this Section the magnitude of science teaching has increased enormously. As a measure we might take the number of school balances in use. Forty years ago the number could not have exceeded a few hundreds; to-day it must run well into six figures.

In early days our school rays of scientific light were admittedly divergent but gave a fairly general illumination of the facts of experience; to-day they seem to pass through a lens of short focus and perfect optical properties which converges them to form a well-defined image in the examination room, but allows little stray light to illuminate the path of life at more distant ranges. Our beam of school science must be directed in a wider angle so as to envelop the dark areas of ignorance, to enlighten which is its proper function.

There is justification for the impression that, during the period under review, the 'sense' of the advance of school science has become negative rather than positive, that its quality and purpose has retrograded rather than advanced. Common sense alone will give proper direction to our efforts. We must agree as to what school science can do to make better thinkers and more earnest workers and see that it does it, irrespective of the artificial constraints that scholastic and educational machinery at present impose.

This survey of the advancement of science in schools has left me with certain outstanding impressions:

1. The curricula of many schools—especially secondary schools—are based upon the demands of external examinations, and take little thought of the human material handled or the shape into which it should be moulded to fit accurately into its place in the machine of life. It results in mass-production from the same mould without reference to the markets it is intended to supply.

2. We must be prepared to justify every rectangle in our school time-table to the satisfaction of a *competent* authority. We must define clearly what we mean by 'culture' and must adopt the most direct and most economical route to it. We must test our products more broadly and more sanely, and keep our curricula fluid and experimental.

3. School science for the average boy and girl should, in the first place, provide broad and real knowledge that will, as far as possible, render intelligible the phenomena of common experience; and, secondly, provide a training in the formation of sound judgments and alertness. Its teaching cannot be adapted to traditional linguistic methods.

4. Science teaching is a profession the preparation for which is at present neither deliberate nor adequate.

SECTION M.—AGRICULTURE.

SHEEP FARMING: A DISTINCTIVE FEATURE OF BRITISH AGRICULTURE

ADDRESS BY

PROF. R. G. WHITE,

PRESIDENT OF THE SECTION.

EARLY in the sixteenth century Master Fitzherbert wrote:

> 'An housbande can not well thryve by his corne without he have other cattell, nor by his cattell without corne. For else he shall be a byer, a borrower or a begger. And because that shepe in myne opynyon is the mooste profytablest cattell that any man can have, therefore I pourpose to speake fyrst of shepe.'

The first part of this extract is a clear statement of the belief responsible for the traditional policy of British agriculture. The soundness of that policy perhaps is not accepted so readily and generally as it used to be, but, while we might differ on the broad question, we shall at any rate agree that one of the biggest immediate problems which British farmers have to face is that of finding a profitable outlet for their main crop—grass. It therefore seems appropriate that we should give special consideration to the kind of 'cattell' of which Fitzherbert had such a high opinion, and that like him Section M at this meeting should 'speake fyrst of shepe.'

I am sure that he would accept my title without question, or, at most, would assert that it was much too mild, but, without making any reflection on my audience, it is perhaps necessary to produce some evidence in support of my opinion that sheep farming is a 'distinctive feature of British agriculture.' I must restrict my survey to Great Britain, but my claim could probably be justified even if we used the term British in its wider sense. About one-third of all the world's sheep are in the British Empire. They produce about half the world's wool and probably about the same proportion of mutton and lamb.

Table I, compiled from the *International Year-Book of Agricultural Statistics*, shows that in relation to total land area our sheep population is only surpassed by that of New Zealand. Even if we consider actual numbers, Great Britain is eighth on the list, and, except for New Zealand, is only surpassed by countries many times its size.

TABLE I.

Country.	No. of Sheep, 1930 (Thousands).	Total Land Area (Thousand Hectares).	Sheep per 100 Hectares.
Australia (1929)	104,558	770,385	13·6
U.S.S.R. (Asia and Europe)	89,860[1]	2,117,620	·4
U.S.A.	51,911	783,943	6·6
Union of S. Africa (1929)	45,010	122,224	36·8
Argentina	44,413	279,271	15·9
New Zealand	30,841	26,784	115·1
British India	25,539	270,130	9·4
Great Britain	23,965	22,744	105·4
Uruguay	20,558	18,693	90·9
Spain (1929)	19,370	50,521	38·3
France (1929)	10,452	54,405	19·2
Italy	9,896	31,014	31·9
Germany	3,501	46,864	7·5

Table II enables us to examine the position in European countries more comparable with our own than those at the head of the first table. It will be noticed that the area considered—arable and grass land—is different from that in Table I, where total land area was taken as the basis of calculation. The important facts brought out by this table are (1) our low proportion of tilled land, which is only about half the average of the other countries ; (2) our great number of sheep ; (3) the small population employed on a given area of land. In Great Britain sheep are used to consume a large part of the production of the soil which in other countries is of a different character and is disposed of in a different way—e.g. France grows a much larger proportion of crops for direct human consumption ; in Germany, Holland, and, above all, in Denmark, dairy cattle and pigs dominate farming practice.

In assessing the importance of the industry it is perhaps even more necessary to know how sheep compare with other branches of farming in this country, and I have therefore drawn up Table III (p. 232) from figures in the official reports on Agricultural Output. It indicates the extent to which the income of the British farmer depends on receipts from sheep and wool. It should be noted that the figures include only produce sold off the land or consumed in farm households. They do not include sales from one farm to another.

[1] This figure taken from the *International Year-Book* is probably much too low. The 'Wool Survey' recently published by the Empire Marketing Board, quoting the *Journal* of the Soviet Textile Trust, gives 100·5 millions. The number in 1929 was 132·8 millions.

TABLE II.

Per 100 Hectares of Arable and Grass Land.

1930.

Country.	Sheep.	Cattle.	Pigs.	Population occupied in Agriculture per 100 Hectares. Crops and Grass.	Percent. in Total of Arable Land excluding Clover and Temporary Grass.
Great Britain .	199·0	58·8	20·3	11	29·2
Italy . .	49·3	34·3	15·7	51	58·9
France . .	35·6	52·9	20·7	30	65·5
Holland .	21·8	106·5	90·8	28	38·9
Germany .	12·2	64·2	81·5	34	64·4
Denmark .	6·3	102·2	162·8	15	65·1
Great Britain (including rough grazing) . .	*133·0*	*39·2*	*13·5*	*7*	*19·5*
France (including rough grazing) . .	*31·6*	*47·2*	*18·4*	*27*	*58·4*

Thus, in 1925, receipts from sheep and wool constituted between one-fourth and one-third of our receipts from the sales of farm stock, excluding poultry, and about one-tenth of the total British agricultural income.

The main facts regarding our consumption of mutton and lamb in relation to that of other kinds of meat are set out in Table IV (p. 232), prepared from the Marketing Reports in the Ministry's Economic Series.

Whilst Tables I and II justify the claim of sheep to be regarded as a special feature of British farming, the figures in Tables III and IV show that we must not take an exaggerated view of their importance, even though they are immensely more important to us than to continental farmers.

In 1925 mutton and lamb brought to the British farmer rather less income than did vegetables, flowers and fruit. Possibly, by now, even poultry may be more important financially than sheep.

Table III.

Estimated Value of Agricultural and Horticultural Produce from Farms and other Holdings in Great Britain.

	1908.	1925.
	Thousands of £.	
Horses	1,590	1,430
Cattle and Calves	27,264	51,210
Sheep and Lambs	18,196	24,520
Pigs	14,362	28,240
Total Live Stock	61,400	105,400
Wool	2,600	4,100
Farm Crops	46,600	55,250
Milk and Dairy Produce	30,000	66,500
Eggs and Poultry	5,000	17,310
Vegetables, Fruit, Flowers	—	25,430
Total Sales off the Land	150,800	273,990

Table IV.

	Total Consumption per head of population in Great Britain.			Production of Mutton and Lamb in Great Britain.	Proportion of Home-produced to Total Supplies.		
	Mutton and Lamb.	Beef and Veal.	Pork, Bacon, etc.[2]		Mutton and Lamb.	Beef and Veal.	Pork, Bacon, etc.[2]
	lb.	lb.	lb.	Thousand tons.	%	%	%
1904–9 (Average)	27·9	67·4	—	251	51·6	53·6	—
1909–14 (Average)	30·7	65·7	34·2	277	49·3	52·4	57·4
1923–24	23·7	68·6	41·2	190	41·3	44·5	42·8
1924–25	23·8	70·4	43·7	195	41·9	43·0	47·8
1925–26	25·6	71·6	—	215	42·8	42·6	—
1926–27	26·8	70·7	—	234	44·3	42·7	—
1927–28	28·0	70·2	—	261	47·1	45·7	—
1928–29	28·0	—	—	251	45·2	—	—
1929–30	28·6	—	—	239	41·9	—	—

[2] Great Britain and Ireland.

Similarly, our consumption of mutton and lamb is far greater than that of most other populations—28 lb. per head per annum as compared with 6·8 lb. in France, 6·5 lb. in Canada, 5·8 lb. in the U.S.A., and 1·6 lb. in Germany; but Table IV shows that it is only about two-fifths of our consumption of beef and veal. The home supply and the consumption of mutton and lamb per head appear to be recovering from the check caused by the war, but it is clear that the home product has not held its own in the competition for supplying the demands of our increasing population, and we now depend on overseas supplies to a much greater extent than before the war.

At the same time, I feel that these figures must not be taken as an exact measure of the importance of the sheep industry in our national agricultural economy. There are many other considerations to be taken into account, some of which I will discuss later.

Development of British Sheep Farming: Wool Production.

The importance of sheep is no new feature of British agriculture, and a rapid survey of the history of sheep farming in this country will enable us to obtain a better idea of the present position of the industry and its prospects for the future. I cannot go further back than Norman times, and I do not suppose that until the country became comparatively settled and law-abiding, sheep were of very great importance. In a country subject to continual tribal quarrels or internal wars, I imagine that a sheep flock would excite the feelings said to be roused to-day by a rabbit in a Yorkshire mining district. Throughout the Middle Ages it would hardly be an exaggeration to say that the history of sheep farming was the history, not only of agriculture, but of national commerce. Up to the middle of the fifteenth century, Great Britain, and, in particular, the lowland districts of England, provided the most important source of supply of the wool required by continental manufacturers, particularly those of Flanders, but also those of Italy and other countries at a greater distance. Britain almost played the part which Australia plays to-day. Such was the dependence of continental manufacturers on English wool that it was possible to impose export duties, which for long were among the most important sources of revenue available for the mediæval equivalent of our Chancellor of the Exchequer. The nation was not long content with being merely a producer of raw wool, and from the twelfth century onwards there was a whole series of enactments intended to foster woollen manufacture and to keep British wool for British looms. For long periods the export of wool was actually prohibited, though even in those days prohibition was not entirely successful, and the smuggling of wool out of the country became at various times quite an important enterprise.

Legislation of this kind was not the only means adopted to build up a manufacturing industry. It is probable that continental weavers were encouraged to come over and settle in different parts soon after the Conquest, and it is certain that Edward III brought over a number of Flemish weavers between 1330 and 1340. By the middle of the fifteenth century the effects of the various protective measures and of the developing home industry were to be clearly seen. The export of raw wool fell off, less cloth was imported, and the export of cloth became of considerable importance.

In the Middle Ages English woollen manufacture was mainly concentrated in three areas: the West Country—Gloucestershire, Wiltshire, Somerset; East Anglia, particularly Suffolk and Essex; and Yorkshire. I regret to say that Yorkshire was not only third in order of quantity, but it was also rather notorious for poor quality, and it was not until the nineteenth century that the West Riding assumed its present eminent position in manufacture. It is interesting to us to-day to know that York played an important part both in the manufacture and in the foreign trade in cloth. From 1164, for more than a century, the city had the monopoly of the manufacture of dyed and striped cloth in the county, and at the beginning of the fifteenth century it was estimated that of about 2,500 heads of families in the city, 250 were masters of one or other of the Guilds which regulated the making of cloth. By the sixteenth century York had declined as a manufacturing centre, partly owing to the growing competition of the West Riding, but it still held an important position in the trade, largely as a result of its connections with the Merchant Adventurers, who so largely controlled the export of Yorkshire cloth up to the seventeenth century.

As regards the production of wool, it is important to note that the developing agriculture of the country, though called upon to provide the food required by the increasing industrial population, was also able to supply the wool needed for the continually expanding manufacture, as well as a certain amount for export. There must, therefore, have been a steady increase in the number of sheep, doubtless accompanied by some improvement in the weight of fleeces. In the main, the country was self-supporting up to the end of the eighteenth century, and, although there were at times considerable imports of wool from overseas, on the other hand we read of agitations for the removal of restrictions on export, so as to enable the British farmer to secure a better price for his wool. These agitations came to a head about the end of the eighteenth century, and the prohibition of the export of wool was removed in 1825. It is possibly not generally known that, although we now import colossal quantities of wool, a large proportion of our home-grown clip is exported. Up to 1927 nearly 60 per cent. was sent abroad, principally to the United States and Italy. The weight of home-grown wool exported is such that Great Britain is about eighth on the list of wool-exporting countries.

On the more definitely agricultural side of the sheep industry, our information of early developments is in many ways very meagre and unsatisfactory. For instance, we know little of the origin of our domesticated breeds of sheep, and I do not suppose that anyone would care to express a very definite opinion regarding the character or origin of the sheep in the country at the time of the Norman Conquest. From the Conquest onwards records of various kinds throw some light on the nature of the sheep kept in different parts of Great Britain, though early writings deal much more fully with the wool than with the sheep themselves. The monasteries were very large sheep farmers, and information regarding the prices they obtained for their respective clips gives us some idea of the distribution of different types of sheep in the thirteenth and fourteenth centuries. Even at that time, Hereford and adjoining counties produced very valuable wool, while the Midland counties and Lincolnshire also received high prices. Scotland, the North of England, and Wales, as now, evidently produced a good deal of wool of low market value. Certain exceptions may possibly indicate isolated areas in which sheep of an old local kind survived, or, on the other hand, the results of the introduction of new types from abroad.

From the fourteenth century onwards there was a regular succession of writers on agriculture, and from them we obtain more definite ideas of the sheep in different districts. For instance, Gervase Markham, writing in the early part of the seventeenth century, observes :

> ‘ If then you desire to have Shepe of a curious fine staple of Woole from whence you may draw a thread as fine as silk, you shall see such in Herefordshire about Lempster side and other special parts of that country ; in that part of Worcestershire joining upon Shropshire, and many like places ; yet these shepe are very little of bone, black faced, and bear a very little burthen. The shepe upon Cotsall hills are of better bone, shape and burthen, but their staple is coarser and deeper. The shepe in that part of Worcestershire which joyneth on Warwickshire and many parts of Warwickshire, all Leicestershire, Buckinghamshire and part of Northamptonshire, and that part of Nottinghamshire which is exempt from the forest of Sherwood, beareth a large boned shepe, of the best shape and deepest staple ; chiefly if they be Pasture shepe, yet in their woole coarser than that of Cotsall. Lincolnshire, especially in the Salt Marshes, have the largest shepe, but not the best Woole, for their legs and bellies are long and naked, and their staple is coarser than any other. The shepe in Yorkshire and so northward are of reasonable big bone, but of a staple rough and hairy, and the Welsh shepe are of all the worst, for they are both little and of coarse staple ; and indeed are praised only in the dish for they are the sweetest mutton.’

This extract not only gives some idea of the sheep kept in different parts of the country, but Markham's last remark shows the unimportance in his day of mutton compared with wool.

At the present time wool is of such secondary importance in this country that it is well to be reminded of the fact that until the eighteenth century wool production was the main purpose for which sheep were kept.

Folding of Sheep.

Probably the next most important function which the sheep served was that of fertilising the arable land in the days when very little farmyard manure was produced and artificial manures were yet unthought of. In the old village system the arable land was usually cultivated on a primitive rotation of two corn crops followed by a fallow. The village flock was grazed on the wastes and commons during the day, and at night was brought back to be folded on the fallows and stubbles (or, in some cases, fastened in houses or sheds). They thus provided the means of enriching the arable land at the expense of the commons and wastes, which often lay at some distance from the village. Most of us have seen at one time or another remarkable demonstrations of the wonderful efficiency of a flock of sheep as transporters of fertilising material. Tusser's verse describes the system sufficiently well and indicates one of its incidental disadvantages in the days when fences were almost non-existent and sheep dogs had not had the benefit of the education provided by our Sheep Dog Trials.

> ' The land is well hearted with help of the fold,
> For one or two crops, if so long it will hold.
> If shepherd would keep them from stroying of corn,
> The walk of his sheep might the better be borne.'

The system was general in all arable districts up to the time of the great enclosures in the eighteenth century. At the end of that century the folding of sheep in the South Midlands was still valued at about 40*s.* an acre, or from 4*s.* to 5*s.* per sheep per annum, though many writers suggest that the return was dearly bought. Walking the sheep long distances every day and the discomfort and semi-starvation which they often experienced on the fallows made mutton production impossible. It is perhaps worthy of note that the Wiltshire and Norfolk breeds were regarded as specially suitable for folding because they were active and ' stood well out of the dirt.' This early system of folding on fallows and stubbles must not be confused with the modern system of folding on root and forage crops, which is a very different matter.

Milk Production.

A subsidiary, but not unimportant, additional return from the flock in old times was the cheese made from the ewes' milk after the weaning of the lambs. The practice of milking the ewes survived in many hill districts until comparatively recently, but has now almost completely disappeared. Walter of Henley, Tusser and other early writers deal rather fully with the matter. The lambs were weaned comparatively early and the ewes milked for six or eight weeks, care being taken to discontinue the milking soon enough to allow the ewes to get into good condition before the approach of winter. In the *General View of the Agriculture of Roxburgh* (1798) it is estimated that a score of ewes would give about two quarts of milk a day ; thirty-six score of ewes, with the addition of 25 per cent. of cow's milk, should give a cheese of about 45 lb. a day. These were, of course, small Cheviot ewes kept on poor hill pasture. When we think of the labour involved in collecting and milking thirty-six score of ewes every day, and the value of cheese at the present time, we can hardly be surprised that the practice has died out. At the same time, there are other aspects of the milking of ewes which require mention, and to them I will return.

Meat Production.

Early agricultural writers make little reference to mutton. Tusser advises the purchase of old crones at the end of August for autumn fattening, and included ' fat crones and such old things ' in the farmer's daily diet between Michaelmas and Hallowmas. Tusser, Lisle and other early writers refer to fat lambs and ' House Lambs,' but the usual practice was to kill for meat only those sheep which were too old and infirm for further keeping. Losses from disease were very heavy, and the lambing percentage was low, so that the need for maintaining the numbers of the flock for wool production would make it impossible to slaughter young sheep in any great numbers.

In the eighteenth century great changes took place. The demand for wool was greater than ever, but the developments which took place in agriculture made it possible to maintain larger numbers of sheep and to fatten them in either winter or summer. Among these changes were the enclosures, increased attention to drainage, and, above all, the cultivation of roots and clover. The growth of the towns and the demands of a large industrial population provided the necessary outlet and stimulus for the production of mutton on a large scale. The application of Bakewell's genius to the development of a sheep capable of maturing early, feeding quickly and producing a heavy fat carcase, completed the sequence of changes which, for the first time, made meat production the object of prime importance in the British sheep industry.

Following on the changes I have mentioned, and stimulated by the constantly growing markets for both mutton and wool, there were other important developments in the latter half of the eighteenth and the early part of the nineteenth centuries.

Mountain Sheep Farming.

The first of these is the development of Mountain sheep farming, which, in its present form, dates very largely from the second half of the eighteenth century. It is fairly safe to estimate that in Great Britain Mountain sheep now outnumber all other breeds put together, and their importance is such that we are apt to assume that sheep have always been the chief stock kept on mountain land. This certainly was not the case. In the Scottish Highlands and in the mountain areas of Wales sheep were, until comparatively recently, of very much less importance than cattle. The estimated numbers of different classes of stock in Scotland even at the end of the eighteenth century were :

	Horses.	Cattle.	Sheep.	
	243,000	1,047,000	2,852,000	
as compared with	156,316	1,235,999	7,649,551	in 1930

The figures for Perth, Inverness and Argyll were :

	Horses.	Cattle.	Sheep.	
	36,544	185,937	550,450	
as compared with	21,640	166,738	1,874,177	in 1930

Had the first estimate been made fifty years earlier, the comparison with present-day figures would have been even more striking.

The Gwydyr Papers throw a very interesting light on the position in mountain districts of Wales in the sixteenth century. The following table gives the numbers of different classes of stock on eight mountain farms in 1569, together with particulars of the stock in 1931 in a neighbouring parish. I should like to express my indebtedness to the authorities of the National Library of Wales and the Ministry of Agriculture for permission to quote the figures.

TABLE V.

Eight Large Farms (1570).		Neighbouring Parish (1931).	
Cows	432	Cows and heifers in calf or in milk	267
4 year old Bullocks	80	Bulls	5
3 ,, ,, ,,	66	Other cattle:	
2 ,, ,, ,,	76	2 years and above	39
3 ,, ,, Heifers	80	1 year and under 2 years	118
2 ,, ,, ,,	70	Under 1 year	144
Bulls	16		
Calves	213		
Total cattle	1,033	Total cattle	573
'Sheep'	495	Ewes kept for breeding	6,712
'Yearlings'	152	Rams and ram lambs	203
Lambs	383	Other sheep:	
		1 year and above	2,165
		Under 1 year	5,180
Total sheep	1,030	Total sheep	14,260
Horses (1569)	39	Horses	37
Goats	215	Goats	No information

Watson has recently given a full account[3] of the development of the sheep industry in the Highlands between 1760 and about 1810 and has shown how the Black-face replaced both cattle and the old type of sheep often referred to by early writers as the Dun-faced breed. In Wales and the North of England a similar process undoubtedly took place in many mountain areas, but the change was much more gradual, and, doubtless partly for that reason, there was no sudden substitution of a new breed. In Wales, for instance, I think it is very likely that the old Dun-faced breed was also the original type, but it had been gradually

[3] *Transactions of the Highland and Agricultural Society*, 1932.

improved and modified until it became the Welsh Mountain sheep well before the period of which we are speaking.

Arable Sheep Farming.

Up to the eighteenth century sheep in all parts of the country were necessarily what we should now describe as 'grass sheep.' The weeds and miscellaneous herbage of the fallows and stubbles could contribute comparatively little to the sustenance of the flock. In the fifteenth and sixteenth centuries, when wool production was particularly profitable, a great increase in sheep stocks took place, and the extra food required for them was provided, not by ploughing up land, but by the reverse process of converting arable land into pasture, much to the dismay and indignation of all except the large landowners and flock-masters. The long-wools, which formed the bulk of the production of the country, were mainly the product of the grass lands of the Midlands. At the same time, the folding of the sheep on the fallows was, as we have seen, an essential part of the old English arable system. Therefore, when the fallow was replaced by root crops and various forage crops, it was natural that a system should be devised under which sheep consumed the crops where they grew. Gradually there was developed the system of intensive sheep management, best seen about the end of the nineteenth century in counties such as Wiltshire, Dorset and Hampshire. There the flocks might be kept closely folded on arable land throughout the whole year, consuming crops specially grown for them. For such a system our Down breeds of sheep are particularly suitable, and without it they would not have reached their present degree of excellence as mutton sheep. The Dorset Horn in its own country, the Leicester on the Yorkshire Wolds, or the Lincoln on the light arable land in its own county are other examples of arable sheep, though the system of management in the North was never so intensive as that in the South.

Fat Lamb Industry.

In recent times the most important changes have been associated with the great development of the fat lamb industry, but it would be wrong to regard it as a new activity. Tusser, Lisle and others refer to it in writings from the seventeenth century onwards, and in the neighbourhood of London the practice of obtaining very early fat lambs appears to have been quite common. Dorset Horn ewes, as now, were commonly employed for this purpose, and the practice of rearing the lambs indoors led to the term 'House' lamb. At the same time, the practice of producing early fat lambs was by no means confined to the Home Counties or to Dorset Horn ewes. Lisle describes the sending of fat lambs from Wiltshire to London at the beginning of the eighteenth century, and in the County Reports, to which I must make frequent reference, there is very general mention of fat lambs. For instance, in Durham, the draft mountain ewes were sold from the high western districts to the lower eastern parts of the county, where occupiers could not keep permanent breeding flocks on account of the 'rot.' The proceeds in 1810 are given as follows :

	£	s.	d.
Lamb sold beginning of July . .		16	0
Ewe sold beginning of October . .		18	0
Fleece		2	0
Total	£1	16	0
Deduct the price paid for ewe . .		12	0
Leaves for a year's keeping . .	£1	4	0

To show that our large autumn movements of ewes to distant parts of the country had their counterpart more than a century ago, I may mention that Welsh ewes were largely used in South-East England for fat lamb production. I am inclined to think that the fat lamb industry was of relatively greater importance at the beginning of the nineteenth century than it was in the latter part of the century. The general development of agriculture, and particularly of root growing, during the first half of the century, encouraged the keeping of lambs for fattening on roots during the winter, and of yearlings to be fed on clover leys during the summer. In any case, most of us know from our own experience that up to quite recently little early lamb was marketed, and the meat most commonly consumed was that of young sheep ranging from about six months to eighteen months in age, whilst in the hill districts, and also in some lowland districts, wethers were kept until they were three or four years old. This is now a thing of the past. Two years ago the Ministry of Agriculture, in addition to the usual June census, collected figures for numbers of stock in January. The following table brings out clearly the fact that now the majority of lambs in England and Wales are slaughtered before reaching the age of eight or nine months. The number of lambs under one year in June was nearly 7 millions, and less than half that number in the following January. Of the 3·4 millions then returned, probably not less than 1 million would be ewe lambs intended for breeding purposes, so that of 6 million lambs not intended for breeding, 3½ millions left our farms between June and December. Actually, this underestimates the sale of early lambs because the spring lambs sold in April and May ought to be added to the June figures, whilst from the January number should be taken the autumn lambs born in the south of England and the store lambs purchased from Scotland.

Table VI.

England and Wales.	June 1929.	Jan. 1930.	June 1930.
Ewes for breeding .	6,717,000	7,120,300	6,810,700
Other sheep, 1 year and above . .	2,267,000	1,218,900	2,213,700
Under 1 year .	6,934,000	3,440,500	7,099,300

THE PRESENT POSITION OF SHEEP FARMING IN GREAT BRITAIN.

The rough survey of the history which we have made enables us to summarise the present position very briefly, and Table VII enables us to consider recent changes. Our sheep can be divided into three large groups :

(*a*) Mountain and hill flocks.

(*b*) Flocks kept largely or mainly on arable land.

(*c*) Lowland grass flocks maintained primarily for the production of fat lambs.

Mountain Sheep.—In the Census of Production made in 1908 an attempt was made to secure information regarding the numbers of each breed of farm livestock in Great Britain. Even at that time the mountain breeds included about half the total sheep population. Since 1908 they have become of much greater relative importance, not so much because of any great increase on their native grazings, but because of their invasion of the lowlands, particularly to form temporary flocks for the production of fat lambs.

Table VII brings out the relative stability of the flocks in areas where there is a great deal of hill or mountain land. Under present conditions, even more than in the past, sheep farming is the only possible system of utilising the greater part of such land agriculturally. At the same time, there has been little, if any, increase in the number of sheep on the mountains, although financial returns from sheep were satisfactory until a year or two ago. In many cases the number is strictly limited by the area of suitable winter grazing which can be secured within a reasonable distance for the lambing ewes and the ewe lambs. In others, where this consideration does not arise, the land was fully stocked years ago and has probably deteriorated in recent years. In certain Highland counties there has even been a substantial reduction in the numbers. This has been discussed by Greig and King, and more recently by Watson. Deterioration of grazings and, above all, the disappearance of the wether flocks are probably the main reasons. In mountain flocks everywhere there has been an important change in the type of sheep kept. Formerly very large numbers of the wethers were kept until three or four years old. Now there is no demand for such old mutton, and practically all the wether lambs are sold off the hills in their first autumn. This has enabled larger numbers of breeding ewes to be maintained, and has provided the lowland farmer with a larger supply of draft ewes and store lambs, but in many cases the clearance of the wethers has led to deterioration. After the first winter they spent the whole of the year on the mountains and ate down a good deal of the rough grass left over from the summer, thus contributing to the growth of attractive nutritious herbage in the following spring. Moreover, the weight of protein and mineral matter annually sold off the grazing is now much greater than formerly.

TABLE VII.—CHANGE IN SHEEP POPULATION OF DIFFERENT COUNTIES OF GREAT BRITAIN BETWEEN 1900 AND 1930.

Decreases.

Over 40 %.		20 % to 40 %.		Under 20 %.	
England :					
Cambs.	65	Notts.	35	Kent	19
Berks.	60	Somerset	31	Warwick	15
Suffolk	60	Staffs.	28	Worcs.	15
Wilts.	59	Glos.	26	Cheshire	12
Hants.	58	Derby	26	E. Riding	7
Norfolk	53	Leics.	25	W. Riding	2
Surrey	50	Cornwall	23	N. Riding	1
Essex	50	Northants.	21	Shrops.	2
Dorset	50	Bucks.	21		
Lincoln	49				
Bedford	45				
Oxford	41				
Sussex	41				
Herts.	41				
Wales :					
				Glam.	2
				Merioneth	1
				Monmouth	3
Scotland :					
		Moray	26	Inverness	17
		Argyll	24	Roxburgh	13
				Bute	9
				Perth	8
				Stirling	2
				Lanark	2

Increases.

Over 40 %.		20 % to 40 %.		Under 20 %.	
England :					
				Westmorland	16
				Hereford	11
				Northumb.	10
				Cumberland	10
				Lancs.	9
				Durham	4
				Devon	2

TABLE VII.—*continued.*

Increases—continued.

Over 40 %.		20 % to 40 %.		Under 20 %.	
Wales :					
Anglesey	76	Denbigh	35	Mont.	19
Flint	52			Radnor	13
				Pemb.	12
				Card.	11
				Carm.	11
				Caern.	10
				Brecon	2
Scotland :					
Kincard.	68	E. Lothian	38	W. Lothian	14
Caithness	57	Fife	34	Wigtown	9
Banff	47	Aberdeen	29	Selkirk	8
		Berwick	26	Peebles	8
		Dumfries	23	Sutherland	7
				Ross	6
				Midlothian	5
				Ayr	4

Arable Sheep Farming as developed in the south of England well deserves special notice, because it is the one British system in which sheep are managed really intensively. The flock is folded on forage and root crops practically all the year round. The relatively high productivity of arable land and the systematic management of the fold enable large numbers to be kept on a given area of land. The sheep secure their food with the minimum of exertion on their part; they usually receive generous supplies of cake or concentrated food, and the land is well and evenly manured for succeeding crops of corn. Table VII shows how this system of farming has suffered. In the fourteen English counties in the first column the number of sheep was 5,040,000 in 1900 and is now only 2,393,000. The reduction in arable flocks must be even greater than the figures indicate, because in practically all counties there has been some increase in grass sheep. With present costs of labour and prices of produce, it is no longer profitable to transfer labour and exertion from the sheep to the shepherd, and it is becoming more difficult to obtain men to 'wait on the sheep,' if I may use a Yorkshire expression. Even more important is the fact that the manurial residues left by the sheep fold can only be valued at a very low figure, whether one takes the cost of purchasing corresponding amounts of manurial ingredients or the direct return received in the form of corn. Until last year prices of mutton were fairly well maintained, but the disastrously low prices for corn cut away the foundation on which the whole system was based.

The system has been most highly developed on poor thin chalk soils, and it is often maintained that such soils can only be kept in cultivation by the aid of the fertilising effect of the sheep fold. This is claimed to be necessary, not only to build up suitable reserves of plant food, but to secure satisfactory physical structure in these loose, shallow soils. It is worthy of note that the idea finds some confirmation in researches now proceeding at Rothamsted. None the less, I am inclined to think that, even if corn growing again becomes profitable, other methods of maintaining soil fertility will be adopted.

The system of arable sheep farming which, in its fully developed form, is peculiar to some of the southern and eastern districts of England can not only claim to be a form of intensive farming with relatively high production and employment of a large amount of labour, but it is also the system under which the mutton qualities of many of the British breeds were developed. To it may largely be attributed the clear supremacy which our breeds enjoy in all countries where sheep are kept primarily for the production of meat. The work of Hammond and others has clearly shown that genetic variability in size, rate of growth, early maturity, and general carcase quality is only fully expressed under optimum conditions of nutrition. Under less satisfactory conditions, the animal of exceptionally high potential characters may be indistinguishable from the individual which is merely moderately good. This variability must be secured if improvement by selection is to be effected, and the reduction in arable sheep is therefore not without its disquieting aspect to the live-stock improver. It will be noticed that the fourteen counties already referred to include the homes of all our Down breeds except the Shropshire. It is not improbable that the Shropshire also has suffered to the same extent, and that the maintenance of the sheep population in the native county of the breed is due to a great and overriding influx of grass sheep from the Welsh border.

The Longwools were in the main developed originally on good grass land liberally supplemented with produce of arable crops. The Down breeds originated in districts where there is little good grassland, and owe their improvement largely to breeders whose selective methods were aided by the ample food supplies provided by a succession of arable crops.

For modern conditions, the Longwools with their large, excessively fat carcases, and the Downs, handicapped by the cost of labour and other considerations already discussed, are (as the table shows) falling behind as commercial sheep. It will, however, be necessary for ram-breeding flocks to be continued—even if only to provide rams for crossing purposes—and for such flocks some system of arable management would appear to be practically essential, if the standard of our sheep is to be maintained.

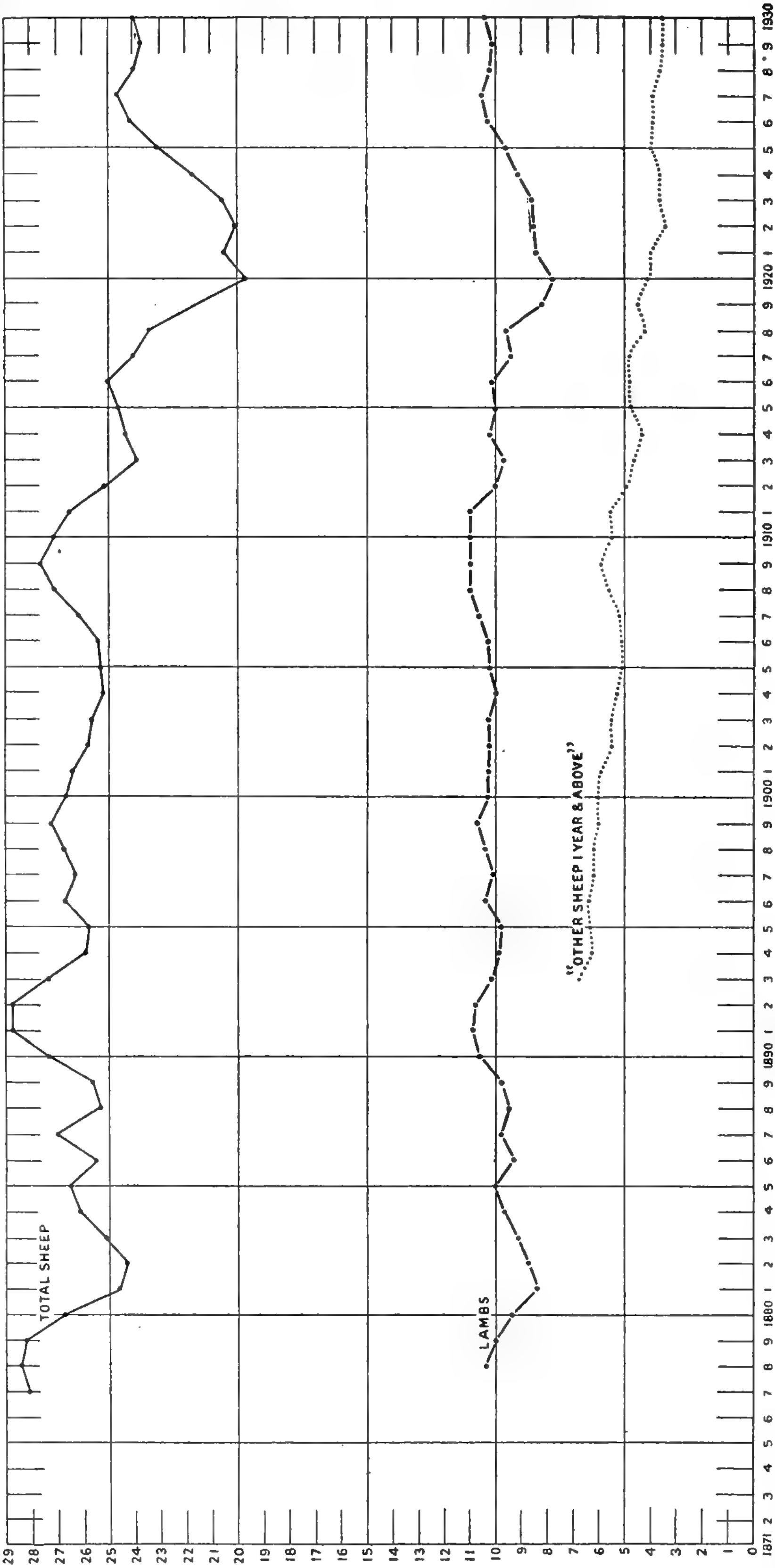
The Production of Fat Lambs is no new feature of British sheep farming, but during the last thirty or forty years it has attained an importance far exceeding its position in any previous period, and now probably the majority of lambs not to be kept for breeding purposes are sold for slaughter before they are six months old. Changing demands are the main reasons for this development. Formerly, early fat lamb was regarded as a luxury article only to be consumed by wealthy or extravagant people. Now, regardless of cost, the public demands small joints of pale, tender meat which can be cooked at once. To provide these, well-fattened carcases of 30 to 40 lb. at three or four months old are required, and in their production perhaps the main consideration is a liberal supply of milk. It is largely because of their excellence as milk producers that the hill and mountain ewes have become so popular for fat lamb production, other reasons being their small size and their ability to find a living on lowland pastures during the winter with little expenditure on either labour or feeding stuffs. They are available in large numbers every autumn, when the drafts from the hill flocks are being made, and it suits the lowland farmer better to buy these ewes than to rear his own. His land is often too wet and unhealthy for a permanent flock, and in most cases it can be put to more profitable use than grazing yearling ewes. A very large proportion of the land laid down to grass since the war is now stocked with such 'flying' flocks, and recent work of my colleague, E. J. Roberts, has shown that fresh young pastures give far better results in fat lamb production than old pasture on similar land. One of the questions regarding fat lamb production which I think is likely to arise is that of securing satisfactory 'finish' on the lambs when reared on recently formed pastures which every year will become more similar to old grass land.

The special suitability of young grass for fat lamb production largely accounts for the remarkable increase in the number of sheep kept in the lowland areas of North Wales and the eastern counties of Scotland (see Table VII). In both cases there is a considerable area of arable land farmed on a rotation which includes a temporary ley. The very simple modification of the system involved in extending the length of the ley made it easy to secure the relatively attractive returns from fat lamb production, and enabled farmers to reduce labour costs and unprofitable corn production.

Summing up the whole situation, we may say that we have almost reached the state of affairs in which hill and mountain flocks are maintained primarily to produce breeding ewes of a hardy, heavy-milking character; a relatively few arable sheep have as their chief object the breeding of rams of excellent mutton qualities mainly for crossing purposes; and the draft ewes from the hills and the rams from the arable flocks meet in the lowland pastures to produce lambs for sale almost entirely in the summer and autumn months.

The great concentration on production in summer is one of the dangerous features of the present situation. It makes our supply over the year very uneven, and there can be no doubt that this is one of the reasons for the decrease in the proportion of home-fed meat shown in Table IV.

So far I have not discussed our sheep population as a whole, and in doing so it is necessary to remember that it is composed of sections of widely differing character. The graphs enable us to see the position at a glance. The one for total numbers shows that there has been a great deal of fluctuation, and indicates very well the big drop (nearly 4 millions) caused by the fluke years 1879–80, and that brought about by food production measures during the war. There is also evidence of a general



The Sheep Population of Great Britain, 1877–1930.

downward trend, which, for the time being at least, has been arrested, but I fail to see anything which would suggest the existence of regular movements similar to the well-known cycles in the case of pigs. In fact, it seems absurd to expect anything of the kind when during the last thirty years we have had such conflicting changes as those shown in Table VII, with great increases in some parts of the country and great decreases in others.

The other two curves show how the general downward trend has been caused. The number of lambs, and presumably, therefore, the number of ewes, has remained remarkably steady throughout the fifty years, with the exception of the two periods already mentioned. If we allow for the greater number of lambs now sold off the farms before June 4, and therefore not included in the returns, there has probably been a slight upward tendency. The downward trend of the figures for total sheep is mainly due to the steady reduction in the number of 'other sheep one year and above.' This class consists almost entirely of animals to be fattened as yearlings or older sheep kept for fattening. These have dropped by at least 50 per cent. in the last forty years, and this decrease has rather masked the position of ewes and lambs.

Desirability of Sheep Farming.

Before considering possible developments, we may perhaps put the question whether we consider our large sheep population to be a desirable feature of British agriculture.

The keeping of sheep on a large scale is usually associated with extensive farming in zones beyond the areas in which cultivation or dairying is economically possible. Yet in this densely populated country we find to-day sheep grazing over large areas of land which formerly grew good corn and appears to be not unlike that used to-day in other countries for corn growing, dairying or some other form of more intensive cultivation. Some idea of the effect of a large sheep population can be obtained from a study of Table II, where it will be seen that per unit area we have the largest sheep population of any European country, and the smallest human population employed in agriculture. We cannot attempt to make an exact correlation, but no one is likely to question the effect of grass sheep farming. At different periods in British history it has caused hardship and bitterness, and has even led to legislative action.

The high price of wool about the beginning of the sixteenth century led to the conversion of arable land to pasture in order to provide for increased flocks. At that time the welfare of agriculture and the maintenance of the rural population was a matter of prime concern to both Church and State, so that preachers and writers declaimed against the sheep 'that were wont to be so myke and tame, and so smal eaters, now, as I hear saie, be become so great devowerers, and so wylde, that they eat up and swallow down the very men themselfes,' while legislation was framed to try to keep the land in cultivation.

Another well-known period was the latter half of the eighteenth century when large sheep farms were being established in the Highlands. The Black-face sheep were able to utilise many of the higher grazings which previously had never given any considerable return ; but they required for wintering the lower slopes and the land which up to then had been cultivated. The establishment of sheep farms therefore involved the removal of the Highland cattle and of the population which depended so largely on them. The feeling of the time is well and moderately put by Dr. John Smith in the *View of the Agriculture of Argyll* (1805) : 'That our mountains are better adapted for sheep than for black cattle cannot admit of a doubt. Under the sheep system they make a much better return both to the farmer and to the landlord ; and furnish in the wool of the sheep a large fund for manufacture and commerce. But all these advantages are more than balanced by the effect which sheep have produced upon population. When one man occupies space which would suffice for twenty families, his private gain will by no means compensate for public loss.'

Possibly, in time to come, the present period may be regarded as comparable with those I have just mentioned. In many counties the situation is obscured by the fact that, along with the laying of land to grass and a great increase in the number of grass sheep, there has simultaneously been a great reduction in arable sheep. In some counties this complication does not exist, the most striking areas being North Wales and the arable counties of the east of Scotland. I had hoped to be able to correlate the changes in the former, but, unfortunately, the detailed results of the 1931 census will not be published for some time, so that I can only say that a remarkable increase in the number of sheep has obviously been accompanied by a very marked decline in employment and in the general life of the countryside.

We must, however, be fair to the sheep, and those who wish to impute blame must take care that they put it on the right shoulders. But for the development of the sheep industry, the farmers of many areas would indeed be in a parlous condition by now. We know how unsatisfactory are the returns from ordinary arable farming, and there are many districts unsuited for dairying or intensive cultivation.

Grass sheep farming based on fat lamb production has enabled many farmers, not only in North Wales but all over Great Britain, to hold their own when, without it, they would have gone under. It is no use abusing the farmer because of the undoubted evils which have accompanied the adoption of this type of farming. As in the Middle Ages, the cure for the ills can only come through the improvement in the returns from what most of us will regard as more desirable systems of agriculture.

Efficiency of the Sheep.—We may apply another test in considering the desirability of a large sheep population. How do they compare with other farm animals as a converter of crops or raw feeding stuffs into meat for human consumption ? The following table is taken from a report drawn up by a committee of the Royal Society in 1917—*Food Supply of the United Kingdom* :

TABLE VIII.

Lb. Starch equivalent in Fodder required to produce 1,000 Calories in form of:

2·9	Milk from good cow	(800 galls.)
3·0	Pork	
4·7	Veal	(6 months)
4·7	Milk from poor cow	(300 galls.)
5·3	Mutton	(11–12 months)
7·0	Eggs	(140 egg hen)
7·0	Baby beef	(17 months)
9·0	Steer beef	(2½ years)

The figures quoted probably require modification in the light of more recent results and also to adapt them to altered systems of management, but it will generally be accepted that from this point of view the sheep, though better than the steer, compares badly with the milking cow or the porker.

It is, however, necessary to qualify this conclusion by considering not merely the amount and energy value of the food consumed, but also its nature and cost. In the case of the fattening bullock, for instance, the food may consist largely of straw—a by-product of corn-growing, and on most farms an unsaleable article. On the other hand, the pig and the fowl require considerable proportions of meal and grain, which have to be bought at market price either from the grain merchant or, in the case of an arable farm, from the cropping section of the farm business. The sheep occupies an intermediate position. It cannot utilise large quantities of straw, but makes good use of such crops as grass, roots and hay. Except in the case of arable flocks it receives comparatively little corn or concentrated foods.

Still, we are bound to admit that grass sheep under ordinary management give only a low return of food, and to those who wish to see a large rural population they are about the most objectionable form of enterprise in which the farmer can engage.

Viewing the matter from this standpoint, there is much force in the argument that we should leave sheep farming to more remote, thinly populated countries, and use our limited area and large population to produce forms of food which give a high return per acre, require a good deal of labour, and cannot easily be transported over large distances.

On the other hand, if we take the farmer's point of view we can make out a strong case for the sheep.

(1) Even allowing for considerable extensions of forest and woodland, we have large areas of hill and mountain land, which, under present conditions, can only be economically utilised for the production of sheep, and they carry a very large proportion of our total sheep flock. Our mountain flocks can only be maintained if they have an outlet for the draft ewes and store lambs which largely constitute their saleable product.

(2) Although we now have under grass large areas which most of us would like to see used for some kind of arable or mixed farming, grass is the crop to which soil and climate make a great deal—perhaps most—of our land in Great Britain specially suited. The mild, wet, equable climate of the greater part of the country not only makes cultivation difficult, but favours the growth of grass to some extent throughout the year. Sheep managed in such a way as to meet modern market demands fit in extremely well with grass production. So many fat lambs are now sold in summer that the annual cycle of the sheep population very closely resembles that of production from grassland. Numbers are at the minimum in winter and the requirements of the flock are at their maximum in May and June. Even the autumn flush of grass is met by the influx of sheep from hill grazings.

(3) Grass sheep not only require the minimum expenditure on labour and feeding stuffs but, compared with other forms of stock, they involve little outlay on buildings, water supply and other permanent equipment.

(4) Compared with other nations, our consumption of mutton and lamb is very high. The home-produced article has a great advantage in that it can be marketed fresh, whereas practically all imported mutton and lamb is frozen.

Possible Developments.

So far, in discussing the sheep industry, I have had in mind our existing methods of sheep management, but we can be quite sure that they will not continue unchanged, and we may devote a few minutes to considering the directions in which changes and developments would be most desirable.

Winter Lamb.—At present, the weakest point is the low return per unit of the flock. We keep a ewe for two years before she produces anything beyond a fleece, and in these days that is worth very little. Even when she is mature, we keep her for twelve months in order that she may breed a lamb or a lamb and a half, which she suckles for twelve or sixteen weeks. Thus the actively producing period is limited to about a quarter of the year: the product is perhaps 40–60 lb. of carcase. The cow, on the other hand, is producing milk for about ten months in the year.

The remedy often suggested is to keep sheep which will give two crops of lambs a year. Some breeds, of which the outstanding instances are the Merino, and, among British sheep, the Dorset Horn, will breed at almost any time, and this makes it possible to obtain two crops of lambs in a year. It is quite possible to secure this occasionally with other breeds, and I have no doubt that by selection and proper management of the ewes two crops could be obtained fairly regularly in flocks where the lambs are sold at an early age. The advocates of such a system very rightly point to the need for a better distribution of supplies throughout the year. At present there is a huge supply of lambs and sheep on the market from June to October, and very little from January to May. Moreover, the class of meat provided for the winter six months of the year is not the young milk-fed lamb for which there is most demand. They also urge that the production of young lamb in the present off season would enable the farmer to take advantage of the high prices which such lamb at present commands at that time of year. Obviously the argument is open to criticism, because we cannot have it both ways. If we equalise supplies we are likely to equalise prices, and no one would suggest that winter lamb can be produced at the same cost as summer lamb.

There is another possibility to be kept in mind. If means are found for placing New Zealand and South American lamb on the British market in such a state that it compares with our own summer lamb in freshness and condition, we shall be driven to concentrate more exclusively on summer production. In a world perfectly organised this would seem to be the natural way of exploiting fully the difference in the growing seasons of the Northern and Southern hemispheres.

Still, there is something to be said for two crops on farms where the grass land is all of good quality and there is no possibility of putting the ewes on to inferior, cheap pasture for the greater part of the year. In any case, there is no likelihood of winter supplies even approaching summer supplies, and the overhead costs are not greatly increased when the double crop of lambs is raised.

Need for greater prolificacy.—Perhaps a more hopeful way of making better use of the ewe's capabilities of production is by securing an increase in the lamb crop. The lamb crop for Great Britain, calculated from numbers on the farms on June 4, is only about 102 per cent., i.e. almost exactly one lamb from one ewe. Even allowing for the fact that a good many lambs are sold as early fat lambs before June 4, and for the large numbers on poor hill grazings where we do not want twins, this is a very poor result. On good lowland, a ewe rearing only one lamb will put on weight during the suckling period, and, unless she is to be sold for slaughter, this represents wasteful use of grass. A ewe of a good milking type can well rear two lambs on reasonably good grass, and if this were secured as an average on good land, our lamb crop over the country as a whole should be about 150 per cent. This would either give an increase of four or five millions on our present total, or allow of our present numbers to be reared on a much smaller area of land. This, surely, is one of the developments we may anticipate, and I think that we may also expect to see an increase in the practice of breeding from ewe lambs, so that under good conditions the almost unproductive period from twelve to twenty-four months may be eliminated.

Milking Ewes.—I sometimes wonder if we shall not return some day to the old system of milking sheep. A ewe which has had her lamb taken away in mid-June is just at the very height of her milk production, and would give a good deal of milk for a couple of months. Last summer in Norway I was told that girls in the saeters on the mountains each milk and make the cheese from a flock of sixty goats. It occurred to me that it would be just as easy to deal with a flock of twice the number of half-bred ewes on good enclosed land. The invention of a cheap and simple milking machine for sheep and goats might make the idea feasible, even in a country like this where we have come to despise small contributions to income, particularly if they involve work on Saturday afternoons or Sundays.

But in suggesting the possibility of a return to the old system of milking the ewes, I have in mind much more than the question of securing an additional return from the flock. When a heavy milking type of sheep is kept for early fat lamb production, one of the troubles experienced is the occurrence of what is now usually termed toxæmia of pregnancy, which is very often fatal and in some years causes enormous loss. This appears to be associated, among other conditions, with fatness in the ewes at the end of the summer, and, consequently, is encouraged by the practice of removing the lambs at an early age, so that the ewe has no outlet for her productive capacity during the summer.

Production of Wool.—The current price of wool makes the time opportune for considering how far we are wise in trying to combine wool and meat production. Wool is eminently one of the products best suited for production in remote parts of the world, where arable farming, and even meat production, are out of the question. Weight for weight, it is far more valuable than grain, and, unlike meat, it does not readily deteriorate in handling, storage and transport. Apart from the competition from such areas overseas, which shows no signs of slackening, there is the question of the diversion of food from the production of meat and milk. Wool, as taken off the sheep's back, consists mainly of protein and grease, with a little moisture and a certain amount of soil and other impurity. Allowing for the large percentage of water in fresh meat, one may guess that a fleece of 10 lb. represents the product of food capable of producing 15 or 20 lb. of saleable meat. At the present time the meat would be much more valuable, and the diversion of food from meat production to wool production must at the present prices of wool and meat be uneconomical.

Of course, I do not suggest that we should aim at doing away with the fleece altogether. If the sheep is to retain its character as an outdoor animal it must be protected against the weather, but a short, close fleece of, say, 2 or 3 lb. for small breeds and 4 or 5 lb. for the larger breeds would be adequate for this purpose. Actually, the argument against a large, long, heavy fleece is even stronger than I have stated, because it hampers the movement of the animal and does not give good protection against rain.

In days when most sheep were kept to a greater age and had long 'store' periods in which meat production was not particularly desired, the position was different. Now ewes are almost the only adult animals we keep, and the case is at least as strong if we consider the breeding ewe instead of the fattening animal. The young lamb will give a better return for extra protein and fat than the wool merchant will give for the same amount of similar substances in its fleece.

In this connection, I may refer to the fact that in many breeds, ewes with heavy, strong fleeces have not the best reputation for milk production and prolificacy.

Possible Changes in Function, Management and Demand.—One of the possibilities which must not be overlooked is a complete change in the purpose for which the sheep is required. Is it possible that the sheep which already does so much to meet the needs of man has products now almost disregarded which may in time become as important as meat or wool? We may certainly look forward to improvements in feeding, not only by better rationing of supplementary foods, but also by more skilful management of grassland. Is it possible that we may return to the practice of keeping at least a considerable proportion of our flocks in a way less wasteful of heat and energy on the part of the sheep? At present they must utilise a large proportion of their intake of nutriment in obtaining their food and maintaining their body heat. The housing or 'cotting' of sheep is no new idea. Shall we ever return to it on a large scale?

A more probable change is an alteration in demand. At present, lamb is the only form of sheep meat for which there is a real demand. It is difficult to sell mutton even from good quality yearling sheep, and old ewes can hardly be given away, but it is not inconceivable that new methods of cooking, or the establishment of a canning industry, or the need for greater national and individual economy, may again bring larger, older and fatter sheep to the front. If the consuming public are brought to take the same interest in food values that the intelligent farmer shows in the purchase of feeding stuffs, it seems unlikely that they will disregard the great differences in value for money at present provided by different classes of meat. Perhaps it would not be wise to push this suggestion too far. I fear that sheep farming would not be a distinctive feature of a vegetarian Britain!

Multiplicity of Breeds.—Of more immediate interest is the oft-debated question whether we need so many different breeds of sheep. Gervase Markham, in the account which I have quoted, mentioned six breeds. At the end of the eighteenth century we find a considerable increase. George Culley, for instance, describes the following: Leicester, Lincoln, Teeswater, Devon Natts, Exmoor, Dorset Horn, Herefords or Ryelands, Southdown, Norfolk, the Heath breed (Black-faces), Herdwickes, Cheviots, Spanish (Merino), Dun-faces and Shetlands. This list, however, was by no means complete, because he failed to mention such breeds as the Cotswolds, Wiltshires and Welsh, all of which were kept in considerable numbers; and, while we do not expect to find such names as Hampshires and Shropshires, it is surprising that he did not mention some of the local types from which these sprang.

Making these necessary additions, the list of British breeds existing at the end of the eighteenth century becomes quite a formidable one. Therefore, when we are accused of having far too many breeds of sheep, we can at least say that most of them were developed by our rather remote ancestors. We must, however, plead guilty to having increased, rather than reduced, the number, and I feel that I must consider briefly this multiplicity of breeds and discuss the necessity for maintaining so many.

Merino wool constitutes about 40 per cent. of the world's total clip, so that probably about one-third of all sheep are of this one type, and when we reflect that five or six breeds and their crosses probably comprise about half the sheep population of the world, it does seem absurd that we should maintain thirty or forty in a small country, with a sheep population of only 25 millions. The disadvantages, particularly from the point of view of marketing, are obvious.

There are, however, other aspects of the matter which I should like to submit. I have already pointed out that most of our breeds can be traced back at least as far as the eighteenth century. The end of the eighteenth and the first half of the nineteenth century was a period of wonderful development in British agriculture, which, in particular, occupied the attention of landowners who in those days carried out a tremendous amount of experimental work. One of the most popular forms of activity was that of endeavouring to substitute new and improved breeds of live-stock for old local breeds. Replacements did take place in some cases. The old Dun-faced breed was replaced over the greater part of the Highlands by the Black-face; Cheviots were established in the North of Scotland, and so on.

But these examples, though important in themselves, were, after all, exceptions to the general rule that in most cases the new introductions either had no effect or merely modified the existing breeds. They did not *replace* the local breeds. This is the more surprising when we remember that about this time there took place the great change in the relative importance of the functions which the sheep was required to serve. To-day, in Australia and New Zealand, the change over from wool production to meat production involves the replacement of the Merino by a mutton breed of sheep of altogether different origin and character. In this country, in the eighteenth century, the change from wool to mutton did not in the main involve the disappearance of the old breeds. They were modified, but retained their identity. To my mind, this suggests that so far we have failed to fathom the full significance of breed differences and breed distribution. We have paid great attention to meat and wool, but have failed to analyse fully the more basic vital characters on which the survival of semi-wild animals must largely depend. In the case of a sheep which spends its life completely out of doors and is dependent mainly on grass and other semi-natural food, there is almost certainly a delicate adjustment of the animal's physiology to the local environment. Hammond's recently published work on the growth of the sheep suggests all kinds of variables which may have to be fitted to corresponding differences of season, amount and composition of food, rate of growth of vegetation, and so forth. Ought we not to regard the animal's general physiology, including this special adjustment, as the element of fundamental importance on to which the more obvious characters of meat, wool and milk production have to be grafted? If so, is it not deserving of much more study than it has hitherto received?

It might be urged that great differences of environment also exist in other countries, but that they do not think it necessary to maintain special breeds for small areas. For instance, I imagine that the differences of soil and climate are probably no greater in Great Britain than those in New Zealand, and yet we have more than twice as many breeds. In reply to that, one might say that for all we know there may be as great variation in the sheep stock of New Zealand in fifty years' time as at the present time in this country.

Another point occurs to one after reading Hammond's book. The first requirement in our ordinary systems of stock improvement is variation. Maximum variation occurs under optimum conditions. In general it may be said that British conditions at their best are optimum conditions for the type of sheep we have developed. We have no long periods of drought, and, with good management, a generous food supply can be provided all the year round. It is largely because of this that we have in the past been able to do so much in the way of developing our various breeds of live stock. Attempts to standardise our stock too strictly would largely preclude advance in the future and nullify the suitability of our conditions for stock improvement. We have not yet reached finality in any direction.

Present conditions and market demands seem likely to lead to the disappearance of some of our breeds, but I hope that before the process goes very far, a detailed survey will be made of the relationship between the various breeds and the conditions to which each appears to be particularly suited, in the hope that thereby the peculiarities of the breeds may be tested and utilised in other parts of the world. We do not at present require their large size and fat meat, but it is possible that each possesses some special characters which we are not yet able to appreciate properly, but which may be of immense value elsewhere, even if they are no longer specially important in this country. It is pleasing to know that Nichols has already started such an investigation.

Disease.

It would be impossible for me to close my address without some reference to the importance of sheep diseases. In a detailed history of British agriculture, among the dates which would stand out most clearly would be the many years in which disastrous losses of sheep from disease have occurred, but I suspect that at all times what has been regarded as more or less normal loss has been even more important than the exceptional losses experienced periodically. In early days there is no doubt that this annual loss was extremely heavy. For instance, Thorold Rogers quotes records of about the end of the thirteenth century which show that on eight sheep-breeding estates with an average of 1,133 sheep, the average loss was 221, or close upon 20 per cent. He also points out that in the early days of the landlord and tenant system, the owner of the land insured the tenant against extraordinary losses of stock, particularly sheep.

From the earliest days of sheep farming in this country, liver fluke has been much the most important single cause of loss. I have already alluded to the fact that in 1879–81 it accounted for three or four million sheep, or 10 per cent. to 15 per cent. of our total population at the time. More recently, 1920–21, 1924–25, 1931–32 have all been periods of great loss, though more localised than the 1879–81 epidemic. Few things give me greater satisfaction than the reflection that it is largely due to the work at Bangor of my colleagues, Montgomerie and Walton, who followed up the researches of many workers, that this trouble, which has caused such untold losses to British agriculture for centuries, may now be combated with a good chance of success. Various workers have devised methods of control for the most important of the other parasites which infest our flocks, but there is still great need for much more research both on these and on the more obscure sheep diseases which, until quite recently, have received very little attention from veterinary workers.

Gaiger's work on braxy, Dalling's success in producing effective inoculations for the prevention of lamb dysentery, are striking illustrations of work which has already achieved a great measure of success in controlling diseases which twenty years ago were altogether elusive. We may hope that equally fruitful results will attend the investigations of the Diseases of Animals Research Association in Scotland on 'louping-ill' or 'trembling,' and the work of McEwan in Kent on 'strike.' Similarly those of us who are specially interested in hill sheep are eagerly watching the work of the Rowett Institute. But although the sheep farmer has reason to be grateful for the great advances of recent years, he knows that his annual loss is still great, and he feels that it is in this direction that research will be of greatest immediate help to him.

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REPORTS ON THE STATE OF SCIENCE,

ETC.

SEISMOLOGICAL INVESTIGATIONS.

Thirty-seventh Report of Committee (Dr. F. J. W. WHIPPLE, *Chairman*; Mr. J. J. SHAW, *Secretary*; Dr. C. VERNON BOYS, Dr. J. E. CROMBIE,[1] Sir F. W. DYSON, Sir R. T. GLAZEBROOK, Dr. WILFRED HALL, Dr. H. JEFFREYS, Sir H. LAMB, Prof. H. M. MACDONALD, Prof. E. A. MILNE, Mr. R. D. OLDHAM, Prof. H. H. PLASKETT, Prof. H. C. PLUMMER, Prof. A. O. RANKINE, Rev. J. P. ROWLAND, S.J., Prof. R. A. SAMPSON, Mr. F. J. SCRASE, Sir NAPIER SHAW, Capt. H. SHAW, Sir F. E. SMITH, Dr. R. STONELEY, Sir G. T. WALKER).

THIS is the thirty-seventh Report of the Committee appointed by the British Association for Seismological Investigations, the Committee having been formed in 1895 by the amalgamation of two committees. One of these committees had been appointed for the investigation of Earth Tremors in this country and had presented five reports, whilst the other, with John Milne as the moving spirit, had been investigating the Earthquakes and Volcanic Phenomena of Japan for fourteen years. Thus the British Association has given continuous support to seismology for fifty-one years.

Up to his death in 1913 the reports of the Committee were prepared by Milne, and from that date onwards to his own death in 1930 Prof. H. H. Turner, Chairman since 1907, was responsible not only for the reports but for the organisation of the greater part of the work recorded in them.

Since 1921, the year in which the Seismological Section of the International Geodetic and Geophysical Union was constituted, the principal care of the Committee has been the International Seismological Summary. This is a publication in which details are given of all the instrumental records of earthquakes occurring in any part of the world. Returns, known as seismological bulletins, are transmitted from all observatories to Oxford, where the observations for each day are transcribed on cards. By comparison of the observations the epicentre of every appreciable earthquake and the time of occurrence are determined. The distance of each observatory from the epicentre is computed, as well as the times of transmission of the waves which are revealed by the various phases of the seismograms. Finally, for the 'preliminary tremors,' which correspond with the primary waves of compression and distortion, the times of transmission are compared with standard tables. The results of these calculations are tabulated for printing and duly checked. It will be seen that the preparation of the Summary is a task of considerable magnitude. It occupies fully the time of three persons.

The International Seismological Summary was initiated and developed by Prof. Turner. He left the work well organised. In accordance with the wishes of the University authorities, the routine has been continued at the University Observatory during the two years that have elapsed since his death. His successor in the Savilian Chair of Astronomy, Prof. H. H.

[1] Dr. Crombie died on August 6, 1932.

Plaskett, was appointed in 1931 and has recently taken up his duties. Prof. Plaskett, who has been co-opted as a member of the Committee, is anxious that the seismological department of the Observatory shall remain a centre of the international organisation.

For the present satisfactory position of the work much credit is due to Mr. F. A. Bellamy, who has been in charge of the Observatory for two years, to Miss E. F. B. Bellamy, who has been editor of the Summary, to Mr. J. S. Hughes, who has been responsible for the determination of epicentres and the preparation of the manuscript, and to Mr. S. C. Cook, who has served as computer.

Responsibility for the financial arrangements for the production of the Summary has remained with the British Association Seismological Committee. The funds allotted by the International Seismological Association (to give the Seismological Section of the International Union for Geodesy and Geophysics its new name) have not sufficed hitherto to pay the cost of printing the Summary. During the year under review the International Seismological Association has provided £259, whilst the cost of printing four quarters of the International Seismological Summary has been £351. The British Association placed £250 at the disposal of the Committee, £150 from general funds and £100 from the Caird Fund. Roughly speaking, the £100 served to meet the deficit on the printing of the Summary, whilst the £150 was used for computing and for incidental expenses. The principal part of the cost of the preparation of the Summary was borne by the University of Oxford, generous assistance being given, however, by Dr. J. Crombie.

The Committee is informed that, for the present, no increase in the subvention from the International Seismological Association towards the cost of the International Seismological Summary is to be anticipated. It is found that considerable economy can be effected by adopting the 'Replika' process for reproducing the Summary, the cost of setting up the matter in printer's type being obviated. On the other hand, additional expenses must be incurred at Oxford.

In accordance with a resolution adopted by the Council in 1914, an annual grant of £100 is made to the Committee from the Caird Fund. To meet the special expenses of the year the Committee asks for an additional grant of £100.

The Committee is most anxious for the international seismological work to be maintained at Oxford, where it is so well organised, and hopes that, before the International Seismological Association meets next year, it will be possible to announce that the Seismological Department of the University Observatory has been put on a permanent footing. This will be the best way of recognising the part played by British scientists, by Mallet, Knott, Ewing, Oldham, Rayleigh, Love, Davison, and especially by Milne and Turner, in the development of seismology. The Committee would cordially welcome any proposal which might be made by the University of Oxford for establishing a Readership in Geophysics. No better memorial of the work of Prof. H. H. Turner could be conceived.

The International Seismological Summary and the Revised Seismological Tables.

Three quarterly issues of the International Seismological Summary were made during the year ending June 1932, those for the last quarter of 1927 and the first two quarters of 1928. The Summary for the third quarter of

1928 was published in July, and that for the fourth quarter was then in proof.

The following table showing the progress of the Summary has been prepared. The steady increase in the number of pages is mainly due to the growth in the number of well-equipped seismological stations.

Year of Summary.	Pages.	Epicentres.	Cost of Printing. £	Date of Printing.
1918	220	375	241	1922–24
1919	170	323	163	1924
1920	200	324	193	1924–25
1921	176	257	146	1925
1922	222	308	200	1925–26
1923	316	545	267	1926–27
1924	284	470	240	1927–28
1925	324	483	281	1928–29
1926	427	616	360	1929–30
1927	472	663	406	1930–31
1928	440	596	—	1931–32

The tables by Dr. Harold Jeffreys referred to in the last report have been published by the British Association, the cost being met by the Gray-Milne Fund. These tables were despatched from Oxford to all recipients of the Summary, as were two papers, one by Dr. Jeffreys alone, the other by Dr. Jeffreys and Dr. Comrie, dealing with the genesis of the tables.

The new tables are being used together with the accepted Zöppritz-Turner tables in the preparation of the International Seismological Summary for the year 1929. The Summary is to be published in such a form that comparisons between the merits of these and other tables will be facilitated.

Seismographs.

One of the tasks undertaken by the Seismological Committee in 1895 was the development of a seismograph suitable for general use in recording distant earthquakes. The instrument devised by Milne was found to serve its purpose, and a large number of such instruments was distributed to various parts of the world. The principal drawback to the Milne seismograph is the absence of any means of damping the oscillations of the pendulum. In 1912 Milne co-operated with Mr. J. J. Shaw in the design of the Milne-Shaw seismograph, a remarkably efficient machine. After preliminary trials the first Milne-Shaw instrument was brought into regular use at Bidston in 1914. Fifty-five Milne-Shaw seismographs have now been constructed. Of these five have been supplied to the Committee. The distribution of these is as follows :

Number of machine.	Location.	Date of installation.
4	Oxford	1918
6	Cape Town	1919
3	Edinburgh	1919
27	Perth, W. Australia	1923
1	Oxford	1926

The machine at Edinburgh was placed originally at Eskdalemuir in 1915 for comparison with the Galitzin seismographs, and was removed to Edinburgh in 1919. No. 1 was supplied to Mr. W. E. Plummer at Bidston in

1914. It was transferred to Oxford in exchange for No. 32 (see report, 1927).

Early in 1931 a letter was received from Dr. H. Spencer-Jones, H.M. Astronomer at the Cape, in which he expressed the opinion that the seismographic records at the Royal Observatory were of little value. Owing to the instability of the zero of the seismographs it had been necessary to keep the sensitivity very low. The Committee agreed with Dr. Jones's view that the instrument should be moved to another site, but considered it important that it should be kept in South Africa. Subsequently Dr. Grindley volunteered to erect the seismograph at the Cape Town University, which is several miles from the Observatory. In the basement of the University he found both microseisms and changes in zero relatively small. Prof. Alexander Brown, head of the Department of Applied Mathematics, has kindly undertaken to continue the observations until the end of the year 1932. If the results are satisfactory the seismograph will remain in operation at the University.

Mr. Shaw has supplied a Milne-Shaw seismograph to the Department of Geology, Liverpool University, where regular observations are to be commenced in September. Two Milne-Shaw seismographs are being despatched to the Department of Geology, University of Vermont.

Mr. Shaw has also made during the year a seismograph adapted for public exhibition. This instrument is set up on the third floor of the Store of Messrs. Selfridge & Co. Ltd. in London, and attracts much attention. On several occasions the public have watched whilst severe earthquakes were being recorded. The records are on smoked paper on an open scale. It is found that the pendulum, which is supported by one of the main stanchions of the building, is affected neither by traffic in the streets nor by the movement of people in the Store.

British Earthquakes.

In 1932, January 10, at 4.15, a slight earthshake was felt at two villages, Aylesham and Nonington, near Canterbury. Three distinct rumblings were heard below ground in the Snowdown mine, dust flew and hurt men's eyes, mice began to squeak, and the miners ran from the coal face. It is presumed that the earthshake was due to some collapse of old workings in the mine.

A small earthquake, which was felt in Yorkshire in 1932, May 25, at 22 h. G.M.T., was recorded by the seismographs at Stonyhurst and Durham, though not by those at Bidston and West Bromwich. The epicentre appears to have been in the Hope Valley near Sheffield.

Small disturbances not recorded by seismographs were reported by newspapers as occurring on the following dates :

1931, Dec. 18, Nottingham.
1932, Jan. 13, South Carnarvonshire.
1932, Jan. 16, Manchester.
1932, March 17, Oban.
1932, July 7, Shrewsbury.

Deep Focus Earthquakes.

The question of the depth of focus of earthquakes continues to occupy the attention of seismologists. As was mentioned in the last report of the Committee, records of the earthquake which occurred on February 20, 1931, were collected at Kew Observatory. A discussion of the records by Mr. F. J. Scrase will be published shortly. The focus of this earthquake, the epicentre of which was in Siberia near the Sea of Japan, was at a depth of 360 km. A good example of an earthquake with deep focus is dealt with in one of the recent issues of the International Seismological Summary.

For this earthquake, which had its epicentre in the New Hebrides, Mr. Hughes gives in the Summary the focal depth 0·04 of the earth's radius, or 250 km. Excellent confirmation is provided by a special investigation of this earthquake by Father Stechschulte of St. Louis.

High Focus Earthquakes.

That earthquakes with deep foci occur is now well established, but the significance of the observations which led Turner to attribute high foci to certain earthquakes is not yet known. A good example of such an earthquake was that of 1928, January 6, the epicentre of which was in East Africa, midway between Mt. Kenia and Mt. Elgin. Mr. Hughes gives the height of the focus as ·015 R or 100 km. It is certain that the focus of a normal earthquake is at a depth much less than 100 km., so that a height of 100 km. above the normal is not to be taken literally. The difficulty in interpreting the observations is that if the earthquake is treated as normal, the interval between P and S phases is at most stations about 10 seconds greater than that appropriate for the distance from the epicentre. The earthquake in question is to be studied by Mr. E. Tillotson, who is collecting original records, and it may be hoped that he will succeed in solving the mystery of the 'High Focus.'

The Surface Layers.

It is by the study of near earthquakes that information must be sought as to the usual depth of focus and as to the thickness of the layers of the earth's crust. There is at present a remarkable difference in practice between English investigators, who follow the method of Harold Jeffreys, and most seismologists abroad, who keep to the procedure developed by S. Mohorovičić. Calculations by the Jeffreys method lead to estimates of 10 km. for the thickness of the granite (which is generally overlaid by a kilometre or two of sedimentary rock) and 25 km. for the thickness of the intermediate rock between the granite and the ultrabasic rock which transmits the P and S waves. The alternative method has led to estimates of about 60 km. for the thickness of the two upper layers. The nature of the controversy as viewed by Jeffreys in 1928 is explained in the second edition of his book *The Earth*. Following papers by Tillotson and Mourant, in which the method of Jeffreys was used, there have been published in the year under review two papers by A. W. Lee, which consolidate the evidence. The success of the method depends on the detection of waves reflected at the ground or at the upper surface of the granite layer. The method has only been applied hitherto to small European earthquakes. It is to be hoped that reflected waves will be investigated in other regions, so that general agreement as to the merits of the alternative methods of interpretation of the seismological evidence may be reached.

Microseisms.

In continuation of the work summarised in the last report, Mr. Lee has investigated the theory of the propagation of surface waves over an area where there is a known thickness of sedimentary rock over granite. It appears that the larger microseisms are to be expected where the sedimentary rocks are of greater thickness. As far as Great Britain is concerned this conclusion is consistent with the geological evidence. Information is now being collected at Kew as to the microseismic disturbance in all parts of the world, so that the theory may be put to a thorough test.

Membership.

The Committee asks for reappointment, with the addition of Prof. P. G. H. Boswell, F.R.S., Mr. A. W. Lee and Mr. E. Tillotson. The confirmation of the election of Prof. H. H. Plaskett is desired. Sir Napier Shaw has notified his wish to retire from membership of the Committee.

Accounts, July 1931–June 1932.

General Account.

	£	s.	d.		£	s.	d.
Brought forward .	178	11	6	I.S.S.—Printing .	351	3	0
B.A. Caird Fund £100				Printing and Stationery	33	6	6
B.A. General Fund 150				Postage . . .	13	16	5
	250	0	0	Computing . .	87	16	11
U.G.G.I., for I.S.A. .	259	7	10				
Sale of I.S.S. . .	1	9	2		486	2	10
Bank Interest . .	0	3	3				
				Operation of Seismographs . . .	10	15	3
				Cheque stamps . .	0	10	0
					497	8	1
				Balance carried forward	192	3	8
	£689	11	9		£689	11	9

Liabilities—One quarter of I.S.S. passed for press } £200.
One quarter in proof }

Gray-Milne Trust Account.

	£	s.	d.		£	s.	d.
Brought forward .	311	4	6	Miss Bellamy (Honorarium) . . .	30	0	0
Trust Income . .	86	14	10	Reprints . . .	6	9	3
Bank Interest . .	7	9	5	Tables . . .	14	10	0
				Milne Library . .	10	15	3
				Insurance . . .	0	15	0
					62	9	6
				Balance carried forward	342	19	3
	£405	8	9		£405	8	9

MATHEMATICAL TABLES.

Report of Committee on Calculation of Mathematical Tables (Prof. E. H. NEVILLE, *Chairman*; Prof. A. LODGE, *Vice-Chairman*; Dr. L. J. COMRIE, *Secretary*; Dr. J. R. AIREY, Dr. R. A. FISHER, Dr. J. HENDERSON, Dr. J. O. IRWIN, Dr. E. S. PEARSON, Mr. F. ROBBINS, Dr. A. J. THOMPSON, Dr. J. F. TOCHER, and Dr. J. WISHART).

General activity.—Eight meetings of the Committee have been held, in London. Professors Love and Nicholson, Dr. Doodson and Mr. Whitwell, finding themselves unable to take an active part in the work of the Committee, did not accept reappointment.

The grant of £93 has been expended as follows:

	£	*s.*	*d.*
Calculations connected with Emden's equation . .	12	0	0
,, ,, ,, Legendre functions . .	38	15	0
Preparation of copy of tables of Bessel functions . .	21	10	0
Editorial and secretarial expenses	18	8	2
Unexpended balance	2	6	10

Volume I.—This volume of *Mathematical Tables*, which was in the press at the date of the last meeting of the Association, was published in November 1931, and is now on sale by the Association for 10*s*. a copy. One hundred copies were bound, and the demand for the volume has been steady. It was necessary to have a second hundred bound in March of this year.

Volume II.—This volume contains solutions of Emden's equation. The supervision of the calculations, the preparation of printer's copy and the work of seeing the volume through the press have been done by Mr. D. H. Sadler, to whom the Committee expresses its gratitude. The cost of printing this volume has been borne by the International Astronomical Union. The price is 7*s*. 6*d*.

Cunningham Bequest.—(*a*) The preparation of a table of reduced ideals and primitive units in real quadratic fields has been put in hand. Dr. E. L. Ince has undertaken the calculations.

(*b*) The Council has undertaken for Prof. L. E. Dickson, of Chicago, the publication and printing in England of his tables of the minimum decompositions of the numbers 1–300,000 into fifth powers.

Bessel functions.—A sub-committee (Drs. J. Henderson and J. O. Irwin) was formed to draw up a report on the tables of Bessel functions which have appeared in the reports, with a view to the possibility of their publication in one volume. Interim reports dealing with the more important of these tables have been drafted for consideration by the Committee. In many cases the tables will require to be extended and prepared for interpolation. Work on the preparation of a few of these tables has been carried out.

Legendre functions.—At the request of Prof. H. R. Hassé, the Committee has prepared 7-figure tables of the Legendre functions $P_n(x)$ up to $n = 12$ for $x = 1\cdot00(0\cdot01)6\cdot00$ and up to $n = 6$ for $x = 6\cdot0(0\cdot1)11\cdot0$. These tables are required in problems in quantum mechanics. They have been supplemented by values up to $n = 9$ for $x = 0\cdot00(0\cdot01)1\cdot00$, the values up to $n = 7$ being taken from the Committee's report for 1879. It has not been possible to publish the tables with this report, but they are available in manuscript.

Associated Legendre or Toroidal functions.—Preliminary theoretical work on these functions is being done by Dr. J. R. Airey. It is hoped that the calculations will be done next year.

Reappointment.—The Committee desires to be reappointed, with the addition of Mr. D. H. Sadler, and with a grant for general purposes of £50, which it is expected will be expended on the tables of associated Legendre functions and on work for the volume of Bessel functions.

PARACHORS.

Report of Committee appointed to collect and tabulate all available data on the Parachors of Chemical Compounds with a view to their subsequent publication (Dr. N. V. Sidgwick, *Chairman*; Dr. S. Sugden, *Secretary*; Dr. N. K. Adam).

Introductory Note.

This list has been prepared by a sub-committee of Section B of the British Association and gives data for 638 substances. It attempts to tabulate all the parachors which have been calculated and discussed down to June 1931.

The list is divided into two parts, dealing with inorganic and organic compounds respectively. The latter group includes all compounds which contain carbon. The inorganic list is arranged in alphabetical order of symbols, so that any compound can be found by rewriting its usual formula in alphabetical order. Thus sulphuryl chloride is written Cl_2O_2S and its parachor will be found in the part of the list beginning with C. The organic substances are arranged in the order used in Richter's well-known 'Lexicon.'

The references are grouped by years at the end of the list and the abbreviations are, in the main, those used in the *Journal* of the Chemical Society. Where two references follow a value of a parachor the first gives the paper in which the parachor is calculated and discussed, the second the paper in which the experimental values of the surface tension and density are recorded.

Inorganic Compounds in Alphabetical Order of Symbols.

A	Argon 54·0 *1929, 7, p. 186 ; 1902, 1 ; I.C.T.*
Ag	Silver 61·8 *1929, 7, p. 186 ; 1914, 4.*
AgCl	Silver chloride 98·8 *1929, 7, p. 186 ; 1916, 1.*
$AgNO_3$	Silver nitrate 157·2 *1929, 7, p. 186 ; 1917, 1.*
Al	Aluminium 55·0 *1929, 7, p. 174 ; 1916, 1.*
Al_2Br_6	Aluminium bromide 457·6 *1929, 8.*
$AsBr_3$	Arsenic tribromide 253·5 *1929, 2 ; 1917, 1.*
$AsCl_3$	Arsenic trichloride 212·0 *1929, 2 ; 1917, 1.*

Au	Gold 60·6 *1929, 7, p. 186 ; 1916, (1).*
BCl_3	Boron trichloride 178·8 *1928, 7 ; 1927, 5.*
$BaCl_2$	Barium chloride 215 *1929, 7, p. 187 ; 1904, 3.*
Bi	Bismuth 93·2 *1929, 7, p. 174 ; 1921, 4 ; 1928, 12.*
$BiBr_3$	Bismuth tribromide 283·9 *1929, 7, p. 188 ; 1917, 1.*
$BiCl_3$	Bismuth trichloride 236·9 *1929, 7, p. 188 ; 1917, 1.*
Br_2	Bromine 132·1 *1924, 1 ; 1911, 1.*
BrCs	Caesium bromide 207·5 *1929, 3 ; 1917, 1.*
BrH	Hydrobromic acid 85·4 *1927, 2 ; 1906, 1.*
$Br_2H_2O_2Se$	Selenium dihydroxy dibromide 248·5 *1931, 8.*
BrK	Potassium bromide 174·3 *1929, 3 ; 1917, 1.*
BrNa	Sodium bromide 143·8 *1929, 3 ; 1917, 1.*
Br_3P	Phosphorus tribromide 242·9 *1925, 1.*
BrRb	Rubidium bromide 192·7 *1929, 3 ; 1917, 1.*
Br_4Sn	Stannic bromide 325·8 *1929, 1.*
$CaCl_2$	Calcium chloride 177 *1929, 7, p. 187 ; 1904, 3.*
Cd	Cadmium 70·0 *1929, 7, p. 187 ; 1927, 6.*
Cl_2	Chlorine 111·5 *1924, 1 ; 1913, 4.* 104·6 *1930, 5*
Cl_2CrO_2	Chromyl chloride 199·1 *1928, 1.*
ClCs	Caesium chloride 188·7 *1929, 3 ; 1917, 1.*
ClH	Hydrochloric acid 67·3 *1927, 2 ; 1906, 1.*
$Cl_2H_2O_2Se$	Selenium dihydroxy dichloride 222·8 *1929, 2.* 218·9 *1931, 8.*
ClK	Potassium chloride 156·6 *1929, 3 ; 1917, 1.*
ClLi	Lithium chloride 98·4 *1929, 3 ; 1917, 1.*
ClNa	Sodium chloride 124·8 *1929, 3 ; 1917, 1.*
ClNO	Nitrosyl chloride 108·1 *1924, 1 ; 1912, 2.*
ClO_2	Chlorine peroxide 98·7 *1930, 3.*
Cl_3OP	Phosphorus oxychloride 217·6 *1925, 1.* 217·6 *1893, 2.*
$Cl_{10}O_2P_2Sn$	Additive compound $SnCl_4.2POCl_3$ 689·7 *1929, 1.*
Cl_2OS	Thionyl chloride 172·5 *1893, 2.* 174·5 *1925, 1.*
Cl_2O_2S	Sulphuryl chloride 187·0 *1893, 2.* 193·3 *1925, 1.*
Cl_2OSe	Selenium oxychloride 181·1 *1929, 2.*
Cl_3P	Phosphorus trichloride 199·0 *1911, 1.* 201·1 *1893, 2.*
Cl_5P	Phosphorus pentachloride 282·5 *1927, 2.*
Cl_2Pb	Lead chloride 194·5 *1929, 3 ; 1908, 2.*
ClRb	Rubidium chloride 182·8 *1929, 3 ; 1917, 1.*
Cl_2S_2	Sulphur monochloride 205·1 *1925, 1 ; 1893, 2.* 204·3 *1929, 4 ; 1925, 1 ; 1893, 2.* 205·5 *1930, 5.*
Cl_3Sb	Antimony trichloride 227·4 *1927, 2.*
Cl_5Sb	Antimony pentachloride 311·8 *1927, 2.*
Cl_4Sn	Stannic chloride 272·8 *1929, 1.*
Cl_4Ti	Titanium tetrachloride 262·5 *1929, 1.*
$Cr_2K_2O_7$	Potassium dichromate 450·8 *1928, 1 ; 1917, 1.*
CsF	Caesium fluoride 136·9 *1929, 3 ; 1917, 1.*
CsI	Caesium iodide 242·4 *1929, 3 ; 1917, 1.*
$CsNO_3$	Caesium nitrate 218·0 *1929, 3 ; 1917, 1.*
Cs_2O_4S	Caesium sulphate 388·8 *1929, 3 ; 1917, 1.*
Cu	Copper 46 *1929, 7, p. 186 ; 1914, 4 ; 1927, 7.*
FLi	Lithium fluoride 58·5 *1929, 3 ; 1917, 1.*
FK	Potassium fluoride 109·0 *1929, 3 ; 1917, 1.*
FNa	Sodium fluoride 82·7 *1929, 3 ; 1917, 1.*
FRb	Rubidium fluoride 123·1 *1929, 3 ; 1917, 1.*
Ga	Gallium 50·0 *1929, 7, p. 187 ; 1921, 3.*
H_2	Hydrogen 35·2 *1924, 1 ; 1914, 1.*

He Helium 20·5 *1929, 7, p. 186 ; 1925, 5.*

Hg Mercury 68·0 *1929, 3 ; 1914, 4.* 69·0 *1929, 3 ; 1929, 5.* 69·4 *1929, 3 ; 1921, 4.* 69·4 *1929, 3 ; 1928, 12 & 13.*

HI Hydriodic acid 105·3 *1927, 2 ; 1906, 1.*

H_3N Ammonia 60·7 *1929, 7, p. 170.*

HNO_3 Nitric acid 105·0 *1929, 7, p. 169 ; 1908, 1.*

H_2O Water 52·3 *1929, 7, p. 169 ; I.C.T.*

H_2O_2 Hydrogen peroxide 69·6 *1924, 1 ; 1920, 3.*

H_2O_4S Sulphuric acid 144·8 (10°), 152·3 (132·5°) *1929, 7, p. 169 ; 1908, 1.* 143·7 *1929, 4 ; 1911, 5.*

H_2S Hydrogen sulphide 82·9 *1930, 9.*

H_2S_2 Hydrogen disulphide 130·0 *1930, 9.*

IK Potassium iodide 205·2 *1929, 3 ; 1917, 1.*

INa Sodium iodide 170·8 *1929, 3 ; 1917, 1.*

IRb Rubidium iodide 226·8 *1929, 3 ; 1917, 1.*

K_2MoO_4 Potassium molybdate 367 *1929, 7, p. 189 ; 1917, 1.*

KNO_3 Potassium nitrate 189·0 *1929, 3 ; 1917, 1.*

KO_3P Potassium metaphosphate 204·4 *1929, 3 ; 1917, 1.*

K_2O_4W Potassium tungstate 373 *1929, 7, p. 189 ; 1917, 1.*

$LiNO_3$ Lithium nitrate 131·5 *1929, 3 ; 1917, 1.*

Li_2O_4S Lithium sulphate 216·0 *1929, 3 ; 1917, 1.*

$MoNa_2O_4$ Sodium molybdate 288 *1929, 7, p. 189 ; 1917, 1.*

N_2 Nitrogen 60·4 *1924, 1 ; 1902, 1.*

Na Sodium 97·4 *1929, 3 ; 1926, 3.*

NaO_3P Sodium metaphosphate 178·1 *1929, 3 ; 1917, 1.*

Na_2O_4S Sodium sulphate 261·1 *1929, 3 ; 1917, 1.*

Na_2O_4W Sodium tungstate 300 *1929, 7, p. 189 ; 1917, 1.*

Ne Neon 25·0 *1929, 7, p. 186 ; 1925, 6.*

$NNaO_3$ Sodium nitrate 152·9 *1929, 3 ; 1917, 1.*

N_2O Nitrous oxide 81·1 *1929, 7, p. 170 ; 1904, 2.* 80·0 *1930, 10.*

N_2O_4 Nitrogen peroxide 144·4 *1925, 1 ; 1893, 2.*

NO_3Rb Rubidium nitrate 197·9 *1929, 3 ; 1917, 1.*

NO_3Tl Thallous nitrate 177·3 *1929, 8.* 180·7 *1929, 8 ; 1917, 1.*

O_2 Oxygen 54·0 *1924, 1 ; 1902, 1.*

O_4Os Osmium tetroxide 154·0 *1925, 1 ; 1924, 3.*

O_4Rb_2S Rubidium sulphate 361·8 *1929, 3 ; 1917, 1.*

O_2S Sulphur dioxide 101·5 *1929, 7, p. 170 ; 1904, 2.*

O_3S Sulphur trioxide 103·6 *1929, 7, p. 170 ; 1901, 1 ; 1922, 1.*

Pb Lead 114·2 *1929, 3 ; 1914, 4.* 89·3 *1929, 3 ; 1921, 4.* 91·5 *1929, 3 ; 1927, 6.* 93·5 *1929, 3 ; 1927, 7.*

S Sulphur 49·4 *1929, 7, p. 166 ; 1918, 1.*

Sb Antimony 76·8 *1929, 3 ; 1914, 4.* 82·0 *1929, 3 ; 1927, 6.* 83·9 *1929, 3 ; 1927, 7.*

Sn Tin 83·4 *1929, 3 ; 1914, 4.* 83·8 *1929, 3 ; 1927, 6.* 86·8 *1929, 3 ; 1926, 2.*

Zn Zinc 50·7 *1929, 7, p. 187 ; 1928, 12.* 58·0 (?) *1929, 7, p. 187 ; 1914, 4.*

ORGANIC COMPOUNDS.

C_1

CO	Carbon monoxide 61·6 *1929, 7, p. 170 ; 1902, 1.*
CO_2	Carbon dioxide 77·5 *1929, 7, p. 170 ; 1927, 4.*
CCl_4	Carbon tetrachloride 219·9 *1924, 1 ; 1893, 1.* 220·0 *1924, 1 ; 1884, 1.* 218·5 *1924, 1 ; 1911, 3.* 219·8 *1924, 1 ; 1920, 2.* 219·8 *1931, 6.*
CS_2	Carbon disulphide 144·7 *1925, 1 ; 1893, 2.* 143·6 *1925, 1 ; 1911, 1, 3.* 142·9 *1925, 1 ; 1920, 2.* 143·6 *1931, 6.*
$COCl_2$	Phosgene 151·6 *1929, 4 ; 1920, 4.*
CCl_4S	Thiocarbonyl tetrachloride 266·1 *1929, 14.*
CBr_4S	Thiocarbonyl tetrabromide 316·4 *1929, 14.*
$CSSe$	Carbon selenosulphide 156·4 *1929, 10.*
$CHCl_3$	Chloroform 183·4 *1924, 1 ; 1921, 2.* 183·4 *1924, 1 ; 1884, 1.* 182·4 *1924, 1 ; 1911, 3.* 183·5 *1924, 1 ; 1920, 2.* 183·4 *1931, 6.*
$CHBr_3$	Bromoform 221·9 *1929, 4 ; I.C.T.*
CHN	Hydrocyanic acid 81·5 *1929, 7, p. 170.*
CH_2O_2	Formic acid 93·3 *1929, 6.* 93·2 *1931, 6.*
CH_2Cl_2	Methylene dichloride 143·0 *1924, 1 ; 1920, 2.* 147·6 *1931, 6.*
CH_3I	Methyl iodide 146·2 *1931, 6.*
CH_4O	Methyl alcohol 88·8 *1928, 4.* 88·7 *1929, 7, p. 167.* 88·0 *1931, 6.*
CH_5N	Methylamine 95·9 *1929, 7, p. 170 ; 1917, 1.*
CO_2NCl_3	Chloropicrin 236·8 *1929, 4 ; 1884, 1.*
CHO_2Tl	Thallous formate 150·3 *1929, 8.*
$CHCl_2Br$	Dichlorobromomethane 196·8 *1924, 1 ; 1912, 1.*
CH_3O_2N	Nitromethane 132·1 *1924, 1 ; 1920, 2.* 132·0 *1924, 1 ; 1913, 2.* 132·2 *1931, 6.*

C_2

C_2H_2	Acetylene 88·6 *1924, 1 ; 1921, 1.*
C_2H_4	Ethylene 99·5 *1924, 1 ; 1921, 1.*
C_2H_6	Ethane 110·5 *1924, 1 ; 1921, 1.*
C_2HCl_5	Pentachloroethane 292·3 *1931, 6.*
$C_2H_2Cl_4$	Acetylene tetrachloride 259·0 *1924, 1 ; 1912, 1.* 261·0 *1931, 6.*
$C_2H_2Br_4$	Acetylene tetrabromide 311·0 *1924, 1 ; 1912, 1.* 309·8 *1924, 1 ; 1920, 2.* 310·4 *1929, 2 ; I.C.T.*
C_2H_3N	Acetonitrile 122·2 *1924, 1 ; 1913, 1.* 121·6 *1931, 6.*
	Methyl isocyanide 122·1 *1930, 6.*
C_2H_4O	Ethylene oxide 112·5 *1927, 1 ; 1922, 1.*
$C_2H_4O_2$	Acetic acid 133·5 *1929, 7, p. 169.* 130·8 *1929, 6.* 131·2 *1929, 4 ; I.C.T.* 131·0 *1931, 6.*
	Methyl formate 138·6 *1924, 1 ; 1893, 1.* 137·7 *1924, 1 ; 1911, 4.*
$C_2H_4Cl_2$	Ethylene dichloride 189·3 *1924, 1 ; 1884, 1.* 189·1 *1924, 1 ; 1911, 1.* 188·3 *1931, 6.*

$C_2H_4Cl_2$	Ethylidene dichloride 188·5 *1924, 1; 1884, 1.* 188·6 *1924, 1; 1911, 1.* 191·9 *1931, 6.*
$C_2H_4Br_2$	Ethylene dibromide 215·7 *1924, 1; 1911, 3.* 215·1 *1924, 1; 1920, 2.* 215·5 *1929, 4; I.C.T.* 213·0 *1931, 6.*
C_2H_5Cl	Ethyl chloride 151·6 *1931, 6.*
C_2H_5Br	Ethyl bromide 167·6 (?) *1924, 1; 1920, 2.* 165·7 *1931, 6.*
C_2H_5I	Ethyl iodide 187·0 *1931, 6.*
C_2H_6O	Ethyl alcohol 127·5 *1929, 7, p. 167.* 127·3 *1928, 4.* 126·8 *1929, 4; I.C.T.* 126·6 *1931, 6.*
C_2H_6S	Ethyl mercaptan 162·9 *1925, 1; 1913, 1.*
C_2H_7N	Dimethylamine 136·6 *1929, 4; 1917, 1.*
	Ethylamine 137·4 *1929, 4; 1917, 1.*
$C_2H_3O_2Tl$	Thallous acetate 183·5 *1929, 8.*
C_2H_3NS	Methyl thiocyanate 168·6 *1925, 1; 1884, 1.* 170·2 *1929, 9.*
C_2H_5ON	Acetamide 148·0 *1924, 1; 1910, 1.*
	Acetaldoxime 145·4 *1929, 4; I.C.T.*
C_2H_5OTl	Thallous ethylate 177·3 *1929, 8.*
$C_2H_5O_2N$	Nitroethane 171·2 *1929, 4.*
$C_2H_5O_3N$	Ethyl nitrate 189·6 *1924, 1; 1913, 2.*
$C_2H_6ON_2$	Dimethylnitrosoamine 183·8 *1924, 1; 1913, 2.* 184·8 *1924, 1; 1910, 1.*
$C_2H_6O_4S$	Dimethyl sulphate 238·9 *1925, 1.*
$C_2H_6Cl_2Tl$	Dimethyltelluridichloride 282·5 *1929, 11.*
$C_2H_8O_3N_2$	Dimethylammonium nitrate 249·7 *1929, 3; 1914, 3.*
	Ethylammonium nitrate 239·2 *1929, 3.* 234·9 *1914, 3.*

C_3

C_3H_4	Allylene 122·9 *1924, 1; 1921, 1.*
C_3H_6	Propylene 139·9 *1924, 1; 1921, 1.*
C_3H_8	Propane 150·8 *1924, 1; 1921, 1.*
C_3H_5N	Propionitrile 160·5 *1931, 6.*
	Ethylisocyanide 164 *1930, 7.*
C_3H_6O	Allyl alcohol 152·7 *1928, 4.* 153·8 *1931, 6.*
	Acetone 161·7 *1924, 1; 1915, 1.* 162·0 *1924, 1; 1884, 1.* 160·9 *1924, 1; 1911, 2.* 161·5 *1929, 4; I.C.T.* 161·5 *1931, 6.*
$C_3H_6O_2$	Propionic acid 168·7 *1929, 6.* 169·0 *1929, 4; I.C.T.* 169·0 *1931, 6.*
	Ethyl formate 178·4 *1924, 1; 1884, 1.* 177·0 *1924, 1; 1911, 4.*
	Methyl acetate 177·2 *1924, 1; 1884, 1.* 176·7 *1924, 1; 1911, 4.*
C_3H_7Cl	*n*-Propyl chloride 190·2 *1924, 1; 1884, 1.* 187·0 *1931, 6.*
C_3H_7Br	*n*-Propyl bromide 205·3 *1931, 6.*
	i-Propyl bromide 205·1 *1931, 6.*
C_3H_7I	*n*-Propyl iodide 226·0 *1931, 6.*
C_3H_8O	*n*-Propyl alcohol 165·4 *1929, 4; I.C.T.* 165·8 *1928, 4.* 164·7 *1931, 6.*
	i-Propyl alcohol 164·3 *1931, 6.*
$C_3H_8O_2$	Methylal 189·8 *1931, 6.*

C_3H_9N *n*-Propylamine 178·5 *1924, 1; 1910, 1.*
Trimethylamine 177·6 *1929, 4; 1917, 1.*
$C_3H_4ON_2$ Diazoacetone 191·9 *1930, 1.*
$C_3H_4O_2N_2$ Methyl diazo-acetate 207·2 *1930, 1.*
$C_3H_4OCl_2$ α-α-Dichloroacetone 244·1 *1924, 1; 1920, 2.*
$C_3H_5ON_3$ Triazoacetone 220·9 *1928, 10.*
C_3H_5OCl Epichlorohydrin 193·7 *1927, 1.*
α-Chloracetone 192·7 *1924, 1; 1920, 2.*
$C_3H_5O_2Cl$ Ethyl chlorocarbonate 216·9 *1929, 4; 1893, 2.*
C_3H_5NS Ethyl thiocyanate 210·7 *1925, 1; 1893, 2.* 209·1 *1925, 1; 1913, 1.*
Ethyl isothiocyanate 211·7 *1925, 1; 1913, 1.* 211·5 *1929, 9.*
C_3H_7ON Propionamide 181·2 *1924, 1; 1910, 1.*
$C_3H_7O_2N$ Ethyl carbamate 202·2 *1924, 1; 1910, 1.*
$C_3H_9O_3B$ Methyl borate 243·7 *1928, 7.*

C_4

C_4H_{10} *n*-Butane 190·3 *1929, 4; 1928, 3.*
C_4O_4Ni Nickel carbonyl 250·8 *1929, 7, p. 189; 1893, 2.*
C_4H_4S Thiopene 189·3 *1929, 4; I.C.T.; 1928, 11.* 189·3 *1931, 1.*
C_4H_4Se Selenophene 210·6 *1928, 9.*
C_4H_5N Pyrrol 164·7 *1931, 1.*
$C_4H_6O_3$ Acetic anhydride 225·6 *1931, 6.*
C_4H_7N *n*-Butyronitrile 201·2 *1924, 1; 1920, 2.* 198·9 *1924, 1; 1910, 1.* 199·7 *1924, 1; 1913, 1.* 199·3 *1931, 6.*
C_4H_8O Methyl ethyl ketone 198·2 *1924, 1; 1911, 2.* 198·8 *1929, 4; I.C.T.*
$C_4H_8O_2$ *n*-Butyric acid 209·1 *1929, 6.*
i-Butyric acid 207·8 *1929, 6.*
n-Propyl formate 224·4 (?) *1924, 1; 1884, 1.* 216·1 *1924, 1; 1911, 4.*
Ethyl acetate 217·1 *1924, 1; 1893, 1.* 217·8 *1924, 1; 1884, 1.* 215·6 *1924, 1; 1911, 4.* 216·9 *1929, 4; I.C.T.* 215·7 *1931, 6.*
$C_4H_8O_2$ Methyl propionate 215·1 *1924, 1; 1884, 1.* 214·9 *1924, 1; 1911, 4.*
C_4H_8Se *cyclo* Selenobutane 229·5 *1929, 12.*
C_4H_9Cl *n*-Butyl chloride 230·5 *1931, 6.*
i-Butyl chloride 228·4 *1931, 6.*
C_4H_9Br *n*-Butyl bromide 243·5 *1931, 6.*
i-Butyl bromide 243·8 *1931, 6.*
C_4H_9I *n*-Butyl iodide 264·7 *1931, 6.*
i-Butyl iodide 265·0 *1931, 6.*
$C_4H_{10}O$ *n*-Butyl alcohol 202·9 *1928, 4.* 203·4 *1931, 6.*
i-Butyl alcohol 202·1 *1929, 4; I.C.T.* 200·6 *1931, 6.*
sec-Butyl alcohol (methyl ethyl carbinol) 201·9 *1931, 6.*
tert-Butyl alcohol (trimethylcarbinol) 201·0 *1931, 6.*
Di-ethyl ether 211·7 *1924, 1; 1893, 1.* 211·9 *1924, 1; 1884, 1.* 209·5 *1924, 1; 1911, 3.* 211·2 *1931, 6.*
$C_4H_{10}O_2$ Dimethyl acetal 226·0 *1924, 1; 1884, 1.*
$C_4H_{11}N$ *i*-Butylamine 216·1 *1929, 4; 1884, 1.*

$C_4H_4O_2Cl_2$	Succinyl chloride 282·6 *1927, 3.*
$C_4H_4Cl_4S$	Tetrachlorovinylethylsulphide 374·1 *1928, 8.*
$C_4H_5O_2Cl_3$	Ethyl trichloroacetate 327·6 *1929, 4; I.C.T.*
C_4H_5NS	Allyl isothiocyanate 232·4 *1925, 1; 1913, 1.* 230·5 *1929, 9.*
$C_4H_5Cl_3S$	Trichlorovinylethylsulphide 338·4 *1928, 8.*
$C_4H_6O_2N_2$	Ethyl diazo-acetate 248·3 *1930, 1.*
$C_4H_6O_2Cl_2$	Ethyl dichloroacetate 291·7 *1929, 4; 1884, 1.*
$C_4H_7O_2N_3$	Triazo-acetic ester 277·0 *1928, 10.*
$C_4H_7O_2Cl$	Ethyl chloroacetate 252·1 *1929, 4; 1884, 1.*
C_4H_8OSe	1 : 4 Selenoxan 245·2 *1930, 4.*
$C_4H_9O_2N$	*n*-Butylnitrite 251·8 *1925, 1.*
$C_4H_{10}ON_2$	Diethylnitrosoamine 260·3 *1924, 1; 1910, 1.*
$C_4H_{10}O_3S$	Diethyl sulphite 299·7 *1912, 1.*
	Ethyl ethanesulphonate 295·8 *1912, 1.*
$C_4H_{10}O_4S$	Diethyl sulphate 313·8 *1925, 1.*
$C_4H_{10}Br_2Te$	β-Diethyl telluridibromide 377·3 *1929, 11.*
$C_4H_{10}I_2Te$	α-Diethyl telluridi-iodide 425·0 *1929, 11.*
$C_4H_{12}O_3N_2$	Di-ethyl ammonium nitrate 324·8 *1929, 3; 1914, 3.*
$C_4H_{12}O_4Si$	Methyl orthosilicate 330·9 *1931, 2.*

C_5

C_5H_{10}	Amylene 218·2 *1924, 1; 1884, 1.*
	β-*iso*-Amylene 216·9 *1929, 4.*
C_5H_{12}	*i*-Pentane 230·0 *1931, 6.*
$C_5H_4O_2$	Furfural 212·9 *1924, 1; 1913, 2.*
C_5H_5N	Pyridine 199·8 *1924, 1; 1911, 3.* 199·7 *1929, 4; I.C.T.*
C_5H_8O	*cyclo*Pentanone 214·2 *1928, 6.*
$C_5H_8O_2$	Acetylacetone 240·7 *1924, 1; 1913, 1.* 245·4 *1929, 8.*
$C_5H_8O_3$	Laevulinic acid 258·6 *1929, 4; 1917, 1.*
$C_5H_8O_4$	Dimethyl malonate 283·1 *1931, 1.*
C_5H_9N	*n*-Valeronitrile 236·6 *1924, 1; 1913, 1.* 237·4 *1931, 6.*
	i-Valeronitrile 237·3 *1924, 1; 1920, 2.* 237·4 *1931, 6.*
$C_5H_{10}O$	*i*-Valeraldehyde 237·5 *1929, 4; 1884, 1.*
	Diethyl ketone 236·2 *1924, 1; 1911, 2.*
	Methyl-*n*-propylketone 233·0 (?) *1924, 1; 1915, 1.* 238·0 *1913, 2.*
$C_5H_{10}O_2$	*n*-Valeric acid 247·0 *1931, 6.*
	i-Butyl formate 262·4 *1924, 1; 1884, 1.*
	n-Propyl acetate 257·1 *1924, 1; 1884, 1.* 255·0 *1924, 1; 1911, 4.*
	Ethyl propionate 255·2 *1924, 1; 1884, 1.* 254·4 *1924, 1; 1911, 4.* 254·0 *1931, 6.*
	Methyl butyrate 254·1 *1924, 1; 1884, 1.* 254·3 *1924, 1; 1911, 4.*
	Methyl *iso*-butyrate 253·1 *1924, 1; 1884, 1.* 253·5 *1924, 1; 1911, 4.*
$C_5H_{10}O_3$	Ethyl lactate 268·5 *1929, 4; I.C.T.*
	Diethyl carbonate 277·4 *1925, 1.* 274·9 *1931, 6.*
$C_5H_{10}Se$	*cyclo* Selenopentane 264·2 *1929, 13.*
$C_5H_{11}N$	Piperidine 231·5 *1924, 1; 1911, 2.*

$C_5H_{11}C$ *n*-Amyl chloride 270·4 *1931, 6.*
i-Amyl chloride 269·8 *1924, 1; 1920, 2.*
$C_5H_{11}Br$ *n*-Amyl bromide 283·6 *1931, 6.*
i-Amyl bromide 282·9 *1931, 6.*
$C_5H_{12}O$ *n*-Amyl alcohol 243·3 *1931, 6.*
i-Amyl alcohol 241·4 *1931, 6.*
tert-Amyl alcohol 241·1 *1929, 4; I.C.T.* 238·0 *1931, 6.*
Ethyl-*n*-propylether 252·0 *1924, 1; 1913, 2.*
$C_5H_{13}N$ *tert*-Amylamine 252·3 *1929, 4; 1917, 1.*
$C_5H_6O_2N_2$ Diazo-acetylacetone 274·9 *1930, 1.*
$C_5H_6O_3N_2$ Methyl diazo-acetoacetate 295·0 *1930, 1.*
$C_5H_6O_4N_2$ Methyl diazomalonate 305·4 *1930, 1.*
$C_5H_7O_2N$ Ethyl cyano-acetate 262·1 *1929, 4; 1912, 1.*
C_5H_9NS Butyl-*iso*thiocyanate 281·6 *1929, 9.*
$C_5H_{11}O_2N$ *i*-Amyl nitrite 287·4 *1925, 1.*
$C_5H_7O_2BF_2$ Acetylacetoneborondifluoride 300·6 *1929, 8.*

C_6

C_6H_6 Benzene 206·3 *1924, 1; 1893, 1.* 206·1 *1924, 1; 1884, 1.* 206·0 *1929, 4.* 205·7 *1931, 6.*
C_6H_{10} Di-allyl 248·2 *1924, 1; 1884, 1.*
C_6H_{12} Methyl-*cyclo*-pentane 242·8 *1924, 1; 1904, 1.*
cyclo-Hexane 239·3 *1929, 4.* 241·8 *1931, 6.*
C_6H_{14} *n*-Hexane 270·1 *1924, 1; 1884, 1.* 273·3 *1924, 1; 1913, 1.* 270·4 *1929, 4.* 270·4 *1931, 6.*
$C_6H_4O_2$ *p*-Benzoquinone 236·8 *1927, 3.*
$C_6H_4Cl_2$ *p*-Dichlorobenzene 279·5 *1924, 2; 1924, 1.*
$C_6H_5N_3$ Phenyl azoimide 267·3 *1928, 10.*
C_6H_5F Fluorobenzene 214·3 *1924, 1; 1911, 1.*
C_6H_5Cl Chlorobenzene 244·5 *1924, 1; 1893, 1.* 244·9 *1924, 1; 1911, 3.* 243·9 *1924, 1; 1920, 2.* 244·1 *1931, 6.*
C_6H_5Br Bromobenzene 260·6 *1924, 2; 1924, 1.* 258·0 *1924, 1; 1911, 1.* 257·8 *1931, 6.*
C_6H_5I Iodobenzene 282·3 *1924, 2; 1924, 1.* 280·7 *1924, 1; 1911, 1.*
C_6H_6O Phenol 220·2 *1928, 4.* 221·3 *1929, 4; I.C.T.* 222·3 (49·6°), 224·8 (147·5°) *1930, 8.*
C_6H_6S Phenyl mercaptan 257·5 *1925, 1; 1912, 1.* 256·4 *1925, 1; 1913, 1.*
C_6H_7N Aniline 235·7 *1924, 2.* 234·4 *1929, 4; I.C.T.* 232·7 *1931, 6.*
$C_6H_8O_4$ Dimethyl fumarate 308·5 *1925, 2.*
Dimethyl maleate 309·6 *1925, 2.*
$C_6H_8N_2$ Phenyl hydrazine 255·7 *1924, 1; 1910, 1.* 255·9 *1924, 1; 1913, 1.* 257·1 *1931, 1.*
$C_6H_{10}O$ *cyclo*-Hexanone 251·4 *1928, 6.*
$C_6H_{10}O_2$ Propionylacetone 279·7 *1929, 8.*
$C_6H_{10}O_3$ Ethyl aceto-acetate 302·0 *1931, 1.*
$C_6H_{10}O_4$ Diethyloxalate 323·4 *1924, 1; 1913, 1.* 322·2 *1931, 6.*
$C_6H_{11}N$ *n*-Capronitrile 276·6 *1931, 6.*
i-Butylacetonitrile 275·0 *1924, 1; 1910, 1.*
$C_6H_{12}O$ Pinacoline 273·4 *1929, 4; I.C.T.*
cyclo-Hexanol 254·9 *1929, 4; 1913, 5; 1924, 5.*

$C_6H_{12}O_2$	*n*-Hexoic acid 287·2 *1929, 6.*
	i-Amyl formate 303·8 (?) *1924, 1 ; 1884, 1.* 293·7 *1924, 1 ; 1911, 4.* 293·6 *1924, 1 ; 1913, 3.*
	i-Butyl acetate 300·0 (?) *1924, 1 ; 1884, 1.* 295·1 *1924, 1 ; 1911, 1.*
	n-Propyl propionate 295·3 *1924, 1 ; 1884, 1.*
	Ethyl butyrate 293·9 *1924, 1 ; 1884, 1.* 293·0 *1924, 1 ; 1911, 3.* 294·2 *1924, 1 ; 1915, 2.*
	Ethyl *iso*-butyrate 292·9 *1924, 1 ; 1884, 1.*
	Methyl valerate 292·5 *1924, 1 ; 1884, 1.*
$C_6H_{12}O_3$	Paracetaldehyde 299·0 *1924, 1 ; 1884, 1.* 298·5 *1924, 1 ; 1913, 2.*
$C_6H_{12}Se$	*cyclo* Selenohexane 302·1 *1931, 3.*
	2-Methyl *cyclo* selenopentane 304·2 *1931, 3.*
$C_6H_{13}Br$	*n*-Hexyl bromide 322·8 *1931, 6.*
$C_6H_{13}I$	*n*-Hexyl iodide 344·1 *1931, 6.*
$C_6H_{14}O$	*n*-Hexyl alcohol 276·2 *1931, 6.*
	Di-*n*-propylether 290·9 *1931, 6.*
$C_6H_{14}O_2$	Diethyl acetal (Ethylal) 306·9 *1924, 1 ; 1884, 1.* 305·7 *1931, 6.*
$C_6H_{15}N$	Dipropylamine 297·3 *1924, 1 ; 1910, 1.* 297·2 *1929, 1 ; I.C.T.*
C_6H_4ClBr	*p*-Chlorobromobenzene 292·5 *1924, 2 ; 1924, 1.*
C_6H_4ClI	*p*-Chloro-iodobenzene 316·4 *1924, 2 ; 1924, 1.*
$C_6H_5O_2N$	Nitrobenzene 264·5 *1924, 2 ; 1924, 1.* 264·1 *1924, 1 ; 1911, 2.* 262·5 *1924, 1 ; 1920, 2.* 262·1 *1931, 6.*
$C_6H_5O_3N$	*o*-Nitrophenol 273·2 *1928, 4.* 274·7 *1930, 8.*
	m-Nitrophenol 283·3 *1930, 8.*
	p-Nitrophenol 280·8 *1928, 4.* 283·2 *1930, 8.*
$C_6H_5Cl_2As$	Phenyl dichloroarsine 348·3 *1929, 2.*
C_6H_5BrSe	Phenyl selenobromide 321·5 *1929, 2.*
$C_6H_8O_3N_2$	Ethyl diazo-aceto-acetate 330·3 *1930, 1.*
$C_6H_9O_3Tl$	Thallous aceto-acetic ester 332·2 *1929, 8.*
$C_6H_{10}O_2N_2$	*n*-Butyl diazo-acetate 326·0 *1930, 1.*
$C_6H_{10}O_4N_2$	Diethyl azoformate 377·1 *1930, 13.*
$C_6H_{15}O_3B$	Triethyl borate 363·1 *1928, 7.*
$C_6H_{15}O_4P$	Triethyl phosphate 399·1 *1925, 1.*
$C_6H_3O_2NCl_2$	2 : 5 Dichloronitrobenzene 335·4 *1929, 4 ; 1917, 1.*
$C_6H_3O_4N_2Cl$	1-Chloro 2 : 4 dinitrobenzene 351·6 *1929, 4 ; 1917, 1.* 348·2 *1930, 11.*
	1-Chloro 3 : 4 dinitrobenzene 258·7 (?) *1930, 11 ; 1914, 5.* 347·4 *1930, 11.*
$C_6H_4O_2NCl$	*o*-Chloronitrobenzene 299·9 *1925, 3.*
	m-Chloronitrobenzene 298·9 *1925, 3.*
	p-Chloronitrobenzene 300·0 *1924, 2 ; 1924, 1.*
$C_6H_4O_2NBr$	*o*-Bromonitrobenzene 312·9 *1925, 3.*
	m-Bromonitrobenzene 313·5 *1925, 3.*
	p-Bromonitrobenzene 313·5 *1925, 3.*

C_7

C_7H_8	Toluene 246·9 *1924, 1 ; 1912, 1.* 245·5 *1924, 1 ; 1884, 1.* 246·5 *1924, 1 ; 1911, 1.* 246·0 *1924, 1 ; 1921, 2.* 245·0 *1931, 6.*

C_7H_{14}	Methyl *cyclo*hexane 278·5 *1924, 1; 1904, 1.* 282·0 *1931, 6.*
C_7H_{16}	*n*-Heptane 309·3 *1924, 1; 1920, 1.* 310·8 *1929, 4; 1929, 5.*
	γ-Methylhexane 306·6 *1929, 4; 1929, 5.*
	ββ-Dimethylpentane 305·3 *1929, 4; 1929, 5.*
	βδ-Dimethylpentane 305·5 *1929, 4; 1929, 5.*
	ββγ-Trimethyl-butane 301·4 *1929, 4; 1929, 5.*
C_7H_5N	Benzonitrile 259·3 *1924, 1; 1911, 3.* 258·0 *1924, 1; 1910, 1.* 255·5 *1924, 1; 1913, 1.*
	Phenyl isocyanide 255·2 *1930, 6.*
C_7H_6O	Benzaldehyde 256·2 *1924, 1; 1911, 2.* 254·0 *1924, 1; 1920, 2.* 255·1 *1929, 4; I.C.T.*
$C_7H_6O_2$	*o*-Hydroxybenzaldehyde 268·0 *1930, 8.*
	m-Hydroxybenzaldehyde 274·5 *1930, 8.*
	p-Hydroxybenzaldehyde 278·2 *1930, 8.*
	2-Methyl-1:4-benzoquinone 272·0 *1927, 3.*
$C_7H_7N_3$	*o*-Toluylazoimide 303·8 *1928, 10.*
	p-Toluylazoimide 307·0 *1928, 10.*
C_7H_7Cl	*o*-Chlorotoluene 280·8. *1931, 6.*
	p-Chlorotoluene 283·6 *1924, 1; 1924, 2.*
C_7H_7Br	*p*-Bromotoluene 296·8 *1924, 1; 1924, 2.*
C_7H_7I	*p*-Iodotoluene 318·6 *1924, 1; 1924, 2.*
C_7H_8O	*o*-Cresol 257·5 *1928, 4.*
	m-Cresol 257·1 *1928, 4.*
	Benzyl alcohol 259·6 *1929, 4; I.C.T.*
	Anisole 265·6 *1924, 1; 1912, 1.* 265·7 *1924, 1; 1915, 1.* 265·6 *1924, 1; 1911, 3.* 265·2 *1924, 1; 1920, 2.*
C_7H_9N	*o*-Toluidine 269·3 *1931, 6.*
	p-Toluidine 272·4 *1924, 2.* 272·1 *1929, 4; I.C.T.*
	Benzylamine 273·7 *1924, 1; 1910, 1.*
$C_7H_{10}O_4$	Dimethyl mesaconate 341·9 *1925, 2.*
	Dimethyl citraconate 346·1 *1925, 2.*
$C_7H_{12}O$	*cyclo*Heptanone 288·0 *1928, 6.*
	2-Methyl*cyclo*hexanone 288·2 *1930, 4.*
	3-Methyl*cyclo*hexanone 290·0 *1930, 4.*
	4-Methyl*cyclo*hexanone 289·6 *1930, 4.*
$C_7H_{12}O_2$	Ethyl*cyclo*butanecarboxylate 309·4 *1927, 1.*
$C_7H_{12}O_4$	Diethyl malonate 362·0 *1924, 1; 1913, 1.* 360·3 *1931, 6.*
$C_7H_{13}N$	*n*-Heptonitrile 316·1 *1931, 6.*
$C_7H_{14}O$	Oenanthol 318·0 *1931, 6.*
	Di-*n*-propyl ketone 314·1 *1924, 1; 1913, 3.*
$C_7H_{14}O_2$	*i*-Amyl acetate 337·1 *1924, 1; 1884, 1.* 331·6 *1924, 1; 1911, 2.*
	i-Butyl propionate 331·8 *1924, 1; 1884, 1.*
	n-Propyl butyrate 333·8 *1924, 1; 1884, 1.*
	n-Propyl *i*-butyrate 332·6 *1924, 1; 1884, 1.*
	Ethyl valerate 332·1 *1924, 1; 1884, 1.*
	Ethyl *i*-valerate 331·9 *1924, 1; 1920, 2.*
$C_7H_{15}Br$	*n*-Heptyl bromide 363·0 *1931, 6.*
$C_7H_{15}I$	*n*-Heptyl iodide 384·5 *1931, 6.*
$C_7H_{16}O$	*n*-Heptyl alcohol 313·4 *1931, 6.*
C_7H_5OCl	Benzoyl chloride 289·8 *1929, 4; 1884, 1.*
C_7H_5NS	Phenyl thiocyanate 307·3 *1929, 9.*

C_7H_5NS Phenyl isothiocyanate 304·1 *1925, 1; 1913, 1.* 305·4 *1929, 9.*
C_7H_7ON Formanilide 273·5 *1924, 1; 1910, 1.*
Benzamide 279·9 *1924, 1; 1910, 1.*
$C_7H_7O_2N$ Salicylamide 295·3 *1924, 1; 1910, 1.*
o-Nitrotoluene 297·7 *1924, 1; 1920, 2.* 301·1 *1925, 3.*
m-Nitrotoluene 297·0 *1924, 1; 1920, 2.* 300·6 *1925, 3.*
p-Nitrotoluene 302·8 *1924, 2; 1924, 1.* 301·6 *1928, 4.*
$C_7H_7O_3N$ *o*-Nitro-anisole 322·1 *1930, 8.*
p-Nitro-anisole 322·6 *1930, 8.*
$C_7H_8ON_2$ Phenylmethylnitrosoamine 313·6 *1924, 1; 1910, 1.*
$C_7H_{10}O_2N_2$ *n*-Butyl diazo-acetate 326·0 *1930, 1.*
$C_7H_{10}O_4N_2$ Ethyl diazomalonate 381·6 *1930, 1.*
$C_7H_{10}NCl$ Methyl aniline hydrochloride 348·6 *1929, 3.*
$C_7H_{11}O_2Cl_3$ *i*-Amyl trichloro-acetate 443·0 *1924, 1; 1913, 3.*
$C_7H_{15}ON$ Heptaldoxime 343·7 *1929, 4; 1903, 1.*
$C_7H_{16}O_4S_2$ Sulphonal 465·5 *1928, 1.*
C_7H_4NClSe *p*-Chlorophenylselenocyanide 349·3 *1929, 2.*
C_7H_7NBrSe *p*-Bromophenylselenocyanide 366·1 *1929, 2.*
$C_7H_7O_2ClS$ *p*-Toluene sulphonylchloride 367·8 *1928, 1.*

C_8

C_8H_{10} *o*-Xylene 283·3 *1924, 1; 1884, 1.* 283·3 *1924, 1; 1911, 1.*
m-Xylene 284·6 *1924, 1; 1912, 1.* 283·3 *1924, 1; 1884, 1.* 285·1 *1924, 1; 1915, 1.* 284·3 *1924, 1; 1911, 1.* 284·0 *1931, 6.*
p-Xylene 283·8 *1924, 1; 1884, 1.* 283·8 *1924, 1; 1911, 1.* 283·8 *1931, 6.*
C_8H_{10} Ethylbenzene 283·0 *1924, 1; 1884, 1.* 283·8 *1924, 1; 1911, 1.* 284·0 *1931, 6.*
C_8H_{14} Octine 327·4 *1924, 1; 1912, 1.*
C_8H_{16} 1 : 1 Dimethyl*cyclo*hexane 316·1 *1924, 1; 1904, 1.*
C_8H_{18} *n*-Octane 350·3 *1929, 4.* 351·0 *1931, 6.*
Di *iso*butyl 345·0 *1924, 1; 1884, 1.*
β-Methylheptane 348·7 *1929, 4; 1924, 4.*
βε-Dimethylhexane 345·5 *1929, 4.*
C_8H_7N Phenylacetonitrile 293·6 *1924, 1; 1910, 1.* 293·4 *1924, 1; 1911, 2.*
o-Toluonitrile 292·5 *1924, 1; 1910, 1.* 292·9 *1924, 1; 1913, 1.* 290·6 *1925, 3.* 292·7 *1929, 4; I.C.T.*
m-Toluonitrile 280·0(?) *1924, 1; 1910, 1.* 280·7(?) *1924, 1; 1913, 1.* 295·6 *1925, 3.*
p-Toluonitrile 295·2 *1924, 1; 1910, 1.* 295·9 *1924, 1; 1913, 1.* 294·4 *1925, 3.*
o-Tolyl isocyanide 292·9 *1930, 6.*
p-Tolyl isocyanide 295·5 *1930, 6.* 295 *1930, 7.*
C_8H_8O Acetophenone 293·8 *1924, 1; 1913, 2.*
$C_8H_8O_2$ Methyl benzoate 310·4 *1929, 4; I.C.T.*
o-Methoxybenzaldehyde 312·4 *1930, 8.*
p-Methoxybenzaldehyde 313·9 *1930, 8.*
$C_8H_8O_3$ Methyl salicylate 323·7 *1929, 4; 1917, 1.* 322·1 *1930, 8.*

$C_8H_8O_3$ Methyl-*p*-hydroxybenzoate 331·8 *1930, 8.*
p-Methoxy-salicylaldehyde 325·1 *1930, 8.*
$C_8H_{10}O$ Phenetole 303·5 *1924, 1; 1915, 1.* 303·6 *1924, 1; 1911, 3.* 302·8 *1924, 1; 1920, 2.*
$C_8H_{10}O_4$ *normal* Methyl-3-methyl-*cyclo*propene-1 : 2-dicarboxylate 371·6 *1927, 1.*
$C_8H_{11}N$ Dimethylaniline 311·7 *1929, 4; I.C.T.*
Ethylaniline 310·4 *1924, 4; I.C.T.*
$C_8H_{12}O_4$ Ethyl maleate 387·0 *1924, 1; 1912, 1.*
Ethyl fumarate 391·2 *1924, 1; 1912, 1.* 392·4 *1924, 1; 1913, 1.*
$C_8H_{14}O$ 2-Methyl-Δ_2-heptene-6-one 340·7 *1928, 5.*
$C_8H_{14}O_3$ Ethyl dimethylacetoacetate 382·3 *1924, 1; 1913, 1.*
$C_8H_{14}O_4$ Diethyl succinate 396·2 *1931, 1.*
$C_8H_{14}O_5$ Diethyl malate 412·4 *1929, 4; 1913, 3.*
$C_8H_{14}O_6$ Diethyl tartrate 428·1 *1929, 4; 1917, 1.*
$C_8H_{15}N$ *n*-Octylic nitrile 356·0 *1931, 6.*
$C_8H_{16}O$ Methylhexylketone 355·7 *1924, 1; 1911, 2.* 356·8 *1931, 6.*
β-Methyl-Δ_2-heptenol 345·5 *1928, 5.*
$C_8H_{16}O_2$ *n*-Octoic acid (caprylic acid) 365·6 *1929, 6.*
i-Amyl propionate 372·1 *1924, 1; 1884, 1.*
i-Butyl butyrate 370·5 *1924, 1; 1884, 1.*
i-Butyl *i*-butyrate 371·8 *1924, 1; 1884, 1.*
n-Propyl valerate 371·9 *1924, 1; 1884, 1.*
$C_8H_{17}Br$ *n*-Octyl bromide 402·4 *1931, 6.*
$C_8H_{18}O$ *n*-Octyl alcohol 354·4 *1931, 6.*
sec-Octyl alcohol 360·4 *1929, 4; I.C.T.*
Di-*n*-butyl ether 369·9 *1931, 6.*
$C_8H_{18}Te$ Di-*n*-butyl telluride 426·8 *1930, 2.*
$C_8H_{19}N$ Di-*i*-butylamine 372·1 *1929, 4; I.C.T.*
$C_8H_{20}Si$ Tetraethylsilicane 412·1 *1931, 2.*
$C_8H_{20}Sn$ Tin tetra-ethyl 441·1 *1929, 1.*
$C_8H_{20}Pb$ Lead tetra-ethyl 456·6 *1929, 8.*
$C_8H_4O_2Cl_2$ *as*-Phthalyl chloride 367·8 *1927, 3.*
s-Phthalyl chloride 373·9 *1927, 3.*
C_8H_7ON *o*-Anisyl isocyanide 314·1 *1930, 6.*
p-Anisyl isocyanide 314·5 *1930, 6.* 315 *1930, 7.*
C_8H_9ON Acetanilide 321·8 *1924, 1; 1910, 1.*
Phenylacetamide 320·2 *1924, 1; 1910, 1.*
Benz-*anti*-aldoxime O-methyl ether 324·2 *1925, 1.*
Benz-*anti*-aldoxime N-methyl ether 325·9 *1925, 1.*
$C_8H_{10}O_2S$ Benzylmethylsulphone 369·8 *1928, 1.*
$C_8H_{11}O_2N$ Ethyl 1-cyano*cyclo*butane-1-carboxylate 360·4 *1927, 1.*
$C_8H_{11}O_4Cl$ Diethyl chloromaleate 423·3 *1929, 4; I.C.T.*
$C_8H_{12}O_4N_2$ Ethyl diazosuccinate 428·4 *1930, 1.*
$C_8H_{12}NCl$ Ethylaniline hydrochloride 381·9 *1929, 3.*
$C_8H_{12}NBr$ Dimethylaniline hydrobromide 412·8 *1929, 3.* 406·3 *1914, 3.*
$C_8H_{13}O_2N$ Ethyl *i*-propylcyanoacetate 374·8 *1928, 6.*
$C_8H_{17}ON$ Methylhexylketoxime 375·2 *1931, 6.*
$C_8H_{18}O_4S_2$ Trional 493·8 *1928, 1.*
$C_8H_{20}O_4Si$ Ethyl orthosilicate 487·6 *1931, 2.*
$C_8H_{13}O_4NS$ Dimethylaniline bisulphate 469·9 *1929, 3.*

C_9

C_9H_{12}	*n*-Propylbenzene 322·0 *1924, 1; 1884, 1.* 323·1 *1931, 6.*
	p-Ethyltoluene 321·7 *1924, 1; 1884, 1.*
	Mesitylene 320·5 *1924, 1; 1884, 1.* 320·8 *1924, 1; 1911, 1.*
C_9H_7N	Quinoline 306·4 *1924, 1; 1911, 3.*
$C_9H_{14}O$	Phorone 367·9 *1928, 2.* 368·3 *1929, 4; 1909, 1.*
$C_9H_{14}O_4$	Ethyl *cyclo*propane-1 : 1-dicarboxylate 417·1 *1927, 1.*
	Ethyl *cyclo*propane-1 : 2-dicarboxylate 422·8 *1927, 1.*
$C_9H_{17}N$	*n*-Nononitrile 395·2 *1931, 6.*
$C_9H_{18}O$	Methylheptylketone 396·8 *1931, 6.*
	βε-Dimethyl-Δ_2-heptenol 383·2 *1928, 5.*
$C_9H_{18}O_2$	Ethyl-*n*-heptylate 413·3 *1931, 6.*
	i-Amyl butyrate 410·9 *1924, 1; 1920, 2.* 408·5 *1924, 1; 1913, 3.*
$C_9H_{21}N$	Tripropylamine 413·6 *1924, 1; 1910, 1.* 414·6 *1924, 4; 1917, 1.*
$C_9H_{10}O_2N_2$	Benzene azoformic ethyl ester 402·1 *1930, 13.*
$C_9H_{11}ON$	Methylacetanilide 354·2 *1924, 1; 1910, 1.*
$C_9H_{11}O_2N$	Ethyl phenylcarbamate 375·6 *1924, 1; 1910, 1.*
$C_9H_{12}OCl_2$	αα′-Dichlorophorone 427·7 *1928, 2.*
$C_9H_{12}OBr_2$	αα′-Dibromophorone 463·2 *1928, 2.*
$C_9H_{12}O_2S$	Ethyl *p*-toluenesulphinate 410·3 *1925, 4.*
$C_9H_{12}O_3S$	Ethyl *p*-toluenesulphonate 431·8 *1928, 1.*
$C_9H_{19}ON$	Methylheptylketoxime 414·6 *1931, 6.*
$C_9H_{14}NHgI_3$	Phenyltrimethylammonium mercuritri-iodide 719·1 *1930, 12.*

C_{10}

$C_{10}H_8$	Naphthalene 312·5 *1928, 4.*
$C_{10}H_{14}$	*n*-Butylbenzene 361·7 *1931, 6.*
	p-Cymene 356·9 *1924, 1; 1884, 1.* 360·7 *1924, 1; 1911, 1.*
	1 : 2 : 4 : 5 Tetramethylbenzene 355·6 *1929, 4; 1900, 1.*
$C_{10}H_{22}$	*n*-Decane 429·7 *1931, 6.*
	Di-*iso*amyl 422·7 *1924, 1; 1884, 1.* 425·7 *1924, 1; 1911, 2.* 427·8 *1924, 1; 1920, 2.* 426·9 *1931, 6.*
$C_{10}H_{10}O_2$	Benzoylacetone 382·4 *1929, 8.*
	Methyl cinnamate 383·1 (?) *1924, 1; 1912, 1.* 385·2 (?) *1924, 1; 1913, 1.* 373·9 *1925, 2.*
	Methyl *allo* cinnamate 376·1 *1925, 2.*
$C_{10}H_{12}O$	Anethole 363·2 *1924, 1; 1913, 2.*
$C_{10}H_{14}O_4$	*normal* Ethyl 3-methyl-Δ_2-*cyclo*propene-1 : 2-dicarboxylate 450·2 *1927, 1.*
	labile Ethyl 3-methyl-Δ_2-*cyclo*propene-1 : 2-dicarboxylate 447·8 *1927, 1.*
$C_{10}H_{16}O_4$	Ethyl *cyclo*-butane-1 : 1-dicarboxylate 454·1 *1927, 1.*
$C_{10}H_{18}O$	Isopulegol 392·2 *1928, 5.*
	Citronellal 415·2 *1928, 5.*
$C_{10}H_{18}O_3$	Ethyl diethylacetoacetate 446·6 *1924, 1; 1913, 1.*
$C_{10}H_{20}O$	*d*-Citronellol 421·7 *1928, 5.*
	l-Rhodinol 421·6 *1928, 5.*

$C_{10}H_{20}O_2$	*n*-Decoic acid (Capric acid) 447·7 *1929, 6.*
	Ethyl *n*-octoate 452·7 *1931, 6.*
$C_{10}H_{22}O$	Di-*n*-amyl ether 449·9 *1931, 6.*
	Di-*i*-amyl ether 445·7 *1929, 4; 1914, 2.*
$C_{10}H_7O_2N$	α-Nitronaphthalene 363·3 *1928, 4.*
$C_{10}H_9O_2Br$	Methyl α-bromocinnamate 426·6 *1925, 2.*
	Methyl α-bromo-*allo*-cinnamate 427·9 *1925, 2.*
	Methyl β-bromocinnamate 424·8 *1925, 2.*
	Methyl β-bromo-*allo*-cinnamate 427·5 *1925, 2.*
$C_{10}H_{13}ON$	Ethylacetanilide 398·5 *1924, 1; 1910, 1.*
$C_{10}H_{14}O_4Be$	Beryllium acetylacetonate 470·4 *1929, 8.*
$C_{10}H_{15}O_2N$	Ethyl-*cyclo*-pentyl-cyano-acetate 430·1 *1928, 6.*
$C_{10}H_{15}O_2Br$	α-Bromo-α′methoxyphorone 455·3 *1928, 2.*
$C_{10}H_{14}O_4Cl_2Sn$	*bis*-Acetylacetone tindichloride 617·2 *1929, 8.*
$C_{10}H_{16}NHgI_3$	Phenyldimethylethylammonium mercuritri-iodide 754·0 *1930, 12.*

C_{11}

$C_{11}H_{16}$	*n*-Amyl benzene 402·0 *1931, 6.*
	Pentamethylbenzene 390·0 *1929, 1; 1900, 1.*
$C_{11}H_{20}$	Undecine 404·5 (?) *1924, 1; 1912, 1.*
$C_{11}H_{10}O_2$	Ethyl phenyl propiolate 375·2 (?) *1924, 1; 1912, 1.* 410·3 *1929, 7, p. 42.*
$C_{11}H_{12}O_2$	Ethyl cinnamate 417·2 *1924, 1; 1913, 1.*
$C_{11}H_{14}O_3$	Dehydroangustione 435 *1931, 5.*
$C_{11}H_{16}O_3$	α-Acetoxyphorone 459·4 *1928, 2.*
	dl-Angustione 442 *1931, 5.*
$C_{11}H_{18}O_4$	Ethyl caronate (Ethyl *trans*-3 : 3 dimethyl *cyclo* propane-1 : 2-dicarboxylate) 493·2 *1927, 1.*
$C_{11}H_{20}O_2$	Undecylenic acid 478·2 *1929, 4; 1920, 2.*
$C_{11}H_{22}O_2$	Ethyl pelargonate 493·6 *1931, 6.*
$C_{11}H_{22}O_4$	α-Monocaprylin 514 *1930, 15.*
$C_{11}H_{15}O_2N$	Ethyl *cyclo* hexylene cyano-acetate 454·7 *1928, 6.*
$C_{11}H_{15}O_3Br$	α-Bromo α′-acetoxyphorone 506·4 *1928, 2.*
$C_{11}H_{17}O_2N$	Ethyl *cyclo*hexylcyanoacetate 467·6 *1928, 6.*
$C_{11}H_{18}NHgI_3$	Phenylmethyldiethylammonium mercuritri-iodide 789·5 *1930, 12.*

C_{12}

$C_{12}H_{18}$	*n*-Hexylbenzene 442·0 *1931, 6.*
$C_{12}H_{10}N_2$	Azobenzene 429·5 *1930, 13.*
$C_{12}H_{10}Hg$	Mercury diphenyl 448·7 *1929, 8.*
$C_{12}H_{10}Se$	Diphenyl selenide 445·6 *1929, 2.*
$C_{12}H_{10}Se_2$	Diphenyl diselenide 506·5 *1929, 2.*
$C_{12}H_{10}Te$	Diphenyl telluride 457·4 *1929, 11.*
$C_{12}H_{11}N$	Diphenylamine 402·1 *1924, 1; 1910, 1.*
$C_{12}H_{16}O_2$	*n*-Propyl phenylpropionate 468·7 *1924, 1; 1912, 1.*
	i-Propyl phenylpropionate 467·4 *1924, 1; 1912, 1.*
$C_{12}H_{24}O_2$	*n*-Dodecoic acid (Lauric acid) 532·8 *1929, 6.*
$C_{12}H_{28}Si$	Tetrapropyl silicane 565·3 *1931, 2.*
$C_{12}H_8OTe$	Phenoxtellurine 452·9 *1930, 2.*

$C_{12}H_{10}ON_2$ Azoxybenzene 444·7 *1925, 1.*
$C_{12}H_{10}OSe$ Diphenyl selenoxide 461·6 *1929, 2.*
$C_{12}H_{10}O_2S$ Diphenyl sulphone 465·7 *1928, 1.*
$C_{12}H_{10}ClAs$ Diphenylchloroarsine 487·1 *1929, 2.*
$C_{12}H_{10}Cl_2Te$ Diphenyltelluridichloride 547·3 *1930, 2.*
$C_{12}H_{15}O_2Tl$ Dimethylthallium benzoylacetonate 523·7 *1929, 8.*
$C_{12}H_{15}O_4I$ Iodosobenzene propionate 583·5 *1931, 7.*
$C_{12}H_{17}O_2N$ Ethyl *cyclo*-heptylenecyano-acetate 487·7 *1928, 6.*
$C_{12}H_{18}O_4Be$ Beryllium propionyl acetonate 539·0 *1929, 8.*
$C_{12}H_{19}O_2N$ Ethyl *cyclo*heptycyanoacetate 502·7 *1928, 6.*
$C_{12}H_{20}NHg_2I_5$ Phenyltriethylammonium dimercuripentaiodide 1060 *1930, 12.*

C_{13}

$C_{13}H_{12}$ Diphenylmethane 419·0 *1924, 1; 1911, 1.* 414·5 *1924, 1; 1919, 1.*
$C_{13}H_{10}O$ Benzophenone 428·2 *1924, 1; 1912, 1.* 425·2 *1924, 1; 1913, 2.*
$C_{13}H_{10}O_3$ Diphenyl carbonate 467·4 *1925, 1.*
$C_{13}H_{12}N_2$ *o*-Methylazobenzene 463·8 *1930, 13.*
m-Methyl azobenzene 467·3 *1930, 13.*
$C_{13}H_{14}O_2$ *i*-Butyl phenylpropiolate 424·7 (?) *1924, 1; 1912, 1.* 487·1 *1929, 7, p. 42.*
$C_{13}H_{26}O_4$ α-Monocaprin 588 *1930, 15.*
$C_{13}H_{12}O_2S$ Phenylbenzylsulphone 503·5 *1928, 1.*

C_{14}

$C_{14}H_{10}$ Phenanthrene 414·1 *1928, 4.*
$C_{14}H_{14}$ αα-Diphenylethane 449·8 *1924, 1; 1919, 1.*
$C_{14}H_{10}O_2$ Benzil 480·8 *1927, 3.*
$C_{14}H_{14}N_2$ *o-o'*-Dimethylazobenzene 501·3 *1930, 13.*
m-m'-Dimethylazobenzene 504·6 *1930, 13.*
$C_{14}H_{15}N$ Dibenzylamine 485·6 *1924, 1; 1910, 1.*
$C_{14}H_{16}O_4$ Diethyl benzalmalonate 561·1 *1928, 6.*
$C_{14}H_{18}O_4$ Diethyl benzylmalonate 567·7 *1928, 6.*
$C_{14}H_{24}O_4$ Di-*i*-Amyl maleate 613·6 *1924, 1; 1912, 1.*
$C_{14}H_{26}O_4$ Di-*i*-Amyl succinate 621·3 (?) *1924, 1; 1913, 1.*
Di-ethyl sebacate 646·9 (?) *1924, 1; 1912, 1.*
$C_{14}H_{28}O_2$ *n*-Tetradecoic acid (Myristic acid) 605·8 *1929, 6.*
$C_{14}H_{14}ON_2$ *o*-Azoxytoluene 528·6 *1925, 1.*
$C_{14}H_{14}O_2Te$ Di-*p*-anisyl telluride 575·2 *1930, 2.*
$C_{14}H_{14}O_2Cl_2Te$ Di-*p*-anisyl telluridichloride 663·2 *1930, 2.*

C_{15}

$C_{15}H_{16}$ Diphenylpropane 484·6 *1924, 1; 1919, 1.*
Ditolylmethane 488·0 *1924, 1; 1919, 1.*
$C_{15}H_{22}O_8$ Ethyl *cyclo*-propane 1 : 1 : 2 : 2 tetracarboxylate 701·1 *1927, 2.*
$C_{15}H_{30}O_4$ α-Monolaurin 664 *1930, 15.*

$C_{15}H_{21}O_2N$ Ethyl decahydro-β-naphthylene cyano-acetate 582·3 *1928, 6.*
$C_{15}H_{21}O_6Al$ Aluminium acetylacetonate 680·5 *1929, 8.*
$C_{15}H_{23}O_2N$ Ethyl decahydro-β-naphthyl cyano-acetate 594·6 *1928, 6.*

C_{16}

$C_{16}H_{14}O_4$ 2 : 2'-Dimethoxybenzil 596·8 *1927, 3.*
$C_{16}H_{18}O_3$ α-Benzoyloxyphorone 583·9 *1928, 2.*
$C_{16}H_{32}O_2$ Palmitic acid 693·2 *1929, 6.*
$C_{16}H_{33}I$ Cetyl iodide 748·9 *1931, 6.*
$C_{16}H_{17}O_3Br$ α-Bromo-α'-benzoyloxyphorone 642·4 *1928, 2.*
$C_{16}H_{18}O_2Br_2$ α-Bromo-α'-*p*-bromobenzyloxyphorone 684·0 *1928, 2.*
$C_{16}H_{18}O_2Te_2$ Di-*p*-phenetyl ditelluride 723·0 *1930, 2.*
$C_{16}H_{19}O_2Br$ α-*p*-Bromobenzyloxyphorone 630·7 *1928, 2.*
$C_{16}H_{34}N_2S$ Tri-*i*-amylammonium thiocyanate 761·6 (?) *1929, 3; 1914, 3.*
$C_{16}H_{16}O_2Cl_2Te$ Di-2-chloro-*p*-phenetyltelluride (?) 731·2 *1930, 2.*
$C_{16}H_{19}SHgI_3$ Dibenzylethylsulphonium mercuritri-iodide 915·2 *1930, 12.*

C_{17}

$C_{17}H_{14}O$ Distyrylketone 564·5 *1928, 2.*
$C_{17}H_{34}O_2$ Margaric acid 733·2 *1929, 6.*
$C_{17}H_{34}O_4$ α-Monomyristin 740 *1930, 15.*
$C_{17}H_{12}OBr_2$ α-α'-Dibromodistyrylketone 650·7 *1928, 2.*
$C_{17}H_{21}SHgI_3$ Dibenzyl-*n*-propylsulphonium mercuritri-iodide 952·0 *1930, 12.*

C_{18}

$C_{18}H_{15}P$ Triphenyl phosphine 607·7 *1912, 1.*
$C_{18}H_{15}Sb$ Triphenyl stibine 637·4 *1927, 2; 1917, 1.*
$C_{18}H_{36}O_2$ Stearic acid 778·0 *1929, 6.*
$C_{18}H_{15}O_4P$ Triphenyl phosphate 686·5 *1925, 1.*
$C_{18}H_{27}O_6Al$ Aluminium propionylacetonate 788·0 *1929, 8.*
$C_{18}H_{30}O_7N_4$ Tetrapropylammonium picrate 932·2 *1929, 3.*
$C_{18}H_{30}O_{13}Be_4$ Basic beryllium propionate 985·4 *1929, 8.*
$C_{18}H_{23}SHgI_3$ Dibenzyl-*n*-butylsulphonium mercuritri-iodide 1000 *1930, 12.*

C_{19}

$C_{19}H_{38}O_4$ α-Monopalmitin 841 *1930, 15.*

C_{20}

$C_{20}H_{38}O_4$ Di-*i*-Amyl sebacate 877·0 *1924, 1; 1912, 1.*
$C_{20}H_{44}NI$ Tetra *i*-amyl ammonium iodide 895·5 *1929, 3; 1914, 3.*

C_{21}

$C_{21}H_{21}N$ Tribenzylamine 695·7 *1924, 1 ; 1910, 1.*
$C_{21}H_{42}O_4$ α-Monostearin 894·0 *1930, 15.*

C_{23}

$C_{23}H_{46}O_2$ *i*-Amyl stearate 974·2 *1924, 1 ; 1913, 3.*

C_{24}

$C_{24}H_{20}Si$ Tetraphenyl silicane 787·5 *1931, 2.*

C_{26}

$C_{26}H_{54}$ *n*-Hexacosane 1082 *1929, 4 ; 1923, 1.*

C_{32}

$C_{32}H_{66}$ *n*-Dotriacontane 1322 *1929, 4 ; 1929, 6.*

C_{33}

$C_{33}H_{62}O_6$ Tricaprin 1404 *1930, 14.*

C_{39}

$C_{39}H_{74}O_6$ Trilaurin 1648 *1930, 14.*

C_{45}

$C_{45}H_{86}O_6$ Trimyristin 1892 *1930, 14.*

C_{51}

$C_{51}H_{98}O_6$ Tripalmitin 2120 *1924, 1 ; 1912, 1. corrected, 1930, 14.*
2134 *1930, 14.*

C_{57}

$C_{57}H_{110}O_6$ Tristearin 2380 *1924, 1 ; 1912, 1.* 2376 *1930, 14.*

C_{60}

$C_{60}H_{122}$ *n*-Hexacontane 2480 *1929, 4 ; 1923, 1.*

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EAST AFRICAN LAKES.

Report of Committee appointed to co-operate in an Expedition to investigate the Biology, Geology, and Geography of Lakes Baringo and Rudolf, Northern Kenya, and Lake Edward, Uganda (Prof. J. S. Gardiner, *Chairman*; Dr. E. B. Worthington and Mr. J. T. Saunders, *Secretaries*; Dr. W. T. Calman, Prof. J. W. Gregory, Prof. R. N. Rudmose Brown, Dr. L. S. B. Leakey).

The expedition, which was in the field from October 1930 to October 1931, consisted of: Dr. E. B. Worthington as leader and zoologist; Mrs. Stella Worthington as geographer and surveyor; Mr. L. C. Beadle as chemist and zoologist; Mr. V. E. Fuchs as geologist; and Mr. R. E. Dent, Assistant Game Warden in charge of fish in Kenya Colony (for the first two months).

Faunistic, ecological, geographical and geological work was carried out on the following lakes in Kenya: Rudolf, Baringo, Nakuru, Hannington and Naivasha; and also the following in Uganda: Edward, George, Bunyoni, Nabugabo, Kachira, Nakavali and Kijanebalola. The whole work was designed to complete limnological studies of the lakes of Kenya and Uganda, which were started in 1927 by the fishing surveys of Lakes Victoria, Albert and Kioga and were continued by Miss P. M. Jenkin on the small lakes of Kenya in 1929. As a result of the Cambridge Expedition it may now be said that all the important lakes of Kenya and Uganda have received a thorough preliminary biological survey.

Collections of the aquatic fauna and flora were made. At present they are being examined by experts in the different groups, and ultimately the whole collection will be deposited at the British Museum of Natural History.

A summary account of the expedition's work has already been published in the *Geographical Journal*, vol. lxxix, pp. 275–297. Other publications relating to the expedition are in *Discovery*, February 1932, p. 40; *Nature*, January 9, 1932, p. 55; *The Empire Survey Review*, vol. i, p. 217; *The Times*, etc.

Arrangements have been made with the Linnean Society of London to publish the general scientific results of the expedition as a series of papers in the *Journal* of the Society. The following papers are complete and now in the press: (1) Worthington: 'General Introduction and Station List.' (2) Worthington: 'Fishes other than Cichlidae.' (3) Beadle: 'Chemistry in relation to Fauna and Flora.' (4) Beadle: 'Bionomics of African Swamps.' (5) H. W. Parker: 'Amphibians and Reptiles.' (6) Prof. P. de Beauchamp: '*Rotifera* and *Gastrotricha*.'

Another series of about six papers will be ready for publication in the autumn of this year.

The expedition was financed by the Royal Society Government Grants, British Museum (Natural History), Percy Sladen Memorial Trust, Balfour Fund, British Association, Royal Geographical Society, Gloyne Fund, Gonville and Caius College, Worts Fund, and assistance was also received from the Uganda Government. The balance sheets have already been audited by the Royal Society Government Grants, and have been submitted to the British Association through Prof. Stanley Gardiner. All the societies who contributed grants have agreed to allow the balance of £170 at the completion of the field work to be devoted to publication in the Linnean Society's *Journal*.

PETROGRAPHIC CLASSIFICATION.

Interim Report of Committee appointed to examine and report upon Petrographic Classification and Nomenclature (Mr. W. Campbell Smith, *Chairman*; Dr. A. K. Wells, *Secretary*; Prof. P. G. H. Boswell, Prof. A. Holmes, Prof. A. Johannsen, Prof. P. Niggli, Prof. H. H. Read, Prof. S. J. Shand, Dr. H. H. Thomas, Prof. C. E. Tilley, Dr. G. W. Tyrrell).

The Committee first met in December 1931, and after general discussion of possible lines of action decided to issue a questionnaire framed to ascertain the opinions of petrologists on controversial points in nomenclature and classification. The questionnaire, in its approved form, was published in February 1932, in the *Geological Magazine* and in *Science*, in England and the U.S.A. respectively.

As a result, replies to some or all of the questions have been received from H. L. Alling, E. B. Bailey, A. F. Buddington, R. Campbell, T. Gillette, C. K. Graeber, M. G. Hoffman, H. Jeffreys, A. J. Johannsen, W. Q. Kennedy, E. S. Larsen, B. Lightfoot, A. C. Macgregor, A. M. Macgregor, P. Niggli, H. S. Palmer, T. C. Phemister, H. H. Read, J. B. Scrivenor, S. J. Shand, Q. J. Singewald, G. W. Tyrrell, and A. C. Woodford. Dr. A. Brammall has rendered valuable assistance to the Committee in connection with the preparation of the questionnaire and the discussion of the results.

Some of the replies have taken the form of lengthy communications, and, particularly on the more controversial questions, opinions are forcefully expressed.

The problem before the Committee was twofold: the accurate naming of rocks, and their grouping for purposes of classification. The Committee finds that there is little prospect of any one of the several existing schemes finding general acceptance. Replies to the questionnaire indicate an almost unanimous opinion that classification of igneous rocks must be based on ascertainable facts—composition, texture, and mode of occurrence—and that theories of origin must be excluded. Many petrologists are convinced that no one scheme of classification is adequate to meet all requirements and advocate two (or more) classifications: one based on mineral content, the other on chemical composition, i.e. a classification of magmas rather than of rocks. Apart from these, the general opinion strongly favours classification based upon mineral composition and texture.[1] There is even more general agreement that the naming of individual rocks must be so determined.

The Committee is of the opinion that rock nomenclature should be independent of age, geographical distribution, and the nature of the associated rocks. Exception should be made of certain dyke rocks, notably the aplites and pegmatites.

On the question of whether there should be three main divisions or only two, opinion is almost equally divided. Similarly there is a sharp division of opinion as to whether texture or mode of occurrence should be used to separate the groups. In general, opinion favours either two divisions, based on texture; or three, based on mode of occurrence, i.e. habit. The Committee suggests a compromise and advocates three main divisions defined in terms of texture.

When the three divisions are based rigidly on field occurrence it is inevitable that two rocks, identical in composition and in all their physical characters, should bear different names; and that, on the other hand, two rocks differing widely in texture and appearance should bear the same name. Admittedly, field relations are frequently so obscure as to render their interpretation a matter of personal opinion. The Committee thinks it desirable that the personal factor should be eliminated as far as possible in classification and nomenclature, and believes that the ambiguities referred to above would disappear were nomenclature made independent of mode of occurrence. Several of those petrologists who, in general, favour the other course are apparently willing to go half-way, as they raise no objection to the use of such terms as 'dyke-basalt.'

The Committee finds that many petrologists, particularly among the teachers of the subject, experience difficulty in defining and using the terms 'plutonic,' 'hypabyssal' and 'volcanic' (or 'extrusive') when used with reference to individual rocks. This is notably the case with 'hypabyssal'—a misnomer, in that many dyke rocks have consolidated under the same depth-pressure conditions as the plutonic rocks with which they are associated. Further, both granite and gabbro (plutonic rock *types*) occur as dykes (hypabyssal rock *bodies*); while many composite intrusions consist in part of 'plutonic' gabbro and in part of 'hypabyssal' granophyre in intimate association.

The conception of the existence of three phases of igneous activity, commonly referred to as plutonic (major intrusive), dyke phase and volcanic, is of great value in mapping and in the interpretation of geological maps; but the Committee points out that duplication of rock names and other ambiguities arise when these terms are applied to the roughly corresponding, though actually not congruent, main rock groups.

[1] By 'texture' the Committee means 'those features which depend upon the size and shape, and arrangement and distribution of the component minerals.' A. Johannsen, *A Descriptive Petrography of the Igneous Rocks* (1931), vol. i, p. 32.

With regard to rock names, most petrologists favour the retention of names long familiar to readers of Zirkel, Rosenbusch, Iddings, Harker, and Hatch —with the proviso that, where necessary, these names should be revised to meet modern requirements. That some revision is necessary is evidenced by the fact that even the commonest names are used in several different senses. Thus the distinction between basalt and andesite is based by different writers on silica percentage, colour index, and specific plagioclase.

The Committee is of the opinion that agreement on the re-definition of names in common use can be best reached through systematic study, by competent petrologists, of the rocks themselves.

Impressed by the lack of uniformity in, and important omissions from, descriptions of rocks, the Committee believes that systematic petrography would greatly benefit if all authors would embody clear statements of all the diagnostic characters of the rocks they describe. It would be an obvious convenience if these characters were listed in the same order. A recommendation on this point will be made in a subsequent report.

The Committee calls attention to the Report on British Petrographic Nomenclature (*Min. Mag.*, vol. 19, 1921, pp. 137–147), with which, in the main, it agrees, but to which it may propose amendments later.

It is hoped that the suggestions made in this interim report will evoke discussion and correspondence, before they are incorporated as definite recommendations in the final report. Such correspondence should be addressed to the Secretary of this Committee at University of London, King's College, Strand, London, W.C. 2.

EMPIRE SOIL RESOURCES.

Report of Committee appointed to co-operate with the Imperial Soil Bureau to examine the soil resources of the Empire (Sir E. J. Russell, *Chairman* ; Mr. G. V. Jacks, *Secretary* ; Prof. C. B. Fawcett, Mr. H. King, Dr. L. Dudley Stamp, Mr. A. Stevens, Dr. S. W. Wooldridge (from Section E) ; Dr. E. M. Crowther, Dr. W. G. Ogg, Prof. G. W. Robinson (from Section M)).

The Committee was formed as a result of a suggestion put forward by Sir E. J. Russell in his paper on the ' Soil Resources of the British Empire,' given before Section E, at the British Association Meeting in 1931. The function of the Committee is to organise a survey of the soil resources of the Empire on a geographical, ecological and climatic basis. Two meetings of the Committee have been held. At the first meeting, it was decided to invite the Schools of Geography of British Universities and some well-known experts in the overseas Empire to co-operate in collecting the climatic and ecological data of different parts of the Empire, each individual or school to be asked to undertake the work for that country of which he or it should have special knowledge or special facilities for obtaining the required data. At the same time, the Imperial Soil Bureau would undertake to collect all the available information relating to the soils themselves.

The invitations to co-operate with the Committee were accepted by nearly all who were approached on the matter, and the Committee desires to record its sincere appreciation of the willingness with which its request for assistance was answered. The work on the different parts of the Empire has been allotted as follows :

Canada : Prof. P. M. Roxby, Department of Geography, Liverpool University.

India : Mr. A. V. Williamson, Department of Geography, Leeds University.

Ireland : Dr. D. K. Smee, Bedford College, London.

Australia : Prof. O. H. T. Rishbeth, Department of Geography, University College, Southampton.

New Zealand : Mr. R. O. Buchanan, University College, London.

East Africa : Prof. Rodwell Jones, School of Economics, London.

West Indies, British Guiana, etc. : Prof. F. Hardy, Trinidad.

Tanganyika : Mr. G. Milne, Amani (provisional).

Several other individuals have expressed their readiness to co-operate, if necessary.

At the second meeting of the Committee, recommendations for collecting the required climatic and ecological data were drawn up. Those recommendations have been sent to all who are helping in the Survey, and it is hoped that the work on the different parts of the Empire is now well in hand.

EARTH PRESSURES.

Seventh Interim Report of Committee on Earth Pressures (Mr. F. E. Wentworth-Sheilds, *Chairman* ; Dr. J. S. Owens, *Secretary* ; Prof. G. Cook, Mr. T. E. N. Fargher, Prof. A. R. Fulton, Prof. F. C. Lea, Prof. R. V. Southwell, Dr. R. E. Stradling, Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson).

Since the Committee's last report two meetings have been held, one at Burlington House in April 1932, and one at Garston in July 1932. Both were chiefly concerned with the research work which has been carried on at the Building Research Station at Garston by Prof. C. F. Jenkin, who has collaborated with the Committee in this work for the past five years, and who has contributed the report which is attached hereto. His work, of which the Committee would again express high appreciation, may be said to have reached an important stage, as he considers the results now justify his laying down ' rules ' for estimating the lateral pressure of sand on retaining walls, which rules are stated and explained in a notable paper, which was read and discussed at the Institution of Civil Engineers in February 1932. The paper formed the subject of further discussion at the Committee's meeting in April 1932, when the reliability of some of the rules was challenged. The Committee, however, welcomed the announcement that the Research Department intended to publish a paper with the addition of relevant tables, and suggested an introductory note, which Prof. Jenkin agreed to. At the July meeting Prof. Jenkin further explained the work he is doing on clay. At the same meeting Mr. E. G. Walker presented an abstract he had made of an important paper by Mr. Glennon Gilboy, published in the *Proceedings* of the American Society of Civil Engineers (October 1931). The paper summarises the principal features of the programme of research on soils which is being carried out at the Massachusetts Institution of Technology. The work was started some years ago by Dr. Charles Terzaghi, who is still in touch with it. Mr. Walker also presented an abstract of an article in *Engineering* (May 30 and June 13, 1930), describing various experiments, including one with sand and ' till ' on a ' wall ' 10 ft.

high, specially constructed so that the horizontal and vertical loads exerted on it by an earth backing could be measured.

The Committee consider that the research on which Prof. Jenkin is now engaged is likely to be of great value, and they recommend that his and their work be carried on for a further period.

BUILDING RESEARCH STATION,
July 1, 1932.

REPORT FOR THE BRITISH ASSOCIATION EARTH PRESSURES COMMITTEE.

The investigation of earth pressures has been continued without interruption during the past year.

A very large number of measurements of sand pressures on retaining walls has been made with the experimental apparatus, and a fairly complete mathematical theory, which I call the revised Wedge Theory, has been worked out, which agrees with the experimental pressures, but no mathematical theory has been found to explain the heights of the centre of pressure.

A general account of the work was given in a paper illustrated by experiments read to the Engineering Section of the British Association last year, and a discourse on 'The Mechanics of Shifting Sand' was delivered to the Royal Institution on February 19.

The whole of the work was described in a paper to the Institution of Civil Engineers, which was discussed on February 23 and March 1. At the discussion an apparent disagreement between my results and those obtained by Takabeya in Japan was pointed out; this has been investigated, and an article entitled 'Predicting the Internal Motion of Sand' was published in *Engineering* for May 13, which shows that my theory could actually predict the results obtained by Takabeya.

I am now engaged on the problem of the pressure exerted by clay. Some six different ideal materials have been investigated, and their mathematical equations worked out. Experiments with china-clay and oiled glass beads and other substances have begun. The most promising method of testing these materials appears to be the determination of their stress-strain diagrams when subject to torsion (pure shear). Preliminary experiments have turned out more successful than was expected, and a complete recording torsion meter is in course of construction.

Simple large-scale experiments on clay, sufficient to check the theoretical calculations, are being considered, and do not seem to be impossible.

I have received valuable assistance from Mr. Wentworth-Sheilds, who obtained the opinions of a number of experienced engineers on a question I submitted.

The difficulties presented by clay are very great, and it is too soon to offer any opinion as to the probability of the ultimate success of the investigation.

C. F. JENKIN.

ELECTRICAL TERMS AND DEFINITIONS.

Interim Report of Committee on Electrical Terms and Definitions (Prof. Sir J. B. HENDERSON, *Chairman* ; Prof. F. G. BAILY and Prof. G. W. O. HOWE, *Secretaries* ; Prof. W. CRAMP, Dr. W. D. DYE, Prof. W. H. ECCLES, Prof. C. L. FORTESCUE, Sir R. GLAZEBROOK, Prof. A. E. KENNELLY, Prof. E. W. MARCHANT, Sir F. E. SMITH, Dr. W. E. SUMPNER, Prof. L. R. WILBERFORCE).

THE subject of electrical terms and definitions is being considered by many committees in this and other countries. Different views are held in regard to the meaning of some of the fundamental terms used in electromagnetic science, and it is essential that international agreement should be obtained on these important questions of terminology and definition. It is therefore very desirable that this Committee should work in close co-operation with other bodies considering the same subject.

In December 1931 a circular was issued by the Commission on Symbols, Units and Nomenclature of the International Union of Physics. This circular, which was in the form of a questionnaire dealing with the main points on which differences of opinion were known to exist, was sent to the individual members of our Committee.

In May 1932 the British National Committee of the International Union of Physics convened a conference at the Royal Society to discuss proposals drawn up by Sir Richard Glazebrook on the basis of the replies received to the questionnaire. The members of our Committee were invited to attend and take part in this conference. Although no unanimous decisions were arrived at, votes were taken on the chief points of difference and by a majority certain recommendations were approved. These were subsequently discussed at an informal meeting in Paris, held in connection with the Electrical Congress in July 1932, preparatory to the meeting of the International Electrotechnical Commission which is to take place in Chicago in 1933.

The Committee therefore ask to be reappointed.

KENT'S CAVERN, TORQUAY.

Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern (Sir A. KEITH, *Chairman* ; Prof. J. L. MYRES, *Secretary* ; Mr. M. C. BURKITT, Dr. R. V. FAVELL, Mr. G. A. GARFITT, Miss D. A. E. GARROD, Mr. LACAILLE).

THE following report has been received from the excavators, Messrs. F. Beynon and Arthur H. Ogilvie :

'Work was resumed on October 5, 1931, and ceased on May 12, 1932.

'Quarrying operations having opened a way into the North-East Gallery, it was decided to take the opportunity of making some examination of this chamber. The results, however, showed that no previous entrance had existed there. Apart from remains of the usual Late Pleistocene fauna, only one flint implement and a few flakes rewarded the search, during which some 5 ft. of cave earth were removed.

'Excavation in the Sloping Chamber was therefore resumed, and was rewarded by the discovery, at a depth of 8 ft. below the Upper or Granular floor, of two fine specimens of tools—the one an ovate implement of flint, more probably Early Mousterian than Acheulean; the other a typical Acheulean hand-axe, with twisted edges, of chert. This latter implement is the first certain specimen of the Acheulean period so far discovered in the Cavern, and completes the series of cultures represented there—Chellean, Acheulean, Mousterian (Early and Late), Aurignacian (Middle and Late), Solutrean (Early or Proto-Solutrean, and a rather later phase with primitive laurel leaf), and an apparently very late Magdalenian with bi-serial and uni-serial harpoons with trapezoidal barbs.

'The deposit in which the Acheulean flint was found had been to some extent overturned, perhaps by flood water. It consisted of a mixture of the Late Palæolithic cave earth, with its characteristic fauna, and the much earlier deposit of Grit, quite unbrecciated, which elsewhere sometimes contained the Chellean tools, while not many feet from the point of discovery MacEnery had found remains of *Machairodus* at the top of the deposit immediately under the Upper Stalagmite floor.'

The Committee asks to be reappointed, with a small grant for the employment of a labourer to remove excavated material after examination.

PREHISTORIC SITES IN EGYPT.

Report of Committee (Prof. J. L. Myres, *Chairman*; Mr. H. J. E. Peake, *Secretary*; Mr. H. Balfour) *appointed to co-operate with Miss Caton-Thompson in her researches in prehistoric sites in the Western Desert of Egypt.*

To continue the geological and archæological exploration of Kharga Oasis, begun in 1931, Miss Caton-Thompson returned, with Miss Elinor W. Gardner as geologist, to examine the tufa deposits and sheets of gravel on the eastern scarp of the Oasis, which presented difficulties not resolved in the first season's work. The tufas were found to belong to at least three distinct geological horizons; the last two are dated securely by tools. Similarly the gravels must be divided into (*a*) *Plateau Gravels*, (*b*) *Terrace Gravels*, (*c*) *Wadi Gravels*; these also are all three now culturally dated. The conspectus of prehistory in the depression extends from Acheulean and Levalloisean, through late Middle Palæolithic (pre-Sebilian), Aterian, and Capso-Tardenoisean to Neolithic, and all these were found *in situ*.

In the scarp the oldest deposit of the 'drift' sequence is a massive crystalline *Plateau Tufa* with reed impressions but no fauna or human evidence: it is provisionally placed as Plio-pleistocene. There followed a period of great erosion, forming longitudinal and transverse valleys, also without cultural evidence. Then the upper reaches of these valleys were filled by great accumulations of angular breccia, representing a long dry period, and yielding no tools so far. On the breccia filling, rainfall and vegetation permitted palæolithic man to appear. Cellular *Wadi Tufas* yield plant impressions and land shells both palæarctic and tropical. These tufas and the *Plateau Gravels* of this phase yielded Acheulean tools and flaking sites with Acheuleo-Levalloisean industry, and were eroded and redistributed as *Exogyra Gravels* at lower levels. In decreasing rainfall, with formation of another *Wadi Tufa*, pre-Sebilian settlements follow, and the modern drainage system develops. As streams grew weaker, however, narrow channels were cut in maturer valleys with Aterian sites on their terraces. The region now became uninhabitable, and the Capsian and Capso-Tardenoisean sites, in which primitive grinders and ostrich eggshell beads occur, are on the Libyan Plateau.

On the depression floor the ' fossil spring ' deposits discovered in 1931 yielded Acheulean, Aterian, and Capso-Tardenoisean sites.

The explorers reject the fluviatile origin proposed by Dr. Collet for Kharga and Dr. Sandford for the Faiyum ; they find no evidence for a lake at any period in Kharga, but evidence for wind-borne and spring-borne deposits. No dynastic remains were found prior to Twenty-seventh Dynasty, and only one predynastic sherd, on the scarp ; probably because the Oasis was already uninhabitable. Only under Persian rule did new hydraulic skill reach artesian water and give Kharga a second cycle of prosperity.

While Miss Caton-Thompson remains at home to prepare her materials for publication Miss Gardner proposes to continue her geological exploration in the coming season. The Committee therefore asks to be reappointed, with a further grant.

COLOUR VISION.

Final Report of Committee on Colour Vision (Prof. Sir CHARLES SHERRINGTON, *Chairman* ; Prof. H. E. ROAF, *Secretary* ; Dr. MARY COLLINS, Dr. F. W. EDRIDGE-GREEN, Prof. H. HARTRIDGE, Dr. J. H. SHAXBY).

FOR testing individuals for defects of colour vision the most practical test is some form of standardised lantern. The use of coloured lights is indicated as the signals to be recognised in railway and marine work are always coloured lights.

Modifying (neutral) glasses should be used so that the lights can be seen at different brightnesses. This is necessary, as some individuals with defective colour vision recognise colours by their brightness.

The colours used should be standardised spectrophotometrically, and should include some limited to the extremes of the spectrum, so as to detect persons with subnormal sensitivity to light, particularly of the red end of the spectrum.

Coloured traffic lights may be indistinguishable to colour-blind drivers. By giving each coloured light a distinct shape, the colour-blind should be able to judge by the shape.

VOCATIONAL TESTS.

Final Report of Committee on the reliability of the criteria used for assessing the value of Vocational Tests (Prof. J. Drever, *Chairman*; Mr. Eric Farmer, *Secretary*; Dr. W. Brown, Prof. C. Burt, Dr. J. O. Irwin, Dr. C. S. Myers).

Three types of criteria can be defined :

(i) *Objective criteria* in which human judgment does not enter ;
(ii) *Judgments by performance* which are partly objective and partly subjective, for they are the judgments by experts on the quality of work done ;
(iii) *Judgments of ability* are subjective criteria, for they are the judgments concerning an individual's ability.

There are many sources of error in each of these three criteria, but no one way of detecting them. A set of observations can be tested by ' Lexis' theory of dispersion ' to see how far it is a valid measure of individual differences. If the frequency distribution of a set of observations to be used as a criterion has a low or imaginary coefficient of disturbancy, it is an unsuitable measure of psychological tests. The frequency distribution of all criteria should be examined by this method before they are used to measure the value of psychological tests. When a criterion is shown to be unreliable the cause of its unreliability can only be discovered by observation, which may lead to some better criterion being formed.

Newbold has devised a method of determining whether the frequency distribution of reported accidents is due wholly to factors affecting all the members of the group alike, or partly to individual differences in susceptibility. The recorded accidents of a group cannot be used as a criterion for psychological tests unless their frequency distribution is partly determined by individual susceptibility.

The reliability of judgments of performance and ability can be tested by correlating independent judgments; but judgments intercorrelated for this purpose are sometimes not truly independent, in which case their correlation coefficients have no value.

A paper dealing with some of the errors in criteria and methods of avoiding them has been accepted for publication in the *British Journal of Psychology*. The Industrial Health Research Board has started an extensive investigation in which the after-careers of some 2,000 apprentices will be compared with their performances in scholastic and psychological tests given at the time of commencing their apprenticeship.

Both the paper and the investigation are the direct outcome of the interest stimulated by the work of the Committee, which has thus served a useful purpose.

INSTRUCTION IN BOTANY.

Report of Committee appointed to consider and report on the provision made for Instruction in Botany in courses of Biology, and matters related thereto (Prof. V. H. Blackman, *Chairman*; Dr. E. N. M. Thomas, *Secretary*; Prof. M. Drummond, Prof. F. E. Fritsch, Sir A. W. Hill, Prof. S. Maugham, Mr. J. Sager).

Chiefly as the result of the response to two questionnaires widely circulated among the secondary schools, the following points emerge:

(1) That the number of schools including the Biological Sciences in their curricula is increasing.

(2) That this increase is concerned mainly with work on the animal side, directly in the form of Zoology, or indirectly as part of ' Biology.'

(3) That ' Biology ' consists of a varying ratio of animal and plant study—approximately 45 per cent. of the schools giving it as half and half, 10·5 per cent. as one-third plant and two-thirds animal, and 4 per cent. as two-thirds plant.

(4) That ' Biology ' has replaced Botany in one-third of the schools reporting, and that therefore, in spite of the fact that a number of schools have introduced Botany during the post-war period, the study of plant life may be decreasing as a whole.

(5) That the institution and substitution of ' Biology ' is largely in the pre-matriculation curriculum.

(6) That the institution of Zoology courses is largely in the post-matriculation or Higher Certificate forms.

(7) That the majority of these changes have taken place within the last five years, and that therefore their full effect has not yet been seen in examination and University records.

MYCORRHIZA IN RELATION TO FORESTRY.

Final Report of Committee (Mr. F. T. Brooks, *Chairman*; Dr. M. C. Rayner, *Secretary*; Mr. W. H. Guillebaud). *Drawn up by the Secretary.*

It is considered that soil-inoculation experiments in field plots and in pot cultures have now provided convincing evidence of a direct causal relation between mycorrhiza formation (with evidence of normal functioning) and satisfactory growth of seedlings of three species of Pines: Scots Pine, Corsican Pine and Maritime Pine.

This evidence has been rigidly tested by experiments from which the operation of any but the biological factors present in very small quantities of humus used as inocula has been excluded.[1]

On certain parts of the sowings of the Forestry Commission in the Ringwood and Wareham areas, especially in the latter, the young trees have either died outright or lingered in a moribund condition showing varying degrees of stunted growth. This is marked by more or less complete failure to form a root system or make active growth, by an unhealthy condition of such young roots as are present, and by complete or—in the case of stronger plants—almost complete inhibition of mycorrhiza formation.

Apart from consequences following upon the method adopted in the

[1] No satisfactory experimental proof has ever been provided of this hypothesis, first put forward by Frank more than fifty years ago. Incontrovertible evidence concerning it was regarded as a first step in the present researches.

original sowings, and also from those associated with the existence of local areas of soil toxicity probably mainly due to defective aeration, it is believed that the condition of the moribund and semi-moribund plants described is a starvation phenomenon—in large part probably one of nitrogen starvation.

Tentative experiments with inorganic nitrogenous fertilisers have confirmed the results obtained by others both in field and laboratory cultures—viz. that it is difficult to make good deficiencies in this way without serious disturbance of the root-shoot growth ratio in species of Pine.

It is believed that on soils poor in inorganic nitrogen of this type the nutrient requirements of the young trees are normally made good by a profuse development of mycorrhiza. This view is confirmed by examination of the roots of Scots Pine and Maritime Pine in the area adjoining the plantations in question, by that of patches of young trees on the sown or planted areas that have made surprisingly good growth, and by the remarkable fact that the condition of arrested growth described can be relieved in the course of one growing season by induced mycorrhiza formation following suitable humus inoculation.

It is not believed, however, that this treatment alone will permanently remove the trouble on soils where mycorrhiza formation by young trees is inhibited or markedly delayed.

In the area under consideration the view has been reached that the factors permitting healthy mycorrhiza formation annually and, therefore, determining healthy growth must be sought in the condition of certain organic constituents of the humus following upon abnormal decomposition changes.

Attention is now focused on this aspect of the problem. Following the adoption of a working hypothesis, a series of experiments has been carried out involving the application of certain organic composts. The materials for these composts are of the nature of waste products.

The treatments have been applied to experimental plots which reproduce certain features of the Wareham area as originally sown, and also to sowings on a section recently tractor-ploughed. Each compost treatment will be applied in duplicate, one series compost alone, the other the same compost inoculated with known mycorrhiza-formers of the trees concerned, either from pure cultures or from humus material from a native habitat of the species. It may be noted that the cultivation of specific root fungi on composted and other organic materials has provided and is likely to continue to provide a number of independent and intricate problems.

These field experiments have been duplicated in pot cultures using soil from the same area, and this essential part of the work could not have been undertaken without the provision of a suitable shelter house such as has been erected this summer.

Existing experimental plots at Wareham and Ringwood are still under observation, and intensive study of the roots of seedling Pines from these plots is likely to yield interesting comparative data on the causes underlying inhibition of mycorrhiza formation, and interference with its normal structure and functioning when induced artificially by humus treatments of the soil.

Humus inoculation of exotic Pine species.—This aspect of the work was considered in the report presented at the London meeting in 1931. It raises a matter of considerable practical importance involving the desirability or otherwise of applying appropriate humus treatments to seedlings in the nursery stage. The experimental data now available in respect to Corsican Pine and Maritime Pine at Wareham and elsewhere may be summarised as follows :

(1) The addition to seed-beds of small quantities of the appropriate humus in the right condition produces a markedly beneficial effect upon the seed-

lings raised in them. At the end of a year's growth these have larger shoots with longer needles than those of controls raised in the same compost lacking humus treatment, and give evidence of more vigorous growth, especially towards the end of the season. The root systems are remarkably different: those of controls poorly branched with scanty development of sub-lateral roots; those of treated seedlings well branched with abundant sub-laterals, all of which become mycorrhizas. The beneficial effect upon growth continues during the second year: treated seedlings start growth earlier, have longer needles and grow more vigorously.

These beneficent effects are evidently due to developmental changes controlled by factors operating within comparatively narrow limits since they are readily influenced by variation in the experimental treatment, as, for example, the date of sowing. They are well marked in seedlings from sowings up to the end of May, but diminish in those from later sowings. In July sowings there is an improvement in the root systems, but mycorrhiza is not formed during the first year, and improved growth of the shoot is not observable.

(2) It is evident that the improved growth observed depends upon biological causes of a *reciprocal* kind. Thus, seedlings of Corsican Pine and Maritime Pine raised on Wareham soil without treatment are already in an unthrifty condition at the end of one year's growth. Such seedlings do not benefit from appropriate humus treatment in the spring of the second year. Whether they may do so eventually is a matter of some biological interest, but is clearly not one of practical importance. In general, it is clear that the effects produced vary directly with the technique used. It is, therefore, important that a suitable technique should be devised in using methods of humus inoculation for promoting mycorrhiza formation.

These facts provide a clue to the irregular and often confusing results yielded by empirical humus treatments in the hands of foresters.

(3) The marked stimulation to root development and mycorrhiza formation and the improved growth that follow suitable humus treatment do not depend upon proved inability of Corsican Pine and Maritime Pine to form mycorrhiza with fungus species present in the Wareham and Ringwood soils. Both species are capable of forming mycorrhizal associations with indigenous soil fungi—Maritime Pine with comparative ease, Corsican Pine apparently with some difficulty. Whether the improvement effected in this respect by the introduction of small quantities of native humus is due to the introduction of more favourable fungus associates or to other causes is not at present known with certainty.

The significance of mycorrhiza in relation to forestry problems offers a stimulating field for research. For various reasons it has been judged expedient to concentrate attention on certain aspects of the problem likely to yield results of immediate practical interest.

It is clear, however, that fundamental aspects such as the physiology of the nutritive relations between roots and mycelium and the exact nature of the beneficent effects observed call for intensive laboratory research.

All aspects of the problem are bound up with a clearer understanding of the conditions controlling decomposition changes in organic soils, calling for the close co-operation of the soil chemist.

The grant of £25 provided by the British Association has been fully expended, and the Committee do not ask for reappointment.

In presenting this final report they desire to record their appreciation of the services rendered to the work in its initial stages by the three grants provided by the British Association.

The continuance of the work on a somewhat enlarged scale has now become possible, owing to a grant provided by the Forestry Commission.

Part of this grant has been expended on the erection of the shelter house referred to earlier in this report.

EDUCATIONAL AND DOCUMENTARY FILMS.

Report of Committee appointed with the following reference : Educational and Documentary Films : To inquire into the production and distribution thereof, to consider the use and effects of films on pupils of school age and older students, and to co-operate with other bodies which are studying those problems (Sir RICHARD GREGORY, Bt., *Chairman* ; Mr. J. L. HOLLAND, *Secretary* ; Mr. L. BROOKS, Mr. A. C. CAMERON, Miss E. R. CONWAY, Mr. G. D. DUNKERLEY, Mr. A. CLOW FORD, Dr. C. W. KIMMINS, Prof. J. L. MYRES, Mr. G. W. OLIVE, Hon. S. RIVERS-SMITH, Dr. SPEARMAN, Dr. H. HAMSHAW THOMAS, Dr. F. W. EDRIDGE-GREEN).

REPORT OF THE FILM COMMISSION.

THE year which has elapsed since the second Report of the Committee was presented at the London meeting has been, for their part, one of waiting for the Report of the Commission on Educational and Cultural Films. Individual members of the Committee have assisted in the inquiries which have culminated in the Report. There has, however, been no call for the co-operation of the Committee as a body, and as the Report was not published until June, there has been no opportunity for subsequent co-operation. Apart from the general quickening of interest which has followed the publication of the Report, the Committee are of opinion that the Commission have done a great service in maintaining the claim of the film to be regarded as an art form characteristic of the present age, and as a mirror of national life.

The Committee note with pleasure that, in the opinion of the Commission, the future of the film, both sound and silent, as an aid to education is bound up with the 16-mm. projector—a view for which the Committee contended in their first Report at the Bristol meeting in 1930. The Committee also note that considerable extracts from their first Report, dealing with the two types of film material, namely, nitro-cellulose (inflammable) and cellulose acetate (non-inflammable), with sub-standard projectors and with illumination and eye-strain, have been included in Appendix E of the Commission's Report. On the latter subject there is still room for further research. Dr. F. W. Edridge-Green, a member of the Committee, has established the fact that if the screen alone is illuminated and the rest of the class-room or cinema left dark, conditions of eye-strain arise with concomitant headache in the spectators. Illumination must, therefore, be studied as a comparative matter of the relation between the general lighting in the room and the amount of special light concentrated on the screen.

REPORTS ON EDUCATIONAL VALUE OF FILMS.

During the year a number of Reports of inquiries and experiments germane to the Committee's reference have been published, to three of which it is proposed to refer. The Report of the Chief Inspector of Schools to the London County Council on School Children and the Cinema frankly recognises that the film is so considerable a factor in the life of the child that a purely negative attitude toward it cannot be maintained—an admission which many Education Authorities and Teachers still find it difficult to make. He finds that the ordinary film in the ordinary cinema broadens the children's minds and increases their store of useful knowledge, particularly on such subjects as History and Geography, and generally stimulates mental alertness and arouses the critical faculty. On the moral side he suggests that there is no need for serious alarm, so far as the Elementary School child is concerned. He can find no evidence of widespread mischief: 'Evil on the films never pays,' and as a rule the children's sense of justice is satisfied. Since the children will go to a public cinema whatever the educator and the moralist may say, this well-documented Report should bring a sense of relief to older people who do not themselves frequent the cinema, and who, on the principle of *omne ignotum pro terribili*, have perhaps alarmed themselves and others unduly.

The Report of the inquiry into the Value of Films in the Teaching of History, made by Dr. Consitt for the Historical Association in 1929, and the Report of the experiment with Sound Films in Schools undertaken jointly by Local Authorities in Middlesex and the National Union of Teachers in 1930 and 1931, both emphasise the lack of adequate teaching films. 'That the films available at present are almost valueless for the purposes of historical teaching' is the conclusion which one instructed critic draws from the first Report, and the writer of the second Report commits himself to the statement that 'So far as we are aware not a single *ad hoc* teaching film has yet been made by any film-producing company in this country'; and, again, referring to the films which were the subject of the experiment: 'The best of them could no more than indicate what might be achieved if there were available talking pictures specially designed for education.'

With these Reports the first chapter in the story of the relation of the film to education may be considered closed. The case which the Committee of the Imperial Education Conference in 1923 declared to be no more than *prima facie*, though strong, is surely made out, and further experiment can be directed to the exploration of the purposes which the educational film will serve. But for such experiments a new type of film is required. There is in existence a large amount of film material of high artistic quality, though almost entirely of standard size, which has real educational value; and the production of such films is being aided and encouraged by more than one of the Government Departments. But these films are of the general interest class: they are addressed to the adult rather than the child, and their use in the class-room can be at best only illustrative and incidental.

The immediate need is for films, and especially sub-standard films, made for definite educational purposes, taking full account of the methods by which, and conditions under which, the education of the child and the adolescent is carried on in this country. Of such films there are as yet none which are publicly available. On the side of the Industry itself there is no difficulty. Many firms have incurred considerable expense in devising and constructing suitable projectors and apparatus generally, and are only waiting for a lead from the Teaching Profession before proceeding to the manufacture of educational films. Such a lead cannot, however, be given by an individual teacher, or even by groups of teachers; for the expense involved is large and the Industry must be sure of its market. The lead will have to come from some body not less representative than the Films Commission, which can bring to a focus the views and experience of teachers and film experts, and can, as a preliminary, arrange for its conclusions to be tried out in a few representative films specially made for the purpose.

Silent and Sound Films.

It was in some ways a misfortune for the film as an educational instrument that the sound film came when it did. But for its advent the simpler and less costly silent film would probably by now have become a recognised class-room aid, and films of the kind we still desiderate would be available in both quantity and variety. In the Committee's opinion, the silent film will in the long run replace the optical lantern in the class-room. It is easier to make and to manipulate, and therefore cheaper, than the sound film, and it lends itself readily to the give-and-take between teacher and pupil, which is so characteristic of English teaching method. But the sound film has conquered in the Picture House and holds the interest of both teachers and children. The Industry, too, has concentrated upon sound films, and the silent film is not made to-day, save for special purposes. The sound film will undoubtedly have its place in the educational scheme ; and, as things are, will probably dominate the situation for a time.

As though the struggle between sound and silent films were not enough, the sound film itself is a battle-ground of opposing types, both of which are used in the cinemas and neither of which as yet shows signs of being able to oust its rival. In the sound-on-disc type a silent projector exhibits the pictures and a gramophone geared up to it reproduces the sound in synchronisation. In the sound-on-film type there is one instrument, the projector, and the sound is reproduced from a track which runs along the side of the film. With both types, of course, amplifiers and loud-speakers are necessary. Both types of instrument have been made available in the sub-standard 16-mm. size during the last few months. It is, of course, a comparatively simple matter to gear up a silent projector with a gramophone so that they will run in synchronisation, but much more than that is needed to secure a realistic correspondence between sight and sound, and a good instrument is bound to be costly.

The sound-on-film system has its own difficulties to overcome in the recording of an adequate sound track on 16-mm. film. The minimum number of sound variations or cycles which must be recorded in one second, if the reproduction is to be smooth, is 3,000. Frequencies up to 10,000 per second are used now in professional cinema work, and higher frequencies still are being experimented with. The rate at which the pictures go through the gate in a sound film is usually 24 per second, as against a minimum of 16 per second with a silent film, and as there are some 40 pictures to the foot of sub-standard 16-mm. film, the corresponding sound variations per second have to be recorded in a length of not more than 7 in. The width of the sound track on the narrow 16-mm. film presents another problem. The Committee are aware of only two firms which are prepared to market sub-standard sound-on-film projectors. Other firms are, however, understood to be working at the problem.

The time has clearly not yet arrived for a considered evaluation of the comparative merits of the two types—at any rate in the sub-standard size. The two systems will be in competition, which from the point of view of the development of cinematography is all to the good, but for the time the production of sub-standard educational sound films of either type will be inevitably impeded. Whether both types will be so developed as to continue to exist alongside, or whether one will become predominant, is a question for the future.

Suggested National Film Institute.

The Committee were called into being as an auxiliary for research purposes to the Educational and Cultural Films Commission and similar bodies. They now ask to be continued so that they may be in a position to deal with any of the problems indicated in this Report which may assume special importance, or to co-operate with the Film Commission, should such co-operation be called for. The Committee are glad to know that the Commission is to remain in existence for another year, during which it is hoped that a National Film Institute, as recommended by the Commission, may be launched. The foregoing Report has indicated at least one important direction in which such an Institute could render good service to education. The Committee are also impressed with the need of an Institute to act as a clearing-house for the circulation of special films made by University and other research departments. Many such films would be made if their circulation could be guaranteed, but they are not now made because of the cost. There is also a growing number of films made by travellers and private persons which would be made available for general use through such an Institute. The Committee are convinced that, from their point of view, the establishment of a National Institute with adequate funds to carry on its work is an immediate necessity. They would like to think that the passing of the Bill to legalise the opening of cinemas in certain districts on Sundays has brought such an Institute, with adequate funds, within the range of early probability.

PALÆOZOIC ROCKS OF ENGLAND AND WALES.

Report of Committee appointed to excavate critical sections in the Palæozoic rocks of England and Wales (Prof. W. W. Watts, *Chairman*; Prof. W. G. Fearnsides, *Secretary*; Mr. W. S. Bisat, Dr. H. Bolton, Prof. W. S. Boulton, Dr. E. S. Cobbold, Prof. A. H. Cox, Mr. E. E. L. Dixon, Dr. Gertrude Elles, Prof. E. J. Garwood, Prof. H. L. Hawkins, Prof. V. C. Illing, Prof. O. T. Jones, Prof. J. E. Marr, Dr. F. J. North, Mr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, Prof. A. E. Trueman, Dr. F. S. Wallis).

Excavations at Careg Dyfan, Carmarthenshire, by Miss Emily Dix.

The object of the excavation was to test a suggestion made by Dr. T. N. George that some radiolarian cherts exposed at Llandyfan (on the north crop of the South Wales Coalfield) overlie part of the Basal Grit of the Millstone Grit. So far as known hitherto, such cherts mark the junction of the Basal Grit with the underlying Carboniferous Limestone. The work was undertaken by Miss Dix and the digging carried out by Mr. W. D. Ware.

A trench near Llandyfan Church proved 12 ft. of black shale and cherts (with a few poorly preserved goniatites) resting on a thick grit. Above the shales are about 50 to 60 ft. of grit, followed by black shale with banded cherts containing wavellite.

Digging and trenching at Careg Dyfan revealed the following, in descending sequence:

Radiolarian cherts and brown shales containing *Eumorphoceras* sp. and *Posidonomya membranacea*.
(Beds unexposed and inaccessible 9 to 12 ft.)
Coarse Grit proved for 9 ft.
Plastic Clay series, weathered cherts and fine-grained sandstone.

The radiolarian cherts at Careg Dyfan are probably of E age (similar to those at Bishopston in Gower, on the south crop of the South Wales Coalfield), and they are underlain by a thick grit.

The goniatites have been examined by Mr. R. O. Jones and Mr. W. S. Bisat.

SECTIONAL TRANSACTIONS.

(For reference to the publication elsewhere of communications entered in the following lists of transactions, see end of volume, preceding index.)

SECTION A.
MATHEMATICAL AND PHYSICAL SCIENCES.

Thursday, September 1.

Prof. A. M. Tyndall.—*The mobility of positive ions in gases.*

It has been shown by Powell and the author that minute traces of impurity may have a striking effect on the mobility of positive ions in a gas. Changes in the nature of the ions may be brought about by (1) the formation of a cluster of impurity molecules around the ion; (2) the production of ions of the impurity by collisions of the second kind; (3) the phenomenon of electron exchange.

When sources of positive alkali ions are employed traces of impurity are less critical because of the low ionisation potential of these metals. A study of the mobility of these ions in various gases has led in certain cases to a simple law connecting the mobility of an ion with its mass. The apparatus then becomes analogous to a mass spectrograph in that it may be used to analyse the ions emitted by a given source. When the source of ions is a glow discharge the high gas pressures employed permit of the study of types of collision processes relatively infrequent at the low pressures more commonly employed.

Sir R. T. Glazebrook, K.C.B., F.R.S., and Dr. L. Hartshorn.—*Material standards of resistance: the B.A. Coils, 1881–1932.*

(*Ordered by the General Committee to be printed in extenso.* *See p.* 417.)

Joint Discussion with Section J (Psychology) on *The quantitative relation of physical stimuli and sensory events* (Mr. T. Smith, F.R.S., Prof. J. Drever, Dr. J. H. Shaxby, Dr. Wm. Brown, Dr. R. A. Houstoun, Mr. R. J. Bartlett, Dr. S. G. Barker and Mr. C. G. Winson. Experimental demonstration by Dr. L. F. Richardson, F.R.S.):—

Prof. J. Drever.

The world of sense is at once physical and psychological. The general problem of physical science is the more adequate understanding of the world of sense, and this is also a problem for the psychologist. The physicist studies the processes and patterns of the world of sense as they appear to determine one another independently of the individual observer, the psychologist the processes and patterns as they determine the sensory world as experienced. The correlation of the sense experience of the individual with the processes and patterns investigated by the physicist presents a problem for the psychologist, but if its solution is to be attempted quantitatively that must rest on the quantitative systems and methods developed by the physicist as the only practicable basis. The study of the differences between individuals in sensory experience is a second psychological problem, and this too, if its solution is to be attempted in quantitative terms, depends no less on the quantitative relations and concepts developed by the physicist, and most emphatically on the physicist's units of measurement. Apart from quantitative relations, concepts, and units, developed from a point of view which eliminates the individual observer, no solution in quantitative terms of either of these psychological problems is possible. There are not two worlds of sense, one in the mind studied by the psychologist, and another outside studied by the physicist. There is one world of sense studied by both psychologist and physicist, and the units and methods of measurement from the nature of the case must be those of the physicist.

Dr. J. H. Shaxby.

The loudnesses of sounds, though capable of being specified as possessing magnitude, yet cannot be arranged on any single definite and unequivocal scale. The method of measurement affects the magnitudes assigned to a given series of sounds. In particular, phenomena such as sensory adaptation make the formulation of a scale of sensations a dubious procedure.

It is, further, doubtful whether any estimate, other than the purely introspective, really gives a measure of loudness so much as of the physical intensity associated with sounds arranged on a scale more or less arbitrarily assumed to be one of loudness, or with the physiological processes of the auditory nerve.

The decibel, though exceedingly useful in specifying intensities, seems to agree neither with a scale of equal increments of loudness as subjectively judged, nor with the successive steps of a scale based on differential thresholds. Even if we concede its use as a ' loudness ' unit, its utility in that respect rests on its supposed parallelism with the scale based on the Weber-Fechner law ; it is more than doubtful whether this law is valid for audition, and in any case the decibel is commonly used between limits far surpassing the possible range of Weber's law.

Dr. Wm. Brown.

Although G. T. Fechner's assumptions as regards the measurement of sensation intensities are not theoretically justified, the possibility of direct mental measurement in terms of *contrastes sensibles* or ' sense-distances ' was conclusively demonstrated by J. R. L. Delbœuf as far back as 1878. The Weber-Fechner law can thus be rewritten in the form

$$\overline{SS_0} = k \log \frac{R}{R_0}$$

where $\overline{SS_0}$ represents a sense-distance, and S_0 is any finite intensity of sensation taken as the conventional zero (not necessarily liminal) ; R, R_0 are corresponding stimulus values.

At the two extreme ends of the scale there are deviations from the logarithmic law of a continuous and uniform nature.

The method of constant stimuli, which is based upon the accumulation of large numbers of observations and the employment of statistical methods in drawing conclusions from them, is the most reliable psycho-physical method for solving the quantitative problems of psycho-physics.

Dr. R. A. Houstoun.

The speaker was certain that sensation could be measured. The results, though not very accurate, were much better than nothing, and would eventually throw light on the mechanism of sensation. In classifying the visible stars into six magnitudes the measurement of the sensation of intensity had been used for centuries, and in different parts of the world, with consistent and satisfactory results. He thought that those who took the contrary view defined measurement too narrowly and in such a way as would exclude many physical quantities. But it was undesirable to strain too much after definitions. Simple experiments made on a photometer bench with a wedge photometer and two lamps, on building up a scale of the sensation of intensity and halving intervals on such a scale, would bring more conviction, and it was desirable that such measurements should be made as widely as possible.

In conclusion he alluded to his own investigations, which showed that the sensation of intensity was much better expressed as a function of the logarithm of the stimulus by a probability integral than by the conventional logarithmic function. The integral approximated to the latter at the middle point of the range.

Mr. R. J. Bartlett.

As originally stated Weber's law records the fact that, within limits, the change that must be made in the objective physical basis of a stimulus in order that the change may be just noticeable is proportional to the amount present initially. All measurements made are physical measurements. Sensation is not measured, but the amount of change in the objective basis is governed by subjective judgments based in sense experience. The judgments rest on awareness of sameness or difference. The change necessary for detection of difference fluctuates in amount, but the various readings obtained tend to concentrate about a mean value. The necessary change can be expressed as a 'constant error' and a scatter value about that 'error.'

In work reported more fully to Section J it is shown that:

(1) The 'constant error' is a regression towards a central, accustomed value of stimulus.
(2) Weber's law holds for a limited central zone to which we are adapted.
(3) Beyond this zone, in either direction, deviation from the law increases rapidly, and when a geometric series of units is used, apparently, the deviation is proportional to the cube of the 'distance' of the objective basis of stimulus from the central datum value of (1) above.

Dr. S. G. Barker and Mr. C. G. Winson.—*The psychological basis of wool-sorting.*

When wool arrives in the raw state for processing purposes, the first stage is to place it in the hands of the wool-sorter, who disintegrates the fleece into its constituent qualities. Both the tactile and visual senses are employed, and with almost uncanny precision the experienced sorter classifies the wool according to its subsequent manufacturing performance, or in particular to the degree of fineness to which the ensuing yarn may be spun. An examination of the methods employed reveals that whilst fibre fineness from quality to quality proceeds in geometrical progression, it would seem that the qualities themselves proceed in arithmetical progression. A logarithmic law apparently gives the sorter's relationship between quality and fibre fineness for all countries in the world. It is found further that the wool-sorter's work is based on the same psychological factors wherever performed.

Dr. R. A. Houstoun and Dr. L. F. Richardson.—*Quantitative mental estimates of saturation with colour.*

As a preliminary, the results of estimating large intervals of (1) loudness, (2) redness, (3) distance on the skin, were exhibited as lantern slides.

A rotating disc was next shown. Its outer zone appeared grey; its central portion a saturated orange-red; and its intermediate zone was of the same hue but less saturated. All three areas were nearly equally bright. Each spectator was provided with a segment of a line 100 millimetres long, and was asked to put a mark on the line to show where the intermediate tint came on a scale of saturation extending from grey at one end to the saturated colour at the other.

Five persons stated that they could not perform the task.

Fifty-four persons made estimates. The positions, which they marked on the lines, were subsequently measured in per cents., calling the grey 0 per cent. and the saturated colour 100 per cent., with the following results:

Least estimate	5 per cent.
Lower quartile	29 ,, ,,
Median	38 ,, ,,
Upper quartile	59 ,, ,,
Greatest estimate	86 ,, ,,

Five unsigned forms were excluded. Multiple marks on the same line were averaged. Various suggested improvements are gratefully acknowledged.

On the disc the intermediate zone consisted of nearly equal angles of the papers forming the outer zone and central portion. But to reduce contrast, the full colour occupied 46 per cent. of the circumference next the grey and 56 per cent. at the inner edge of the zone. These facts were not known to the observers at the time they made their estimates.

The median estimate of 38 per cent. is significantly less than the angle of 51 per cent. A similar deviation towards the unsaturated side was found in previous experiments on white, pink and scarlet.

Friday, September 2.

Presidential Address by Prof. A. O. Rankine, O.B.E., on *Some aspects of Applied Geophysics.* (See p. 21.)

Discussion on *Supra-conductivity* (Prof. J. C. McLennan, F.R.S., Prof. W. J. de Haas, Dr. W. Meissner, Prof. O. W. Richardson, F.R.S.):—

Prof. W. J. de Haas.

From the experiments previously made, it seemed probable that the metals go over into a new phase when they become supra-conductive. In order to support this point of view experiments have been carried out. Formerly the region of disappearance of resistance was about 0·03°. We found that for good single crystals and small measuring current this region does not exceed 0·0005°. We investigated the influence of the crystal lattice on grey and white tin, which differ only in this respect: grey tin does not show supra-conductivity, white tin does. Gold-bismuth alloys show the same influence—the alloy becomes supra-conductive though neither of the components do; but X-ray experiments showed that it has a crystal lattice of its own.

Investigations of the thermal conductivity of supra-conductors showed an influence of the supra-conductive state. At the transition point indium shows a small sudden increase of thermal conductivity. When the supra-conductivity is disturbed by a magnetic field the thermal conductivity is increased for pure metals. The results for $PbTl_2$ are very complicated, probably as a result of the lack of homogeneity of the alloy. The specific heat of tin increases when the metal becomes supra-conductive. In a magnetic field, high enough to disturb supra-conductivity, this increase disappears.

Prof. O. W. Richardson, F.R.S.

There is one point on which I should like to hear the opinions of Prof. McLennan and Prof. de Haas before this meeting closes. It concerns the views of Dorfman to which Prof. McLennan referred. These go further than the relations between the frequency and the magnetic field necessary to destroy the superconductivity which have been mentioned.

There is some resemblance, even though it may be only superficial or accidental, between superconductivity and ferromagnetism. Following this idea, Keesom and his associates at Leiden measured the specific heat of superconductors in the neighbourhood of the critical point, where one might expect an abnormality similar to the abnormality in the specific heats of ferromagnetic substances in the neighbourhood of the Curie point; but no such effect could be detected. This, however, is not entirely conclusive. The number of electrons concerned in the superconductive phenomenon might be too small a fraction of the total number, or of the number of atoms present, to exert any appreciable influence on the specific heat, or, alternatively, there might be some compensating effect on the atoms which might counterbalance any changes in the specific heat of the whole substance arising from changes in the energy of the electrons.

Dorfman has pointed out that what is in some respects a more direct test of this particular issue can be made if the specific heat of electricity (Thomson effect) in the superconductive region of temperature is considered. The magnitude of this can be deduced from the thermoelectric measurements of Keesom and his associates which refer to lead and tin. These show that there is such an abnormality in the Thomson effect. It is true that it does not occur exactly at the superconductive critical temperature. For example, in the case of lead this critical temperature is 7·2° K.; whereas the anomaly in the Thomson effect sets in at about 5° K. and rises to a maximum at a little over 10° K., after which it falls. This anomaly is quite similar to the corresponding anomaly in the case of ferromagnetic substances near the Curie point.

If it is admitted that this anomaly in the Thomson effect is associated with the establishment of superconductivity, it is a natural inference that it is a result of the change in the energy of an electron connected with this phenomenon. On this basis the thermoelectric data enable the difference ΔW_0 between the energy of a superconducting and a non-superconducting electron to be estimated. The interesting fact then emerges that, approximately,

$$\Delta W_0 = \mu H_0 = h\nu_0$$

where μ is the spin moment of the electron, H_0 the magnetic field necessary to destroy the superconductivity, h is Planck's constant, and ν_0 McLennan's destructive frequency; ΔW_0, H_0 and ν_0 are all extrapolated to the absolute zero of temperature. In other words, the magnetic energy and the vibrational energy required to break up the superconductive structure are each approximately equal to the energy of the structure itself.

What, in particular, I would like to ask Prof. de Haas is this: Does he consider it likely that this anomaly in the Thomson effect is really so intimately associated with superconductivity? Or is the disparity between the temperature ranges in which the two phenomena manifest themselves too great for this to be possible?

(In his reply Prof. de Haas was understood to say that he considered the temperature disparity to be too great for the effects to be so intimately connected (or connected at all, I am not certain), and that he thought the numerical agreement was an accident. He added, however, that Keesom had recently found a real change in the ordinary specific heat at the superconductive critical temperature.)

Sir R. T. Glazebrook, K.C.B., F.R.S., and Dr. Ezer Griffiths, F.R.S.—*Electric and magnetic units. The Paris Conference of July 1932.*

Dr. J. M. Holm.—*The initiation of gaseous explosions by small flames.*

Experiments are described in which a commonly accepted belief is disproved—i.e. that the limiting diameter for propagation along a tube filled with an explosive mixture is determined primarily by the thermal conductivity of the tube material. The variation of the limiting diameter for propagation along tubes, and for ignition through circular apertures in thin plates, is represented by a series of graphs for explosive mixtures of hydrogen, methane and ethyl ether with air. An experimental equation has been found to fit the curves. A description is given of an almost spherical flame which may burn in certain mixtures for several seconds without producing general ignition. The shape of the various types of flame formed by an explosive mixture burning at a circular orifice is shown by several photographs.

A theory of the failure of flames to travel along small tubes containing an explosive gaseous mixture has been developed on the assumption that the extinction of the flame is caused chiefly by the cooling effect of the unburnt gas in contact with its external surface and an approximate formula, which gives reasonable agreement with experimental values, deduced for the limiting diameter.

Afternoon.

Visit to the Physics Department of the University of Leeds, where the following demonstrations were arranged:

Mr. J. Ewles.—*Cathodo-luminescence.*

Mr. A. W. Foster.—*Some thermo-electric measurements.*

Mr. F. A. Long.—*Electromagnet protection.*

Dr. J. E. Roberts.—*Electron impacts in gases at low pressures.*

Dr. J. E. Shirodker.—*A new method of measuring the temperature of flames by the use of α-particles.*

Mr. F. W. Spiers.—*The crystalline nature of tin amalgams.*

Dr. J. E. Taylor.—*Photographic action of electrons.*

Monday, September 5.

Discussion on *The conservation of energy and nuclear phenomena* (Dr. C. D. Ellis; Prof. C. G. Darwin, F.R.S.; Prof. O. W. Richardson, F.R.S.; Dr. Mott):—

Dr. C. D. Ellis.

The majority of nuclear phenomena appear to be controlled by the same general laws that apply to the outside electronic structure. In particular, it is possible to explain what is actually observed as the aggregate of a number of similar processes, involving, for example, a nucleus and α-particle or nucleus and quantum, in each of which energy is conserved. In one case, however, that of the β-ray type of radioactive disintegration, this method of description meets with difficulties. This problem has often been discussed, and it is generally recognised that of the possible explanations there are two which deserve special consideration. The first is that energy is not conserved exactly in each elementary process, the second is that in contradistinction to the non-radioactive elements, the different nuclei of a radioactive element are not identically the same. A considerable amount of new experimental material has been published in the last year which bears on these problems, and which justifies reopening the discussion. On the one hand, our knowledge of the nuclei of the lighter elements has been extended both from spectroscopic evidence and from the study of artificial disintegration, and on the other hand, new experimental methods have added greatly to our information about the emission of α-particles from the radioactive elements. There appears to be a close connection between the energies of the α-particles in the nucleus and the frequencies of the γ-rays, which is entirely in accord with the validity of the energy principle and the principles of quantum mechanics. A detailed consideration of these points tends only to strengthen the view that the nucleus is governed by the same laws as the electronic structure and to render more acute the contrast with the β-ray type of disintegration. Important new information about the β-ray disintegration has been obtained by different workers, and a review of the present position shows it to be now more definite and more susceptible to attack.

Prof. O. W. Richardson, F.R.S.

We have listened to a most lucid account by Dr. Ellis of a very puzzling group of phenomena associated with the emission of electrons, or β-rays, by radioactive bodies. I believe this to be one of the most important unsolved problems outstanding in present-day physics, and that its ultimate solution will be found to be intimately bound up with the structure of the nucleus. As we have seen, it leads, on the face of it, to a contradiction of the principle of the conservation of energy.

This is not the first time that this principle has found itself in difficulties. On previous occasions it has evaded the difficulty by calling into existence a new kind of potential energy and thus balancing the account. This method of escape is not possible in the present case, because it would be necessary to invoke a special potential energy for each atom concerned in β-ray nuclear disruption, or, at any rate, for each of a considerable number of groups of such atoms emitting β-rays within a certain range of velocities.

I believe that this difficulty is essentially connected with the smallness of the dimensions of the nucleus. It is not possible to define in any exact way the energy of an electron which is in some way confined to such a small structure—that is to say, to a region of space whose dimensions are smaller than the wave-length of the de Broglie wave of the electron. As the energy of the electron when in or attached to the nucleus is incapable of specification, it is not surprising that the energies of the emitted electrons should be represented by a curve representing a probability distribution rather than by definite discrete values. This is not, of course, an explanation of the detailed structure of such distribution curves, but I believe that this structure will be found to depend fundamentally, and in some such way as I have indicated, on the smallness of the linear dimensions of the nucleus.

DISCUSSION on *The neutron* (Dr. J. CHADWICK, F.R.S.; M. LE DUC DE BROGLIE; Prof. O. W. RICHARDSON, F.R.S.; Dr. N. FEATHER; Mr. P. I. DEE):—

Dr. J. CHADWICK, F.R.S.

An account was given of the evidence which led to the discovery that in some cases of artificial transmutation by α-particles, notably those of beryllium and boron, neutral particles are emitted. The mass of these neutrons can be deduced from experiment; it is probably between 1·005 and 1·008. This suggests very strongly that the neutron is not an elementary particle but is formed by the close alliance of a proton and an electron. Such a particle will have a very small electric field except at very close distances, and will therefore only rarely be deflected by atomic nuclei in its passage through matter. It should be able to enter easily an atomic nucleus and occasionally cause a disintegration. Some cases of disintegration by neutrons have already been observed by Feather.

M. LE DUC DE BROGLIE.

Experiments on the absorption and scattering of neutrons in their passage through matter were described. The relative scattering of different atomic nuclei seems to depend markedly on the velocity of the neutron, and he suggested that this anomalous behaviour may be analogous to the Ramsauer effect.

Prof. O. W. RICHARDSON, F.R.S.

These investigations are going to lead to many important developments. As an illustration I will mention some interesting possibilities in connection with the building-up of nuclei out of neutrons and protons. These have been put forward by J. H. Bartlett, but they may be unfamiliar to some of you. Starting with the proton H^1, we add a neutron and get the hydrogen isotope H^2. If we add first a proton and then a neutron, we should get in succession He^3 and He^4. We can regard this as a building-up process analogous to the completion of the K shell in extranuclear atomic structure. After this we reverse the order of alternate addition, and so proceed up to O^{16}. We may regard this stage as the nuclear analogue of the completion of the L shell. At this stage we change the addition process again, adding successively two neutrons, then two protons, and then repeating. We carry this on until we reach A^{36}, which we may regard as the nuclear analogue of the completion of the M shell. In this way we obtain the successive structures shown in the table :

$$H^1 \quad \overset{n}{H^2} \quad \overset{p}{He^3} \quad \overset{n}{He^4} \;\Big|\; \text{K shell}$$

$$He^4 \;\Big|\; \overset{n}{He^5} \quad \overset{p}{Li^6} \quad \overset{n}{Li^7} \quad \overset{p}{Be^8} \quad \overset{n}{Be^9} \quad \overset{p}{B^{10}} \quad \overset{n}{B^{11}} \quad \overset{p}{C^{12}} \quad \overset{n}{C^{13}} \quad \overset{p}{N^{14}} \quad \overset{n}{N^{15}} \quad \overset{p}{O^{16}} \;\Big|\; \text{L shell}$$

$$O^{16} \;\Big|\; \overset{n}{O^{17}} \quad \overset{n}{O^{18}} \quad \overset{p}{F^{19}} \quad \overset{p}{Ne^{20}} \quad \overset{n}{Ne^{21}} \quad \overset{n}{Ne^{22}} \quad \overset{p}{Na^{23}} \quad \overset{p}{Mg^{24}} \quad \overset{n}{Mg^{25}} \quad \overset{n}{Mg^{26}}$$

$$\overset{p}{Al^{27}} \quad \overset{p}{Si^{28}} \quad \overset{n}{Si^{29}} \quad \overset{n}{Si^{30}} \quad \overset{p}{P^{31}} \quad \overset{p}{S^{32}} \quad \overset{n}{S^{33}} \quad \overset{n}{S^{34}} \quad \overset{p}{Cl^{35}} \quad \overset{p}{A^{36}} \;\Big|\; \text{M shell}$$

All these are known except He^3 and He^5. Apart from these two exceptions these isotopes, and only these, occur for masses below 37. We might, of course, have closed the ' K shell ' at H^2 and started reversing the order of alternate addition at that point. This would make the third member H^3 instead of He^3. Above 36 the rules are evidently more complicated.

I feel confident that the regularities exhibited in the table represent something important. (In the unlikely event of this not being the case, at least they give a convenient way to remember all the isotopes below 37.)

I was glad to hear that Dr. Chadwick regarded the neutron as some kind of a combination of a proton and an electron. Some authorities with whom I have discussed the matter seem disposed to look upon it as some entirely new kind of ultimate structure. The only advantage that this seems to confer is that it might afford a way of accounting for the inconvenient abnormal nuclear spin of a body like N^{14}. I feel that this is too small a matter to invoke an entirely new material entity to account for, and that the abnormal spin is probably due to something else. There is no known *a priori* reason why any such new entity should have any particular mass, at any rate not a mass approximating to that of H^1. The occurrence of an entirely new entity with a mass just under that of H^1 seems to me so improbable that, until some new reasons in favour of it are put forward, it is hardly worthy of serious consideration.

Dr. N. Feather.

Experiments were described in which the expansion chamber was used to study the disintegration of nitrogen and oxygen by neutrons. It seems that the disintegrations are not all of the same type. In many cases the neutron is captured and an α-particle ejected ; in others the neutron is not captured and the ejected particle may be a proton.

Mr. P. I. Dee.

The author described experiments to examine the collisions of neutrons with electrons. These are extremely rare, even compared with the nuclear collisions : not more than one such collision occurs in a path of 3 metres in air.

Mr. T. Smith.—*Hamilton and aplanatism.*

Afternoon.

Visit to the works of Messrs. Cooke, Troughton & Simms, Ltd.

Tuesday, September 6.

JOINT DISCUSSION with Section G (Engineering) on *The theoretical and practical aspects of the control of humidity in industrial processes.* (Representatives of the woollen, timber, photographic and cocoa industries participated, together with manufacturers of humidity control and measuring apparatus.) (Dr. EZER GRIFFITHS, F.R.S., Mr. J. H. AWBERY and Mr. R. W. POWELL; Mr. J. FRITH and Mr. F. BUCKINGHAM; Dr. S. G. BARKER and Mr. M. C. MARSH; Dr. S. F. BARCLAY; Prof. S. LEES; and others):—

Dr. EZER GRIFFITHS, F.R.S., Mr. J. H. AWBERY and Mr. R. W. POWELL.—*The evaporation of water in an air-stream.*

Mr. J. FRITH and Mr. F. BUCKINGHAM.—*The theory of drying.*

(1) The problem. Methods of drying. The application of Dalton's Laws. Relative humidity.

(2) The wet and dry bulb thermometer. Interpretation of its readings. The constancy of the wet bulb reading during evaporation and the suggestion that this reading is a measure of the total heat of a given mass of any mixture of air and water vapour. Discussion of the accuracy of the simplified expression:

$$p' - p = K\,(T - T').$$

(3) The proof of the total heat theory. The calibration of a wet bulb thermometer as an instrument to measure total heat per pound of any mixture of air and water vapour. Comparison of the above calibration with that calculated from the latest experimental figures of Awbery and Griffiths. Calculation of hygrometric tables from the total heat theory and comparison with Awbery and Griffiths' results. Actual value of the constant K in the simplified expression above.

(4) The application of all the above to the practical solution of drying problems.

Dr. S. G. BARKER and Mr. M. C. MARSH.—*Controlled humidity in woollen and worsted mills.*

Prof. S. LEES.—*The drying of air, particularly by the silica gel process.*

Dr. F. J. W. WHIPPLE.—*Continuous records of vapour-pressure.*

Mr. B. G. MCLELLAN.—*The significance of humidity conditions on the making and marketing of foodstuffs.*

Mr. R. S. WHIPPLE.—*The instrument-maker and the control and measurement of humidity.*

Dr. A. FERGUSON.—*Evaporation from plane and spherical surfaces.*

Mr. F. SHORT.—*Humidity-measuring instruments.*

Mr. R. G. BATESON.—*The control of humidity.*

Dr. F. T. PEIRCE.—*The influence of moisture on cotton technology.*

DISCUSSION on *The organisation required for the recording of water level and river flow in the British Isles* (Capt. W. N. McCLEAN; Capt. J. C. A. ROSEVEARE; Mr. W. J. S. BINNIE; Mr. E. G. BILHAM; Mr. J. K. SWALES; Mr. C. CLEMESHA SMITH; Mr. W. J. M. MENZIES; Maj. J. G. WITHYCOMBE; Mr. D. HALTON THOMSON; Vice-Admiral H. P. DOUGLAS, C.B., C.M.G.; Mr. W. T. HALCROW; Mr. A. W. McPHERSON; Mr. J. S. THOMS):—

Capt. W. N. McCLEAN.—*Introduction.*

After pointing out that water records in the past, owing to lack of co-ordination and continuity, have been less useful to the country than could have been hoped, the author points out the necessity for an organisation to deal with such records, and shows how his own work on the Ness Basin has resulted in an organisation which, with possible slight modifications, could be applied to other areas.

This is the 'local' organisation, and the idea is developed to show how such subsidiary areas may be brought under a central organisation such as, in the case of Scotland, the Fishery Board for Scotland. In England there seem to be too many departments and too many opposing interests engaged in the collection of water data on different lines, and all these interests would be better served by systematic water survey.

A brief summary of the work already accomplished on the Ness area is given as typical of the necessary investigations, and suggestions are made that the organisation should be in the hands of local associations, representing fairly large areas, for the collection of observations and maintenance of records, and that the flow measurements should be carried out by the Ordnance Survey Department on the principal river-basins, and by water authorities or specialist surveyors in the case of small areas, the whole being co-ordinated under a water survey department of a ministry with inspectors or area supervisors.

Capt. J. C. A. ROSEVEARE.

Necessity for full information regarding river flow if true economy is to be obtained.

Little information available at the present time.

Catchment Boards set up by the Ministry of Agriculture and Fisheries under the Land Drainage Act, 1930, are the proper authorities to undertake the survey.

Catchment Boards cover 67 per cent. of area of England and Wales, are fully representative of County Councils, and can precept on latter for revenue.

Catchment area correct unit for water questions. Boundaries determined by survey.

Water survey necessary before Catchment Board undertakes land drainage works.

Catchment Boards interested in water supply for every purpose, and can make by-laws for prevention of pollution.

Government grants to Catchment Boards.

Mr. E. G. BILHAM.—*The evaluation of general rainfall over drainage areas.*

The term 'general rainfall' is used by the British Rainfall Organisation to specify the space-average of the depth of rain over an extended area in a definite period, such as a month or a year, the terms 'average,' 'normal,' or 'mean' being reserved for time averages. It is the general rainfall of which a knowledge is required in such studies as that of Capt. McClean on river flow. The procedure adopted by the B.R.O. in estimating general rainfall consists in measuring, on a rainfall map, by means of a planimeter, the areas included between successive isohyetal lines and the boundaries of the drainage area, and then working the space-average of the fall per unit area. Thus if an area a square miles, within the drainage area, is included between the isohyets $r + \delta r$ inches and $r - \delta r$ inches and A is the whole area, the general rainfall is given by the expression $\Sigma ar/A$ inches. The accuracy of the result depends simply on the accuracy of the isohyetal lines, and this again depends on the number of rain-gauges and their distribution. In regions where gauges are relatively numerous, monthly evaluations of general rainfall over drainage areas of moderate size can be made with fair precision.

As an illustration of the part that can be played by the B.R.O. in studies on water level and river flow, monthly maps of rainfall over the Tees drainage area (prepared for the Department of Scientific and Industrial Research in connection with the biological and chemical survey of the river Tees) will be shown, with evaluations of general rainfall over the sections of the watershed concerned in the level measurements.

Mr. C. Clemesha Smith.—*Stream-flow measurement.*

Every self-respecting business concern keeps strict account of its assets or resources. Water is a national asset of paramount importance—the available supply is limited and the demand is always increasing.

In order that the claims of the various users may be considered and met, it is necessary that the quantities available should be known.

Gauging of streams and rivers is the only accurate method of obtaining the requisite knowledge.

Gauging must be carefully organised so as to cover the whole country if water problems relating to domestic supply, trade supply, navigation, drainage, flooding, etc., are to be satisfactorily solved.

The public spirit of Capt. McClean has urged him to initiate an experiment which may be the germ of the necessary organisation.

It should be possible to develop an organisation on the following lines: The division of the British Isles into suitable areas—possibly watersheds: the collection, verification and recording of all existing stream-flow measurements. The provision of further stations as circumstances permit or demand. The publication of results in brief.

The organisation should be elastic, on lines made capable of expansion—use should be made of existing records and observers. The services of rivers boards, drainage boards, navigation companies, corporations and private observers should be used to the fullest extent.

Such an organisation involves expenditure, but wise expenditure is true economy.

Mr. W. J. M. Menzies.

On water flow, of primary importance to salmon, sea trout and trout fisheries, depends the ascent of migratory fish and the health, and indeed very life, of all fish.

Exact knowledge of actual flow is of great practical importance in determining water available for power or for domestic purposes, in fixing the regulated flow allowed from diversion schemes and in computing dilution of polluting effluents.

At present exact knowledge is entirely lacking: calculations required for vast hydro-electric schemes affecting important Scottish salmon rivers have been based entirely on empirical formulæ.

Series of accurate figures from gauge posts, maintained by many anglers, could be easily obtained under the supervision of a central authority.

The popular conception of the salmon fisheries of Scotland is as a sport: the more important side is commercial fishing. The average annual value of net-caught Scottish salmon recently has been almost £500,000; 2,000 men are engaged taking the fish, and many are employed as ghillies, in making boats, ropes, nets, etc. Indirect benefit is derived from money spent by anglers in rent and in localities which they visit. Salmon, sea trout and brown trout fishing also provide recreation for people of humble means.

Undue abstraction of water, or a low standard of dilution of pollutions, may jeopardise, and even destroy, the valuable commercial asset and recreational facilities.

Maj. J. G. Withycombe.

Need for systematic survey of water resources and collection of data, including rainfall statistics, maps, profiles, records of run-off and water levels, power sites and storage accommodation, existing and potential.

Catchment areas the best units.

Catchment Area Boards under the Land Drainage Act.

Danger of overlapping and duplication without some co-ordinating organisation.

Allocation of water: variety of competing interests; potable supply; sewage disposal; industrial supply; power; land-drainage; fisheries.

The Water Resources Committee Report (1921): recommendations regarding collection and recording of data, the establishment of a Water Commission and Inter-Departmental Committee.

Situation to-day compared with 1921.

Advantages of an Inter-Departmental Committee.

Ministries of Health and Agriculture, Board of Trade, Electricity Commissioners, Department of Industrial and Scientific Research.

Position of the Ordnance Survey.

Pending Government action much could be done by a voluntary organisation, such as the Land Utilisation Survey.

University Engineering and Geography Schools might co-operate, especially by collecting data relating to low-fall rivers.

Present neglect of low falls.

Gauging methods: rating curves; current meters, weirs.

Recording systems: maps; card indexes, folders.

Importance of geology; underground water.

Period necessary to establish co-relation of rainfall and run-off.

Study of typical rivers.

Mr. D. Halton Thomson.

The absence of a nationally organised water survey in this country is a remarkable omission in the development of its natural resources. There are a national land survey, a national geological survey, and a national rainfall organisation, all of which have a bearing on the national water resources, but there is no official organisation dealing directly with those resources themselves. This omission is probably partly due to the ingenuity of the civil engineer in deducing the data he requires by indirect means, but he would be the first to admit that he does so only in default of better information. This country is far behind many others in the systematic collection of stream-flow and underground-water records.

It is not sufficient to leave the matter to private enterprise, which usually has in view only particular purposes in particular areas. What is wanted is (*a*) continuity and (*b*) records under different topographical and geological conditions in all parts of the country, where they are likely to serve ultimately some practical purpose. The longer are the records prior to their application, the more certainly will they promote development on the most economical lines.

It is suggested that the Geological Survey (as in the United States) would be the most appropriate department to organise the work, being almost exclusively a fact-finding organisation and independent of any direct interest to which the information would ultimately be put. This department has already issued many valuable Water Supply Memoirs.

Vice-Admiral H. P. Douglas, C.B., C.M.G.

There is no doubt that some form of organisation for the survey of water resources would be most useful, and in the long run economical. The present somewhat haphazard way of obtaining information is obviously not satisfactory, for should it be required at some future time it is doubtful whether it would be readily available, or perhaps even not be recorded.

As regards the Hydrographic Department and the Surveying Service of the Navy in respect of observations, a considerable amount has been done in the course of the survey of the river Tees, and a discussion on the data obtained has already been published by the Department of Scientific and Industrial Research. If other water-flow observations are required by us, it is an easy matter for the surveyor to obtain them as needed, and, naturally, a record is kept in the Hydrographic Department.

Should such an organisation as that visualised by Capt. McClean be set up, it is thought that one of its first duties should be to collect all data available from the various departments which could provide them, these being added to or checked if necessary from local organisations.

It does not appear that there would be any difficulty for the hydrographic surveyor and the Ordnance Survey to carry out such measurements, but it would certainly mean increases in staff, although possibly this would be a cheaper way of tackling the problem than the organisation suggested having its own surveyors. Moreover, local bodies could probably provide the data required from their own surveyors more cheaply than the organisation, so that all that would be needed is a central organisation of comparatively small size to collect, organise and supervise.

Mr. W. T. Halcrow.

The author agrees with Capt. McClean that it would be of great assistance to all waterworks and hydro-electric engineers were reliable records of stream flow available throughout the country.

A great deal of information exists with respect to rivers already utilised for water undertakings, but this is not usually available to all engineers. What is more important is that a record should be kept of the flows of rivers which may be utilised in the future.

As a hydro-electric engineer, the author has been impressed by the amount of data which has frequently been placed at his disposal in foreign countries, the records of river discharge having been kept, in some cases, for many years, although no development has materialised.

Referring to the power developments carried out in the Highlands of Scotland, it would have been of great assistance to him had statistics relating to the rivers been available when the works were designed. The schemes were worked out on rainfall data alone.

The author considers that there should be a central authority under a Government Department to collect the existing data, and to institute, through such subsidiary organisations as may be necessary, the measurement of rivers not yet utilised.

Wednesday, September 7.

Prof. J. J. Nolan.—*The diurnal variation of the ionisation in the lower atmosphere.*

Miss M. D. Waller.—*A demonstration of the maintenance of vibration by the application of cold.*

If a solid block of carbon dioxide be held against a metal, a chattering or singing sound will often be heard, due to vibrations of the latter. This fact is familiar to some of those who handle carbon dioxide commercially.

Under proper conditions a very loud note may be produced. Thus, for example, let the body to be set into vibration be a somewhat massive tuning-fork of high frequency, e.g. 3,000 p.p.s., and let the solid carbon dioxide be of high density. Then when suitable contact is made between one of the prongs of the fork and the block, the fork may be set into violent vibration which may be maintained for some seconds if the contact be skilfully adjusted.

Bodies of different shapes (bars, discs, rings, etc.) and of different metals may be similarly excited, and irregularly shaped bodies will sometimes give out much noise.

In explanation of the phenomenon it would appear that the source of energy for producing the vibrations is the heat which is given up by the metal to the solid carbon dioxide, and that the efficacy of the carbon dioxide in producing vibrations is determined by the fact that it sublimes and that considerable gas pressures are produced during the momentary contacts of the metal with the block.

Prof. L. S. Palmer.—*Short-wave reception with frame aerials.*

When a frame aerial receives wireless waves comparable in length with the frame dimensions, the maximum current depends not only upon the tuning, but also upon the ratio of the wave-length to the width and height of the frame. The critical frame dimensions also vary with the angle of incidence of the wave. By considering the interaction between the currents in adjacent parts of the frame, the critical dimensions can be calculated. It is then found that for a frame of any given width there are, within one wave-length, at least two critical heights for which the received current will be a maximum. Furthermore, any increase in the width can be compensated by a proper decrease in the height, and *vice versa*. The greatest current will be produced in those correctly proportioned frames which have the largest area, but *in*creasing the area without maintaining the correct dimensions (depending on the wave-length λ and angle of incidence) will cause a *de*crease of current. Thus the areas of the frame are also critical, and vary from $0 \cdot 15\ \lambda^2$, $0 \cdot 50\ \lambda^2$, etc., to $0 \cdot 24\ \lambda^2$, $0 \cdot 73\ \lambda^2$, etc., depending on the angle of incidence of the waves.

Different critical dimensions are necessary when frames are used for transmission.

The word 'formatised,' as distinct from 'tuned,' is suggested for such critically proportioned frames.

Prof. D. A. Keys.—*Magnetic and electrical surveys over mineral, diabase and artificial dikes.*

Magnetic dikes which do not outcrop may be located and their strike and dip determined with fair accuracy with the modern types of horizontal and vertical magnetic variometers. As a result of calculations and laboratory experiments, magnetic measurements may also be used to determine approximately the amount of overburden and to estimate the vertical height of the dike. Resistivity and electromagnetic geophysical methods may be applied to confirm these results and to distinguish mineral from diabase dikes.

Examples of the variation in horizontal and vertical intensities over magnetic models were given. The results of surveys made over buried diabase and pyrrhotite nickel dikes in the Sudbury Basin, Ontario, indicate the possibilities of these magnetic and electrical methods. The geophysical interpretation of the results over the pyrrhotite vein indicated the proper strike and dip of the dike and the amount of overburden, as was determined from diamond drill records. The electrical methods differentiated the diabase from the pyrrhotite dike.

The strike of these dikes was approximately east-west, but the methods may also be extended to buried veins lying in other directions. This investigation was carried out in collaboration with Prof. A. S. Eve, F.R.S., and Dr. F. W. Lee.

Prof. G. Temple.—*Certain aspects of Quantum Theory.*

DEPARTMENT OF COSMICAL PHYSICS (A†).

Thursday, September 1.

Dr. R. Stoneley.—*The long-wave phase of earthquake records.*

The long-wave phase, the beginning and the maximum amplitude of which are respectively designated as L, M on seismograph records, consists mainly of waves that have travelled over the surface of the earth. These waves are of two types—the Rayleigh-waves, in which there is no displacement perpendicular to the plane through the vertical and the direction of propagation, and the Love-waves, in which the displacement is in this direction only. Accordingly, the waves are best studied in records of shocks that arrive in a nearly due easterly or westerly azimuth : the N.–S. record then shows the Love-wave and the Rayleigh-waves are recorded on the E.–W. and Z records.

Both types of wave show dispersion—i.e. dependence of velocity on period—and the velocity of travel of a given group of waves is the 'group-velocity.' The various maxima observed presumably denote the arrival of waves of stationary group-velocity. The *i*L corresponding to the sudden commencement of the surface waves, corresponds to Love-waves of very long period, and the velocity of about 4·4 km./sec. is that of distortional waves in the ultrabasic substratum below the surface layers, as general theory leads us to expect. Corresponding to very long Rayleigh-waves is an iL (about 4 km./sec.) which travels with the velocity appropriate to Rayleigh-waves in the ultrabasic material—i.e. about $4 \cdot 4 \times 0 \cdot 92$ km./sec. These two onsets, iL_L and iL_R, are seen in the velocities found by the late Prof. H. H. Turner for L; sometimes he found that for some earthquakes iL fitted 0·42 min./deg., while for other shocks he found 0·47 min./deg. These are evidently iL_L and iL_R respectively.

The observations of group-velocity of Love-waves of known periods give, on certain assumptions, an estimate of the thickness of the continental granitic layer; for Eurasia this is about 12 km., if it is assumed that there is a tachylyte layer twice as thick as the granitic layer.

For Rayleigh-waves in a surface layer the calculations are rather heavy. The results available show that on the extremely hazardous assumption that the floor of the Pacific Ocean is a layer of material of which the rigidity is half that of the underlying material (this is roughly the case for tachylyte, diorite, or syenite resting on dunite), the thickness of the layer is of the order of 20 km. Further calculations are in progress.

Mr. J. J. Shaw, C.B.E.—*Earthquake recording in the heart of London.*

Dr. H. Jeffreys.—*Near earthquakes.*

Mr. E. G. Bilham.—*The climate of York and its variations during the sixty years, 1871–1930.*

The paper is mainly devoted to a comparison of the climatological data for York (the Yorkshire Museum) during the two periods of thirty years, 1871–1900 and 1901–30. It has commonly been asserted that since the turn of the century winters have become less 'wintry' and summers wetter and less sunny. The data show that in the latter period mean temperature has risen in most months, the increase amounting to from 1° to 1½° F. in January, March, May, October and December. Sunshine increased by approximately 30 per cent. in November, and decreased by approximately 15 per cent. in February, March and May. Rainfall was on the average 7 per cent. less in the latter period, the months showing the biggest changes being January (plus 12 per cent.), February (minus 15 per cent.), June (minus 15 per cent.), July (minus 12 per cent.), September (minus 28 per cent.), October (minus 17 per cent.), and December (plus 14 per cent.).

The following table summarises the results for the four seasons and the year, a positive sign indicating an increase in 1901–30 as compared with 1871–1900 (1881–1900 in the case of sunshine).

Season.	Mean Temperature.	Rainfall.	Sunshine.
Spring (March, April, May) . .	+ 0·7° F.	No change	− 9%
Summer (June, July, Aug.) . .	− 0·1° F.	− 9%	− 1%
Autumn (Sept., Oct., Nov.) . .	+ 0·3° F.	− 17%	+ 9%
Winter (Dec., Jan., Feb.) . .	+ 1·0° F.	+ 5%	− 6%
Year	+ 0·5° F.	− 7%	− 3%

The table supports the popular belief that winters have become milder, but there is no support for the supposition that summers have, on the whole, deteriorated since 1900. The season showing the most marked change is autumn, with 17 per cent. less rainfall and 9 per cent. more sunshine.

A similar investigation shows that at Oxford (Radcliffe Observatory) corresponding changes of temperature have occurred. Oxford, however, has experienced an increase of rainfall amounting to 22 per cent. in spring and 14 per cent. in winter, though winter sunshine has increased by 12 per cent.

Mr. M. G. Bennett.—*The effect of the spectral transmission of the atmosphere upon visibility by artificial light.*

(1) Summary of experimental work bearing on the transmission by the atmosphere of light of different wave-lengths.

(2) Application of the results of this work to the problems of—

(*a*) the visual range of point sources of light;

(*b*) the visual range of objects illuminated by the beam of a searchlight or motor-car headlight;

with conclusions as to the effect of the colour of the light on the visual range in the two cases.

Mr. W. M. H. Greaves.—*The new transit circle under construction for the Royal Observatory, Greenwich.*

Television Demonstrations.

The Marconi Company kindly gave demonstrations of television by radio from Chelmsford to the meeting-room of Section A (Mathematical and Physical Sciences).

SECTION B.—CHEMISTRY.

Thursday, September 1.

Presidential Address by Dr. W. H. Mills, F.R.S., on *Some aspects of Stereochemistry.* (See p. 37.)

Discussion on *Stereochemistry* (Prof. Dr. J. Meisenheimer; Mr. T. W. J. Taylor and Mr. L. E. Sutton; Dr. N. V. Sidgwick, F.R.S.; Dr. F. G. Mann; Dr. S. Sugden; Mr. J. D. Bernal):—

Prof. Dr. J. Meisenheimer.—*The stereochemistry of oximes, hydroxylamines and amine-oxides.*

An attempt is made to explain the inconsistency that compounds in which nitrogen is 2-co-ordinate should show stereoisomerism, whilst unsymmetrically substituted tertiary amines have not been found resolvable, although in both types a pyramidal arrangement of the valencies must be assumed.

The possibility that the relatively great stability of stereoisomeric oximes is connected with the presence of the hydroxyl-group is excluded by the failure to resolve the substituted hydroxylamines EtNMeOH, $HO_3SC_6H_4$, NMe.OBz.

The circumstances under which the co-ordination number 3 is associated with a pyramidal configuration and the causes that determine the stability of a pyramidal arrangement are discussed.

Stress is laid on the fact that although quinoline oxide shows the greatest similarity to the sulphoxides in the arrangement of electrons round the central atom, it has proved non-resolvable.

Mr. T. W. J. Taylor and Mr. L. E. Sutton.—*The configurations of the oximes from measurement of electric di-pole moment.*

The configurations of the oximes have been established by the measurement of the electric moments of certain of their derivatives. For the ketoximes this can be done absolutely from the moments of their N-methyl ethers. In the case of the aldoximes this method cannot be applied, because one and the same N ether is obtained on methylating either of the two isomeric oximes. The two O-methyl ethers of *p*-nitrobenzaldoxime, however, are known, and their relation to their parent oximes is unambiguous. By comparing their moments with those of the O-ethers of the closely related *p*-nitrobenzophenoneoximes, whose configurations are known from the above argument, the configurations of the aldoximes themselves are established. The results show clearly that the modern view as to the configurations of the aldoximes is correct—i.e. that in the reaction used for obtaining configuration, the action of Na_2CO_3 on the acetyl compounds, the loss of acetic acid in the β series involves groups *anti* to one another, and that the original configurations of Hantzsch and Werner must be reversed.

Since it was found previously that the one N-methyl ether of *p*-nitrobenzaldoxime has a moment $6 \cdot 4 \times 10^{18}$, it appears that the N ethers of aldoximes have the β configuration, as has been suspected.

Dr. N. V. Sidgwick, F.R.S.—*Molecular di-pole moments and inter-valency angles.*

The di-pole moment of a molecule is the vector sum of those of its constituent links; hence if these moments are known, the valency angles can be calculated.

Qualitatively it follows that a molecule AB_3 if polar (NH_3, PCl_3) is pyramidal: if non-polar (BCl_3) is plane, with angles of 120°. AB_2, if non-polar (CO_2, CS_2, N_2O), is rectilinear; if polar (H_2O, H_2S, SO_2) is bent.

Quantitatively, by comparing the moment of, say, diphenyl ether with that of its para-di-substitution product, e.g. $(Cl–C_6H_4)_2O$, we can determine the angle between the oxygen valencies (Smyth, Bergmann, Hassel, Sutton). The mutual—electromeric and inductive—effects of the moments can be eliminated by using substituents of different types.

The conclusions so far reached are:

(1) With valency groups of less than eight electrons, two valencies are approximately at 180° (mercury diphenyl), and three in a plane at 120° (BCl_3).

(2) With a complete octet the tetrahedral arrangement holds. The angles found are approximately: of the C–C valencies 110° in diphenyl methane, 130° in benzophenone; of the C–O and C–S valencies in diphenyl ether and thioether about 140°. This is in striking opposition to Pauling's theory, which requires smaller angles (about 90°) for oxygen and sulphur.

Dr. F. G. Mann.—*Chemical evidence on the configuration of the 4-co-valent compounds of the metals of the platinum group.*

Werner's work on the stereochemistry of complex metallic salts was directed chiefly towards the salts of metals showing a co-ordination number of 6, and the configuration of such compounds is now beyond reasonable doubt. Recent work has therefore concentrated more particularly on the stereochemistry of complex salts of metals showing a co-ordination number of 4.

The configuration of the tetramino metallic complex—whether tetrahedral or uniplanar—is still in doubt, however, since the available experimental evidence remains indecisive.

The salient points in this evidence are briefly reviewed, and their significance discussed.

Dr. S. Sugden.—*Planar configuration of diamagnetic nickel complexes.*

The wave-mechanics valency theory of Pauling gives a correlation between (*a*) the space distribution of valency links; (*b*) the azimuthal quantum numbers of the electron levels taking part in the links; and (*c*) in some cases the magnetic moment of the atoms.

The case of nickel is of special interest, since not only *s* and p_1 electrons (with azimuthal quantum numbers 1 and 2) are concerned, but also *d* electrons (with azimuthal quantum number 3). If one *d* electron level is concerned, then Pauling finds that four strong links should be formed in one plane. At the same time the nickel should change from a paramagnetic ion to a diamagnetic complex.

Co-ordination complexes of nickel are found to be sharply divided into two groups as regards their magnetic behaviour. One group is paramagnetic, the other diamagnetic. Of the latter the double cyanide $K_2Ni(CN)_4$ and the dimethylglyoxime are the best-known compounds.

By synthesising unsymmetrical glyoximes it has been found that the nickel derivatives occur in two forms, which are interconvertible. These appear to be the cis-trans isomerides required by Pauling's theory of a planar configuration.

Mr. J. D. Bernal.—*Crystal structure and stereochemistry.*

Friday, September 2.

Discussion on *The constitution of polysaccharides, with special reference to fibres* (Prof. W. N. Haworth, F.R.S.; Prof. Dr. L. Zechmeister; Prof. Dr. H. Staudinger; Dr. E. L. Hirst; Prof. Dr. H. Mark; Mr. W. T. Astbury):—

Prof. W. N. Haworth, F.R.S.—*Introduction.*

In a brief historical survey of the development of the constitution of polysaccharides, it is shown that the occurrence of cellobiose as preformed units in cellulose is established by chemical methods, and that the structure of cellulose rests ultimately on the constitution previously assigned to this biose. The mutual linking through position 1 : 4 of β-glucopyranose units in chain fashion is thus the fundamental principle of modern cellulose structures. Recent work by Haworth and Machemer has indicated that a methylated cellulose can be utilised to gain valuable information (1) as to the character of the chain, whether open or closed, and (2) as to the approximate chain length in this very representative derivative. Tetramethyl glucose, in yield of 0·6 per cent., is obtained by hydrolysis of this specimen, so that the minimum mean value for the chain length of cellulose is given as 200 glucose units. Similar experiments with intermediate hydrolysis products of cellulose have been carried out and their molecular size determined.

Prof. Dr. L. Zechmeister.—*The enzymatic cleavage of cellulose and cellulose break-down products. Relationship between cellulose and chitin* (in collaboration with Dr. W. Grassmann and Dr. G. Toth).

An investigation of the action of enzymes on break-down products of cellulose containing a comparatively small number of glucose units has revealed unexpected relationships which suggest that the action of enzymes is dependent not only on the nature and stereochemical arrangement of the groups in the molecule undergoing reaction, but also on the chain length of the molecule. This conception opens up a new field of investigation in connection with the chemistry of enzymes, the exploration of which is important in view of the new idea thus afforded of the relationship between enzyme action and the chemistry of the polysaccharides. From Aspergillus extracts an oligosaccharase and a polysaccharase have been separated.

Chitobiose, the break-down product obtained from chitin, yields an acetyl derivative and has chemical properties which show it to be constituted analogously to cellobiose, the corresponding break-down product of cellulose, and it appears that chitin is to be regarded as built up of continuous chains of chitobiose units, joined together in a manner similar to the cellobiose units in cellulose. The observation that chitodextrine undergoes a rapid break-down, when treated with emulsin, proves the presence of β-linkings in chitin.

Prof. Dr. H. Staudinger.—*The nature and size of the colloid particles of cellulose and related substances.*

The work of Haworth and his school has shown the mode of linking of glucose units in cellulose. The question of how many such units are combined in the molecule can be answered by investigating the nature and the size of the colloid particles of cellulose dissolved in Schweizer's reagent or of the acetate or nitrate in organic media. These colloid particles are the molecules themselves and, contrary to McBain, Meyer and Mark, have not a micellar character. This is shown by the examination of 'polymer homologous series' of break-down products of cellulose, the lower molecular members of which are recognised, by ordinary chemical methods, as thread-molecules of different lengths. These products exhibit a relationship between their molecular length and their viscosity in solution, which is expressed by the viscosity law: $\frac{\eta sp}{c} = K_m.M$, where ηsp is the specific viscosity, c the concentration, K_m a characteristic constant for each polymer homologous series, and M the molecular weight. K_m can now be derived from other viscosity measurements—e.g. in the paraffin series and in substances with 6-rings.

These investigations were facilitated by the parallel study of synthetic polymeric substances of known constitution. By these methods, cellulose in Schweizer's reagent is found to have mol. wt. 120,000—that is, 750 glucose residues are combined in one molecule. The molecules are long threads which in one dimension are 500 times longer than in the two others. This provides an explanation of the colloid nature of cellulose solutions.

Dr. E. L. Hirst.—*Amylose and amylopectin.*

Analogues of cellulose, containing mutually linked glucose units, are represented by starch and glycogen. But whereas in cellulose the units are β-glucopyranose, in starch and glycogen they are α-glucopyranose, the model of which does not permit of its forming a straight chain pattern such as is possible with cellulose. No sure evidence has been available as to the size of the molecular unit, and the situation has been rendered complicated by uncertainty concerning the relationships between amylose and amylopectin. Work with Miss M. M. T. Plant has thrown light on both these problems. It was found that the essential differences between amylose and amylopectin do not depend on the phosphorus content. On careful methylation the special characteristics of each modification were retained in the methylated derivatives. Methylated amylopectin yielded on hydrolysis 5 per cent. of tetramethyl glucose, representing a minimum mean chain length of about 25 glucose units for amylopectin. Methylated amylose gave the same amount of tetramethyl glucose, and it would appear that the differences between amylose and amylopectin depend on hydration and micellar structure rather than on length of chain.

Similar work with E. G. V. Percival on methylated glycogen resulted in a yield of 8·5 per cent. of tetramethyl glucose, indicating a minimum chain length of about 12 units for this polysaccharide. Glycogen does not retrograde into an insoluble modification as does amylose, and it would appear that in glycogen the chain length is insufficient to bring about the micellar changes which take place in starch.

Prof. Dr. H. Mark.—*The space model of cellulose.*

The question of the structure of cellulose is an old and fascinating problem of organic chemistry. Many attempts have been made to solve it, but they all failed to reach the final point of linking up structure and properties. The formula of aniline represents to every organic chemist an expression not only of the percentage composition, but also of the properties of the substance. But the expression $(C_6H_{10}O_5)_x$ for cellulose does not represent anything but the percentage composition.

There appeared a favourable chance of making progress in regard to the formula of cellulose by building up a model from the molecular point of view. Two stages of new knowledge were necessary. The first step was provided by the very remarkable progress of the researches in the field of sugar chemistry, largely carried on by British chemists. The other was our increased knowledge of the size and shape of molecules, which was mainly the work of Sir William and Professor W. L. Bragg. The combination of these two lines of attack, supported by some results of Freudenberg, rendered it possible to build up a reasonably accurate and detailed model of the cellulose structure which illustrated the peculiarities of its properties and behaviour as a high molecular substance. Such a combination was first made by Sponsler and Dore, and about two years later with more efficiency by K. H. Meyer and his co-workers.

Mr. W. T. Astbury.—*Protein fibres and the formation of polysaccharide chains.*

The fruitful combination of the results of organic chemistry with those of X-ray analysis has now defined with some precision the concept of long-chain molecules in the field both of the polysaccharides and of the proteins ; but whereas cellulose appears to be laid down in biological structures as fully extended chains, protein fibres are undoubtedly built up of polypeptide chains in various states of extension. X-rays have as yet revealed only two proteins, the fibroin of natural silk and the β-keratin of stretched hair, which would appear to be in a fully extended state. Since in natural processes the formation of cellulose and other polysaccharides seems to be brought about through the intervention of proteins, the possibility thus arises that the protein chain may act as a pattern or framework down the sides of which sugar units are laid in order to be linked up into a polysaccharide configuration. It is an interesting point that the chief longitudinal spacings of muscle and unstretched hair are almost equal to the length of a glucose residue as it is known in cellulose; while the fact that the crossed cellulose chains of the wall of *Valonia ventricosa* are laid down according to a definite plan indicates that they are formed on a network pattern in the underlying protoplasmic layer.

Saturday, September 3.

Visit to works of Imperial Chemical Industries (Fertilisers and Synthetic Products) Ltd., Billingham.

Sunday, September 4.

Excursion to Kirkham Abbey.

Monday, September 5.

DISCUSSION on *Water pollution (survey of the River Tees)* (Dr. H. T. CALVERT; Mr. J. LONGWELL; Dr. R. W. BUTCHER and Mr. F. T. K. PENTELOW; Dr. B. A. SOUTHGATE; Mr. W. B. ALEXANDER; Mr. R. BASSINDALE):—

Dr. H. T. CALVERT.—*The purpose and nature of the survey of the River Tees.*

Mr. J. LONGWELL.—*The decomposition of sewage in river water.*

The self-purification of the upper reaches of the river Tees has been studied from the results of chemical analysis combined with measurements of the flow of the river—that is, from determinations of the actual quantities of the polluting constituents. Rate of self-purification from sewage pollution appears to be dependent mainly on temperature. Thus, below Croft, where the Tees receives sewage pollution from the Skerne, a much greater distance is required in the winter than in the summer for the same amount of purification.

Dr. R. W. BUTCHER and Mr. F. T. K. PENTELOW.—*The effects of pollution on the biology of the non-tidal reaches of the River Tees.*

The biological work in the upper reaches of the Tees has dealt primarily with 'sewage fungus,' the algæ and the macroscopic fauna. Above Croft the river is relatively pure, except for short distances below two sewage outfalls. At Croft the Skerne joins the Tees and carries a considerable quantity of sewage. The area occupied by sewage fungus varies with changes in the chemical composition of the water. Large quantities of the filamentous alga, *Cladophora glomerata*, occur in May and June from Croft down to the tidal reaches, but only small quantities grow just below the two sewage outfalls above Croft. The distribution of some other algæ appears also to be affected by pollution. The flora, microscopic and macroscopic, is much richer below than above the Skerne. Sewage pollution also has a marked effect on the fauna, water-snails, leeches and *Asellus* being most abundant just below Croft. In the Skerne, sewage fungus is abundant but *Cladophora* is absent. Tubificid worms and red chironomid larvæ occur in quantity in the Skerne, but are found only over a short distance in the Tees.

Dr. B. A. Southgate.—*The effects of sewage and industrial pollution in the Tees estuary.*

The estuary of the Tees receives large quantities of crude sewage and of industrial effluents, mainly in the section from Stockton to Cargo Fleet. The principal industrial effluents are coke-oven effluents containing tar acids, cyanides, etc., and spent pickle liquor, which is an acid solution of iron produced in the cleaning of iron and steel. Oxidation of the sewage and effluents occurs in the estuary at the expense of dissolved oxygen. Large numbers of fish are killed in the estuary, especially salmon and sea-trout smolts during their spring migration to the sea. In 1930 and 1931, the death of migrating smolts was not due to the deficiency of dissolved oxygen, but to cyanides frequently found in lethal concentrations. Other poisonous substances, including tar acids, were not found in toxic concentrations, and it has been concluded from numerous chemical and physiological experiments and observations that, in the absence of cyanides, migrating smolts would not have been killed in 1930 and 1931. Laboratory and semi-technical scale experiments have demonstrated that cyanides in coke-oven effluents can be converted into relatively non-toxic ferrocyanide by treatment of the effluents with spent pickle liquor and lime.

Mr. W. B. Alexander.—*The effects of pollution on the biology of the Tees estuary.*

There is a scarcity of living organisms in the middle portion of the estuary of the Tees between Stockton and Middlesbrough. This section is subject to the greatest variations in salinity resulting from tidal flow and to the greatest amount of pollution. In addition, organisms living on the banks must be able to withstand exposure to the air for certain periods at low tide, and those living on the bed of the estuary have to withstand the effects of movement of bottom deposits and of sedimentation. It was impossible to determine, therefore, from a biological survey of the estuary of the Tees only, to what extent the flora and fauna are affected by pollution. A survey of the relatively unpolluted estuary of the Tay has shown a distribution of organisms in the section subject to variations in salinity similar, in general, to the distribution in the corresponding section of the Tees, although there are some differences. It thus appears that the scarcity of plant and animal life in the middle portion of the estuary of the Tees is not primarily due to the effects of pollution.

Mr. R. Bassindale.—*The susceptibility of invertebrate animals to poisons.*

Certain animals have a restricted range of distribution in the estuary of the Tees as compared with their range in the relatively unpolluted estuary of the Tay. The effects on these animals of changes in salinity and of the presence of cyanides and tar acids, in concentrations similar to those found in the estuary of the Tees, have been determined. In water of suitable salinities, tar acids at the maximum concentration found in the Tees are not toxic to *Neomysis vulgaris*, *Crangon vulgaris*, *Gammarus marinus*, and *Corophium volutator*. Cyanide at the maximum concentration found in the Tees is toxic to *Neomysis vulgaris* and *Crangon vulgaris*, but not to *Gammarus* and *Corophium*.

Experiments on *Eurytemora hirundoides* and on the Dog Crab (*Carcinus mænas*), both of which occur in the most polluted part of the Tees, have shown these organisms to be of relatively high resistance to cyanide. The lack of certain animals in the estuary as food for fish is of secondary importance, as the fish are more susceptible than invertebrates to poisons.

Tuesday, September 6.

Prof. C. H. Desch, F.R.S.—*Re-arrangements in the solid state.*

Systems in which a series of solid solutions, stable at high temperatures, resolves itself into two or more phases on cooling are of frequent occurrence. In most instances the change takes the form of the separation of a new phase from solution in the same manner as the crystallisation of a salt from water. A solubility curve may be drawn, and eutectoid structures, similar to the eutectics formed from liquid solutions, are produced. The iron-carbon and iron-nickel systems are familiar examples. In recent years another type of re-arrangement has become known, and is typified by the gold-copper alloys. A solid solution, homogeneous at high temperatures, and having the solute atoms statistically distributed throughout its lattice, assumes a new arrangement on cooling through a certain point, the solute atoms taking up regular positions and so forming a super-lattice. This change is reversed on heating. The number of such systems may be considerable. The nature of the re-arrangement and its effect on the structure of the solids are discussed.

Discussion on *Liquid mixtures* (Prof. Irvine Masson; Prof. J. Kendall, F.R.S.; Dr. N. V. Sidgwick, F.R.S.; Dr. J. A. V. Butler) :—

Prof. Irvine Masson.—*Introduction ; Phenomena in liquid mixtures.*

Prof. J. Kendall, F.R.S.—*Compound formation in liquid mixtures.*

Compounds existent in liquid mixtures may be divided into two types—*addition compounds* and *substitution compounds*. In the first type, of which acetic acid-aniline is an example, there is a definite increase in molecular complexity, and the physical properties (e.g. viscosity, specific conductivity) diverge considerably from the mean of the components. In the second type, of which phenol-cresol is an example, there is no increase in molecular complexity and the physical property-composition curves are more nearly linear.

The main factor inducing compounds of the first type is diversity in electrochemical character of the radicals of the components, the extent of compound formation in solution increasing with such diversity. The main factor inducing compounds of the second type is similarity in the radicals of the components, part of an associated molecule being replaced by essentially equivalent groups.

A detailed examination of the two ternary systems ethyl acetate-water-alcohol and ether-water-alcohol has been made, and the results obtained have been analysed in the light of the above generalisations.

Dr. N. V. Sidgwick, F.R.S.—*Di-pole association in liquid mixtures.*

The molecular polarisation of a polar substance in a non-polar solvent varies with the concentration, usually being greatest at infinite dilution, but rarely (alcohols) rising to a maximum and then falling. This phenomenon is called di-pole association. It may be due either to an orientation of the molecules by the di-pole forces, or to their polymerisation. Its correct interpretation is important as throwing light on the relations between the molecules in a liquid.

The marked case of nitrobenzene, whose molecular polarisation is five times as great at infinite dilution as in the pure liquid, has been investigated both electrically and cryoscopically by various authors. The 'degree of association' x can be calculated on the hypothesis that non-polar double molecules are formed. In benzene the values of x obtained electrically and cryoscopically agree roughly up to about 2-normal solutions (x by polarisation 0·46, by F.P. 0·57). But the mass-action association 'constant' rises considerably (at $\frac{1}{10}$ normal 0·26; at 2-normal 0·39 and 0·77 respectively). This shows that the association is not due to a definite polymerisation, but to an orientation of the polar molecules which diminishes their activity.

Dr. J. A. V. Butler.—*Free energies of normal aliphatic alcohols in water.*

SECTION C.—GEOLOGY.

Thursday, September 1.

Mr. C. E. N. Bromehead.—*The geology of the York district and the excursions.*

Reports of Research Committees. (See pp. 284, 299.)

Miss E. W. Gardner.—*Some problems of the Pleistocene hydrography of the Kharga Oasis, Egypt.*

Kharga Oasis, 100 miles W. of the Nile, is a depression 300–400 metres below the level of the Libyan Plateau. Eocene and Cretaceous rocks form scarps on the northern and eastern sides.

The Scarp.—Tufa is found along the eastern scarp and is of two types:

(*a*) Plateau tufa, a massive rock practically devoid of life.

(*b*) Wadi tufa, a softer, more cellular type of wider distribution. It contains seven kinds of plants, and eight land and eight fresh-water gastropods. It is considered to have been formed by chemical aggradation, in a manner similar to tufa deposition at the present day in Brazil, and called there 'Catinga' type.

Associated tools date the wadi tufas to three different periods:

(1) Lower Palæolithic—Acheulean.
(2) Transitional—Acheuleo-Levalloisean.
(3) Middle Palæolithic—Pre-Sebilian.

Of these (2) was the longest and most important.

The Floor of the depression was supplied in Pleistocene times by 'mound' springs, which are associated in groups. They have been formed by water under pressure breaking through Cretaceous clays.

The structure of the mounds suggests periods of relative quiescence and activity. Associated implements range from Acheulean to Aterian (Early Upper Palæolithic).

(Full accounts of the hydrography and physiographic development will be found in the *Geological Magazine*, September 1932, and in the *Geographical Journal*, 1932.)

AFTERNOON.

Excursion to Helmsley, Stamford Bridge, etc.

Friday, September 2.

SYMPOSIUM on *The relations of the Millstone Grit to the Carboniferous Limestone* (Prof. W. G. FEARNSIDES; Prof. G. HICKLING; Miss E. DIX and Prof. A. E. TRUEMAN; Dr. W. B. WRIGHT; Mr. L. H. TONKS; Dr. R. G. S. HUDSON):—

Prof. G. HICKLING.—*Carboniferous earth-movements in relation to the millstone grit problem.*

The Lower Carboniferous rocks of the Pennine area show marked evidence of contemporary folding, indicated both by changes of thickness and facies and by the occurrence of local unconformities. The three main tectonic units of the region—the Northumbrian, North Pennine and Derbyshire domes—were marked out during this period. On these elevations the Lower Carboniferous rocks are relatively thin and unfolded, in contrast with the thick development of deeper-water facies found in the intervening troughs of south Northumberland and the Bolland-Skipton area. The rocks in the troughs are strongly folded, and evidence is adduced to show that this folding was largely contemporaneous. The 'Millstone Grit' type of lithology becomes dominant at different horizons in different districts, but there is no evidence that any major discontinuity in sedimentation is associated with the advent of these conditions.

Miss E. DIX and Prof. A. E. TRUEMAN.

The problem of selecting a suitable boundary between Lower and Upper Carboniferous varies in its nature in different areas. In South Wales a natural base is frequently provided by an unconformity which usually separates rocks of Carboniferous Limestone type from rocks of more or less typically Millstone Grit type. This unconformity is of varying extent.

The faunal evidence indicates that the mid-Carboniferous unconformity is not so great as has appeared to be the case from the interpretations placed on the floral records hitherto available. Recently rich floras have been discovered in the Millstone Grit and the lowest Coal Measures in several parts of South Wales which are similar to those of corresponding strata of the north of England, Scotland, and Devon. When these floras are taken into account the supposed discrepancy between the correlation based on the flora and fauna disappears.

In South Wales the base of the Millstone Grit should be drawn at such a position that it will fall within the unconformity, but its actual position in terms of palæontological zones is more difficult to fix. There is some evidence that it should fall above the zone of E, which appears to be more closely related to the Lower Carboniferous of this area. This will, of course, involve the transference to the Lower Carboniferous of a small thickness of rocks hitherto regarded as Upper Carboniferous.

If this line is accepted it appears that it may fit with the boundary required in Scotland. The cephalopod evidence as far as it is known supports this view; particularly is this true of the distribution and range of *Tylonautilus nodiferus* and *Anthracoceras glabrum*, which are widely known in zone E of England and which occur in Scotland in the Upper Limestone Group.

Mr. Bisat has taken the base of zone E as the base of his Lancastrian, but Dr. M. Macgregor has pointed out that it might well be taken at the base of zone H. This would accord in general with our views on the evidence in South Wales, although so far very little is known concerning the palæontology of zone H in South Wales.

As Dr. Macgregor has pointed out, this line would be more in accord with that drawn by the late Dr. Kidston on palæobotanical evidence. Kidston, it will be recalled, emphasised the importance of a plant break which he considered to occur a third of the way up the Roslin Sandstone Group of Scotland, this line forming the boundary between his Lower and Upper Carboniferous floras. He believed that he was also able to recognise this plant break in north Staffordshire. In our opinion this line does not coincide with any great floral change of the nature indicated by Kidston. The change in flora is merely of similar character to those occurring at higher horizons in the Upper Carboniferous, and the importance ascribed to it by Kidston probably arose from the examination of an inadequate sequence.

There is no evidence for a great plant break in north Staffordshire or South Wales. Certainly there is a change in flora, but no break of the type suggested by Kidston.

Dr. W. B. Wright.

The speaker regretted the absence from this symposium of any contribution from Mr. W. S. Bisat, whose palæontological work was the basis of all modern stratigraphical correlation of marine facies in the Upper Carboniferous. Having established in these beds a zonal system of remarkable precision and constancy, he was enabled thereby to prove the occurrence of extensive transgression and overlap at their base. The very difficult problem of establishing the horizon of the uppermost beds of the Lower Carboniferous present in any district has been attacked by many of the disciples of Vaughan, but by none more successfully than Dr. Hudson, who had established the local absence of great thicknesses of the Yoredale series. There is thus no doubt as to the existence of a great mid-Carboniferous unconformity, and interest centres at present rather round its character and the reasons for its local absence. In this connection much still remains to be done. In the Buxton area, the peculiar conditions of which have been so fully described by Prof. Fearnsides, there is definite evidence of emergence in the karst-like weathering of the limestone surface beneath the overlying shales. Further evidence of a similar character has been adduced by Dr. Hudson in the Craven district.

Afternoon.

Excursion to Doncaster, Park Nook, Stotfield, etc.

Saturday, September 3.

Excursion to the Yorkshire coast.

Sunday, September 4.

Excursion to the Yorkshire coast (*continued*).

Monday, September 5.

PRESIDENTIAL ADDRESS by Prof. P. G. H. BOSWELL, O.B.E., F.R.S., on *The contacts of Geology : the Ice Age and early man in Britain.* (See p. 57.)

JOINT DISCUSSION with Section H (Anthropology) on *The contacts of Geology : the Ice Age and early man in Britain.*

AFTERNOON.

Excursion to Bilborough, Tadcaster, etc.

Tuesday, September 6.

Mr. S. HALL and Dr. A. K. WELLS.—*On rhythmically banded sills at Godolphin, Cornwall.*

The sills described outcrop on the coast between Rinsey and Megaliggar, south-west of the Godolphin granite, south Cornwall. They are doubtless offshoots from the Godolphin mass, and comprise three main sills and numerous smaller ones. The sill-rocks are of granitic composition and are rich in minerals of the pneumatolytic group—tourmaline, topaz, fluorite and apatite—though there is no reason for believing them to be other than primary constituents. In all of these sills a striking banding, parallel to the lower and upper surfaces, is seen. This is due to pronounced differences in (i) texture, coarsely crystalline pegmatitic bands alternating with finer, aplitic ones ; and (ii) mineral content, there being more or less regularly spaced maxima of coloured mineral, chiefly tourmaline, forming graduated dark bands. A less obvious variation in the quartz/felspar and plagioclase/orthoclase ratios becomes evident on microscopic examination of serially cut sections. Comparisons are made with other well-known banded rocks, the origin of the banding is discussed, and reasons are advanced for regarding it as due to a rhythmic crystallisation of the magma after flow-movements had ceased.

Mr. A. T. DOLLAR.—*A study of the granites of Lundy Island, Bristol Channel.*

Lundy is a high rugged island over three miles long and approximately half a mile broad, which lies in the Bristol Channel some twenty-four miles due west of Ilfracombe, off the north-west coast of Devonshire. It constitutes part of a small igneous complex, the relations of which to surrounding rock-bodies are problematical.

About 94 per cent. by volume of the subaerial mass is composed of acid rocks, granite predominating, while the remaining 6 per cent. consists of contorted and contact-altered argillaceous sediments, together with a suite of minor injections, which include banded microgranites, granophyres, an orthophyre (Lundyite), and basaltic or doleritic types, all of which are particularly interesting in relation to the granites. Basic dykes have been mapped magnetically in several cases.

A hybrid junction-rock with xenoliths separates the sediments from discordant plutonic intrusions.

Chemically the granitic types are mainly alkaline, with relatively little lime, magnesia, or iron, but some rare earths.

Texturally these rocks range from porphyritic varieties to micrograna, granophyres, and fine-grained granite-aplites.

They are also characterised by pegmatite facies and junction-zones involving drusy cavities lined with a distinct assemblage of accessory minerals.

Both in the field and under the microscope it is possible to recognise in these rocks the effects of thermal and mechanical stress, differentiation, assimilation and pneumatolysis.

Mr. C. W. Peacock and Dr. H. C. Versey.—*Glacial gravels along the margin of the Yorkshire Wolds.*

A number of isolated gravels occur between the Vale of York moraines and the Humber, at levels ranging from 175 ft. above O.D. down to 50 ft. The composition of these gravels is recorded, and they are correlated with the Purple Clay and Hessle Clay episodes of the Yorkshire coast. Their mode of formation is grouped under (1) marginal drainage gravels ; (2) outwash gravels from Ferriby moraine ; and (3) deltaic gravels round Market Weighton. Their relation to the Bielsbeck deposits is also discussed.

Dr. D. A. Wray.—*The physiographic evolution of the southern Pennine area in the Upper Carboniferous period.*

The Millstone Grits have been shown by the researches of Sorby and Gilligan to be deltaic deposits derived from a large continental mass which extended from what is now the North of Scotland towards Scandinavia. There is a remarkable similarity in character and thickness of the formation along both the eastern and western slopes of the Pennines, but a pronounced south-westerly thickening in the higher beds has been proved by Tonks and Wright to take place in south Lancashire, where a maximum thickness for these beds is recorded.

The distribution and character of the Lower Coal Measure sediments indicate that a marked change in physiographical conditions took place at the close of the Millstone Grit period. These sediments were laid down in a sinking area extending in an east and west direction across the Southern Pennines with the maximum depression taking place in the west. There are clear evidences of a slight though pronounced line of contemporary uplift along an east and west axis in Yorkshire, and this line of uplift, which became more marked at a later period, has produced effects of far-reaching economic importance in the higher Productive Measures.

A thick series of sandy sediments devoid of coals form the upper limit of the Lower Coal Measures, and the present writer has endeavoured to show this horizon marks a faunal and floral break of some importance in the Coal Measure succession. Recent researches appear to confirm these conclusions ; while it is at this stage important physiographical changes occurred within the Southern Pennine area.

The major subdivisions of the Middle or Productive Coal Measures can now be broadly correlated by means of their non-marine fauna from the west of Manchester right across the Southern Pennine area almost to the

River Trent in north Lincolnshire. These measures appear to have been laid down in a broad geosyncline with the maximum depression taking place along the line of the present Pennine axis.

The Productive Measures are fully represented to the east of the present workings in the Yorkshire Coalfield, but there is a marked attenuation of each of the main subdivisions in this direction. This is also accompanied on the whole by a pronounced deterioration of the more important coals. The maximum productiveness of the Yorkshire Coalfield probably lies along or close to the present outcrop of the Main Productive Measures. The geological evidence at present available suggests that any optimistic estimate of the potential resources of the concealed coalfield to the east should be accepted with considerable reserve.

Mrs. S. W. Alty.—*Secondary crystallisation of tourmaline in Lower Devonian sediments in Michigan, U.S.A.*

Grains of tourmaline showing secondary crystallisation have been observed in numerous samples of Lower Devonian rocks from oil-wells in the Lower Peninsula of Michigan. The secondary tourmaline occurs as a colourless margin attached to well-rounded tourmaline grains. The latter are invariably coloured, brown, yellow, pink, etc., and strongly pleochroic. The colourless authigenic portion is in complete optical continuity with the original grain ; it always occurs at one end of the *c*-axis of the grain, and often shows striations on it parallel to this direction.

The original tourmalines are all well rounded and were clearly deposited in the sediment before secondary crystallisation occurred. That this process took place within the sediment is plainly evident from the fact that the secondary margin has a sharp edge which has not suffered any abrasion.

The rocks containing these tourmaline grains vary from arenaceous to dolomitic, and often contain anhydrite and sometimes oil or brine. They belong to the Sylvania division of the Lower Devonian, and form part of a synclinal basin of Palæozoic sediments. There is no sign of volcanic activity in the region.

Dr. A. Raistrick.—*Correlation of the Glacial Retreat stages in the north of England.*

Mr. J. A. Butterfield and Prof. A. Gilligan.—*The Conglomerates underlying the Carboniferous Limestone of the Sedbergh and Tebay districts.*

Conglomerates below the Carboniferous Limestone occur in many isolated patches in the N.W. of England, and are especially well developed and exposed in the river valleys of the Sedbergh and Tebay areas. Settlebeck Gill, Sedbergh, affords a most complete section. The lowest deposits, seen resting on the Silurian rocks, consist of fine-grained Sandstones, which at the top contain lenticles of conglomerates, and then supervenes a thick bed of coarse conglomerate. As the beck is ascended the deposits occur in the reverse order, finishing with red sandstone. In the Tebay area the sections in the conglomerates show a complete passage through coarse red conglomerates, red sandstones, green and grey conglomerates and sandstones (including plant-bearing shales), and brown mudstones into the Carboniferous Limestone. In this area is an interesting local phase of green monogenetic conglomerate occurring as an alluvial fan in the red deposits.

The majority of the pebbles appear to be of local origin, but many are of igneous types which are unlike those in the Howgill Fells. Numerous pebbles of red crystalline limestone containing crinoids and other fossils cannot have been derived locally, and resemble very closely the Keisley Limestone.

The heavy minerals, though plentiful in the fine-grained deposits, comprise only a few types, but these are very interesting and include the following: zircons (large, rounded generally, many purple), tourmaline (generally rounded, brown, blue and a striking plum-coloured type), rutile, apatite, anatase, hornblende, sphene, garnet and abundant ilmenite.

Dr. W. B. Wright.—*On the occurrence of the pre-glacial shore-line in Achill Island, Co. Mayo.*

The extension of the area over which the pre-glacial sea-level in Western Europe can be shown to approximate to that of the present day is a matter of considerable interest, and the writer therefore wishes to take the opportunity of recording the occurrence of an exposure of this shore-line in the Island of Achill in the west of Ireland. The locality in which it can be seen is known as the Cathedral Rocks, and lies about a mile and a half south of the village of River. Here a wave-worn rock platform lies about 20 ft. above the corresponding platform of the recent shore. On it are beach gravel and rounded blocks locally overlain by blown-sand. The old cliff is partially exposed and passes inland behind a bank of drift. Head or scree from its degradation extends outward over the beach materials, and boulder clay covers the whole, thus establishing its pre-glacial age. The level is definitely higher than that of the corresponding beach of southern Ireland.

Afternoon.

Excursion to Kilburn.

Wednesday, September 7.

Discussion on *The origin of Igneous rocks* (Prof. A. Holmes; Prof. H. H. Read; Dr. A. Brammall; Dr. G. W. Tyrrell; Dr. A. K. Wells; and others):—

Prof. Arthur Holmes.

From the fact that basaltic magma fails to produce rhyolites or dacites in the inner Pacific, it is inferred that the magmas of these rocks are not normally products of differentiation of basaltic magma. The association of acid and basic rocks in kratogenic regions and the 'contaminated' characters of dioritic and granodioritic rocks in orogenic belts suggest that granite magma arises independently of basaltic magma, except in so far as the latter may serve as a carrier of heat. Peridotite magmas cannot be accounted for otherwise than by refusion. The conditions that would favour the refusion of crystal accumulations from basaltic magma would also suffice to produce peridotite magma from the upper part of the Lower Layer of the crust. A plausible explanation of the genesis of felspar-free alkali rocks is forthcoming if a peridotitic parentage be assumed. Thus, in agreement with the geophysical interpretation of crustal structure, the evidence of comparative petrology leads to the conclusion that at least three types of parental magmas should be recognised : ultrabasic, basic, and acid. From each of these a wide variety of rock-types can be produced by additive and subtractive processes of differentiation. Further possibilities of variation are introduced by mixing of magmas, assimilation, and differential fusion. Magmas generated under stress are likely to be abnormal as compared with those due to passive refusion.

SECTION D.—ZOOLOGY.

Thursday, September 1.

PRESIDENTIAL ADDRESS by the Rt. Hon. LORD ROTHSCHILD, F.R.S., on *The pioneer work of the Systematist.* (See p. 89.)

Mr. A. J. WOODCOCK.—*Notes on the natural history of the York district.* (See *Scientific Survey of York and District.*)

Mr. A. ROEBUCK.—*The numbers and distribution of rooks in the midland counties.*

The proper study of a species must include its abundance and distribution, especially if its economic position is to be determined.

The rook (*Corvus f. frugilegus*) is a colony nester with, usually, conspicuous rookeries. This study has been made in an attempt to ascertain the factors which influence the distribution and numbers of this species, by taking a sufficiently large area. The area surveyed covers 5,305 square miles and includes the five geographical counties of Lincolnshire, Nottinghamshire, Derbyshire, Leicestershire and Rutland.

It is impossible to define a rookery, as it may consist of a single nest, a series of disconnected small groups, or a large compact mass.

Any kind of tree, sound or unsound, may be used, and of any height. The site may be in a very sheltered dell or on an exposed hill-top.

The survey deals with 1,421 rookeries, containing 128,266 birds. The average size of a rookery is 45 nests. The amount of food consumed is over 4,000 tons per annum.

Factors which influence their distribution are : available food supply, local topography as influenced by the geological formation etc., presence of rivers, abundance of grassland, and their relations with mankind.

Dr. G. S. CARTER.—*Iodine compounds and the level of activity of animal tissues.*

Variations in the level of activity of cells and tissues from time to time during their life occur throughout the animal kingdom and in phenomena of many different types. The activation of the egg at fertilisation and of the sperm in the presence of the egg are examples of these changes, and so also are the seasonal and diurnal variations of activity which result in hibernation and daily sleep. The experiments to be reported refer to these examples, but many others could be given.

Experiments on the eggs and sperm of Echinoderms have shown that substances chemically related to thyroxine play an essential part in the manner in which the changes in the level of activity associated with fertilisation are brought about, and some experiments on the sperm of the rabbit make it probable that this is also true of fertilisation in the Mammalia. It was suggested by Adler that a lowering of the thyroxine content of the circulation is the chief cause of the changes which occur in the vertebrate at the onset of hibernation. This conclusion is supported by some experiments on the excised heart of the frog. The temperature-pulse rate curve of the heart of the winter frog is different in form from that of the summer frog, and it has been found that the addition of thyroxine to the heart of the winter frog produces a curve of the form typical of the heart of the summer frog. None of several other endocrine substances has this effect. Similar results have been obtained with the heart of the tortoise. Further experiments which suggest that a similar rhythm in the amount or activity of iodine compounds in the circulation plays a part in the production of the somatic phenomena of diurnal sleep will be reported.

Thus, these compounds have been found to be associated with changes in the level of activity of animal tissues in several distinct phenomena. It is suggested that this conclusion may be generally true, and that the activity of animal cells is frequently controlled by the amount of these substances present in them.

Mr. C. Bryner Jones, C.B.E.—*The origin and development of British cattle.*

Modern British cattle are of many breeds, each possessing some characteristic—size, conformation or colour—that distinguishes it from other breeds. While to the eyes of the cattle breeder these breeds, if pure-bred, are so distinct as to be unmistakable for one another, to the zoologist they are all the same thing in the sense that they are all referred to one species. The diversity of breeds in the British Isles is remarkable, and to the observer the question that at once suggests itself is, Where did they all come from, and what was the primitive stock from which they derive their origin ?

The general opinion would seem to be that the domestication of cattle belongs to the Middle Neolithic Period, and that the small short-horned ox, known in this country as *Bos longifrons* and on the Continent generally as *Bos brachyceros*, whose remains are found in Neolithic, as well as in later, settlements, represents a domesticated race, which never existed, in Europe at least, in the wild state and was already domesticated when it first made its appearance on the European continent, having been brought hither by migrants from Asia. With the westward trend of human migration, the domesticated ox of Neolithic times was eventually brought by its owners to Britain. The evidence of its Neolithic and later remains furnishes definite proof of variability in which, by a process of selection governed by economic and local conditions, the origin of the diversity of type to be seen in modern British cattle may be found without having to fall back for explanation upon outside influences—Roman, Germanic and Norman—to which historians in the past would appear to have attached an undue importance.

Afternoon.

Dr. C. M. Yonge.—*The influence of the processes of feeding and digestion upon evolution.*

The simultaneous study of morphology and physiology is essential for the full understanding of the living animal. Evolution of function is as important as evolution of structure. The evolution of animals is obviously largely dependent on their ability to obtain and utilise food and to exploit new sources of food. There are well-marked correlations between (1) habitat and available food of any animal; (2) type of feeding mechanism; (3) structure of the gut; and (4) nature and relative strengths of the various digestive enzymes. In the Protozoa feeding mechanisms of all types are present but in all cases digestion is *intracellular*. Metazoa probably evolved from Protozoa with least specialised feeding mechanisms. Porifera are a special case. The evolution of extracellular digestion, at first assisting intracellular digestion—e.g. Cœlenterata, Turbellaria, Echinodermata, many Mollusca—and finally completely replacing this, has enabled animals (1) to reduce size of alimentary system; (2) to complete digestion more quickly; and (3) to remove indigestible matter more quickly. Metabolism is greatly assisted and the animal more efficient. All the most active groups of animals, e.g. Annelids, Arthropods, Cephalopods, Vertebrates, digest extracellularly. These animals have most successfully colonised the land. If feeding mechanisms and digestive system too specialised, e.g. Brachiopods and Lamellibranchs, further evolution almost impossible. Loss of digestive system in parasitism leads to degeneration. Development of special enzymes permits of the utilisation of new sources of food, e.g. cellulase in Teredo and wood-boring Insecta, or greater success in particular habitat, e.g. cellulase in Strombidæ and Helix, chitinase in some Insecta and in Helix, enzyme for digesting collagen in blow-fly larvæ.

Prof. F. Balfour-Browne.—*The colouration of the cocoons of the Small Eggar moth (Eriogaster lanestris, L.).*

In 1886, Poulton described experiments with the caterpillars of the 'Emperor Moth,' *Saturnia carpini*, which, when placed in a black bag, formed dark brown cocoons, while caterpillars freely exposed to the light with a white environment produced white cocoons. These results he described as due to colour susceptibility on the part of the caterpillars.

In 1892, Bateson, having repeated these experiments and failed to confirm them, showed that pale-coloured cocoons were as frequent in the dark as in a well-lighted environment. Some pale cocoons, such as those described by Bateson as 'thin and papery,' are abnormal, but most white and cream-coloured ones are as thick and firm as the dark ones, and the colour of the cocoon is due to the dryness or dampness of the environment in which the caterpillar spins up. Pale cocoons are formed under dry conditions, and if placed in a saturated atmosphere, even after the caterpillar has pupated, these quickly darken to the normal brown colour.

Therefore Poulton's suggestion that the colour is protective is reasonable, since the caterpillars spin up amongst dead leaves, etc., often below a hedgerow, and the dampest places are likely to be those most sheltered and therefore the darkest, whereas the drier places, where the dead leaves are of a lighter tint, are more exposed to light and air.

Dr. J. Gray, F.R.S.—*The mechanism of animal movements, with special reference to fish.*

Three main types of propeller are found in the animal kingdom: (i) jet propellers, e.g. the siphons of squids; (ii) paddles, e.g. the webbed feet of swimming birds; (iii) inclined blades. Of these types by far the commonest is the inclined blade wherein the propulsive elements move as surfaces inclined to the direction of their own motion through the water. In this way pressure is exerted on the blade at right angles to its surface; this pressure has a forward propulsive component. In some cases the moving blades are recognisable as such, e.g. the wings of insects, but in other cases the whole surface of the body acts as a series of inclined blades which move in a definite rhythm and which work reciprocally across the line of forward movement of the organism. The mechanical principle involved is essentially that of the screw-propeller, although the movements are reciprocating instead of rotary. This type of mechanism is very widely spread throughout the animal kingdom and is particularly obvious in fish, although the movements are often sufficiently fast to make photographic records essential for accurate study. Essentially the same type of movement is found in spirochætes, nematodes, and in many aquatic vertebrates, where the reciprocating action of each part of the body is effected by the muscular waves which pass along the body. A study of these waves shows that their form is closely correlated with the degree of resistance offered to the water by the body of the organism.

Contrary to often repeated statements, the tail fin of most fish is only of value as a propeller when the fish is moving at extremely low speeds ; in all normal movements the tail fin plays a negligible rôle as part of the propulsive mechanism ; it is more usually a rudder.

Friday, September 2.

JOINT DISCUSSION with Section K (Botany, *q.v.*) on *Biological balance in fresh water.*

AFTERNOON.

Dr. R. H. LE PELLEY.—*Lygus simonyi* Reut., *causing abortion of coffee flower buds, and the problem of its control.*

Dr. A. E. CAMERON.—*The rearing of Hæmatopota pluvialis* L. (*the Cleg, Tabanidæ*) *under controlled experimental conditions.*

Investigation of the cleg, the most common palæarctic species of European tabanid, has been almost entirely neglected, despite its potential importance in the transmission of parasitic micro-organisms of cattle, as for example *Trypanosoma theileri.* Hitherto the number of larval stages has not been ascertained in any European tabanid. In the course of our experiments adult females were fed on human and rabbit hosts, and they deposited typical tabanid egg-masses. The larvæ emerging from the eggs were reared to the adult stage. Several females partook of a second blood meal and oviposited a second time. The fact that two acts of oviposition can occur separated by an interval, during which a second host is attacked, is of prime significance relative to the biological transmission of micro-organisms from one host to another. There is evidence that triplicate oviposition may also occur.

The number of ecdyses of larvæ hatched from the same batch of eggs, and submitted to the same conditions of rearing in all cases, varied from seven to nine. Some were univoltine and others demivoltine, even from the same egg-batches. It would thus appear as if *H. pluvialis* were heterozygous for univoltine or demivoltine characters.

The earlier ecdyses are readily overlooked, but the risk of their omission has been reduced by a series of measurements of a standard skeletal structure—the paired tentorial rods of the larval head capsule—in all ecdyses recovered. Another reliable index is the number of pedunculate bodies in Graber's organ, of which there are twice as many for any particular instar as the number which designates that instar.

Mr. C. F. A. Pantin.—*The origin of body fluids.*

The evolution of a multicellular organism was necessarily accompanied by the appearance of intercellular spaces. These spaces are cut off from direct communication with the external medium, and the composition of the fluid within them is therefore potentially under the control of the organism. This has two important consequences: it permits chemical intercommunication between different parts of the organism, and by endowing the latter with a controlled internal medium it provides an ideal environment for the tissues. Such an internal medium may be to a great degree independent of the external environment.

It is from this internal medium that the blood of the higher organisms is developed. The organism can only maintain the composition of its internal medium by continuous physiological activity. Substances pass into the blood from the outside world by way of the body surfaces, the respiratory organs and the gut, and to these substances are added the products of metabolism. On the other hand, loss of substances takes place continuously by the same channels and by the excretory organs. It is evident that the blood cannot be in passive equilibrium with the external medium.

In studying the origin of the conditions which maintain the composition of the body fluids, investigation may be turned towards the Turbellarian worms. In these there is no blood system, and the internal medium is restricted to the intercellular spaces. The Triclad *Procerodes ulvæ* is able to withstand vast changes in the composition of the external medium. By studying the conditions which enable it to do this, light is thrown on the nature of the mechanisms controlling the internal medium.

Saturday, September 3.

Excursion to Bylands and Rievaulx.

Monday, September 5.

Dr. C. Tate Regan, F.R.S.—*Some results of the Dana expeditions.* (At the Rialto, Fishergate, by the kind permission of the proprietor.)

Dr. Stanley Kemp, F.R.S.—*Oceanography in the Antarctic.* (At the Rialto, Fishergate, by the kind permission of the proprietor.)

A film illustrating work on the *Discovery II* was shown.

Prof. A. C. Hardy.—*Plankton research in the service of the fishing industry.* (At the Rialto, Fishergate, by the kind permission of the proprietor.)

Earlier work was reviewed. Experiments with an instrument, the Plankton Indicator, carried out on a number of different fishing grounds by herring drifters and patrol ships, were described. During 1930 and 1931 over five hundred records of the quantity of fish caught were obtained, together with samples of plankton taken at the same time. A positive correlation is found between the number of herrings caught and the number of the copepod *Calanus*, an important food organism in the plankton ; a negative correlation is found with the pteropod *Limacina*. Other negative correlations are indicated but not yet established. Reference was made to the beginning of an experiment in charting the plankton on a broad scale by means of continuous plankton recorders on steamship lines across the North Sea, with a view to forecasting the conditions on the fishing grounds later in seasons. The work here described has been carried out in the Department of Oceanography at the University College of Hull, with the assistance of Dr. G. T. D. Henderson and Mr. C. E. Lucas, members of the research staff. An attempt was made to estimate the commercial value to the industry of the results so far obtained with the Plankton Indicator.

Mr. A. C. STEPHEN.—*The faunistic divisions of the floor of the North Sea.* (At the Rialto, Fishergate, by the kind permission of the proprietor.)

Of the various groups of molluscs which occur the Lamellibranchs are by far the most important numerically, and by the major variations in their density the northern North Sea may be divided into three distinct zones : (*a*) the coastal zone occupying the narrow strip within the 20-fm. line ; (*b*) the wide zone of low density occupying much of the area beyond ; and (*c*) the north-eastern portion of the North Sea, where the density is again high, but where all the forms are dwarfed. The fauna of the southern North Sea, below the 30-fm. line, is similar to that of the Scottish coastal zone, so that the division into three zones still holds good. The echinoderms follow much the same course.

A number of workers have accepted the ' community ' concept, but the results from Scottish waters show that, for the North Sea at least, a division by zones provides a better method. Species occur in certain zones, but spat may fall in any part of the zone, causing great fluctuations in density of any species. A species may be abundant in one part of the zone at one period and absent at the next. These fluctuations have an economic aspect.

AFTERNOON.

JOINT DISCUSSION with Section H (Anthropology) on *The Primates and Early Man* (Dr. C. TATE REGAN, F.R.S. ; Dr. A. B. APPLETON ; Dr. S. ZUCKERMAN).

Tuesday, September 6.

SYMPOSIUM on *Applied Helminthology* :—

Prof. R. T. LEIPER.—*General introduction and the applications of helminthology to medicine.*

Dr. T. W. M. CAMERON.—*Applications to veterinary medicine.*

Dr. MARJORIE J. TRIFFITT.—*Applications to agriculture and horticulture.*

Dr. T. SOUTHWELL.—*Applications to fisheries.*

Mr. F. J. BROWN.—*Zoological aspects.*

Dr. J. N. Oldham.—*Helminths as biological controls of pests.*

Dr. B. G. Peters.—*The scope and aims of the Bureau of Agricultural Parasitology.*

Afternoon.

Dr. Michael Grabham.—*Subtropical ichthyology.*

Miss R. C. Bamber (Mrs. Bisbee).—*The impurity of the Mendelian Recessive.*

Mr. W. C. Miller.—*A sheep-goat hybrid.*

Prof. C. J. Patten.—*The mystery of bird-migration.*

Opportunities of making repeated observations at Irish Light-stations have convinced me that migrating birds endeavour to find their way by reacting to their environment, and often profiting by experience in varying degrees according to the exigencies of the situation. Birds possess an 'eye-brain'; their sense of vision is extraordinarily acute and by no means indiscriminating. It seems unreasonable to brush aside the idea that migrants may obtain guidance by taking stock of landmarks. Furthermore, the sense of hearing can play a part. The wash of the waves is a reminder to hug the coast—the guide-line of primary importance. The courses of great rivers are followed by overland migrants. It is noteworthy that most remarkable fraternities are often formed *en route*, thereby affording inexperienced juveniles the opportunities of being piloted by adults who have been over the ground. In thick weather migrating birds often go astray, and, arriving at unaccustomed haunts, are classified as rare and accidental vagrants. When the gloom deepens the voyagers become sorely handicapped, while a dense and prolonged fog will put the brake effectually on migration. It is surmised that birds may be endowed with a special sense of direction—an unconscious, unerring instinct. Herein lies the mystery of migration which furnishes an inadequate and illogical hypothesis, which field observations carried to a further degree will tend to dispel.

SECTION E.—GEOGRAPHY.

Thursday, September 1.

Presidential Address by Prof. H. J. Fleure on *The geographical study of Society and World Problems.* (See p. 103.)

Prof. P. F. Kendall.—*The physical setting of York.*

York is not the capital of the three Ridings of Yorkshire, but constitutes a division of its own as the seat of the Archbishopric. Its geological position is similarly detached, standing upon the lowest rocks of the Secondary series, the Triassic sandstones, into which many wells penetrate.

The three Ridings do not correspond exactly with the geological structure —the North Riding embraces not only the area of Archean, Ordovician, and Silurian rocks and Lower Carboniferous rocks of the west, but also includes an inlier of Coal Measures and Permian at Ingleton and the belt of Magnesian

Limestone, which enters the Riding at the Tees, the Triassic sandstones and Marls of the Vale of Mowbray, and the Jurassic delta of the Cleveland Hills, which divides the town of Filey from the parish church.

The West Riding, economically the most important of the three divisions, comprises the remaining portion west of the Ouse, and by consequence the coalfield, down to the Notts-Derbyshire boundary.

The East Riding is of simpler structure than the other two, consisting mainly of the Chalk formation and a fringe of Triassic and Jurassic rocks by extensive deposits of glacial origin. On the seaward side they constitute the coast-line from Sewerby to Spurn Point.

In this review the Quaternary deposits should not be ignored, for it is to them that York owes its existence. Two terminal moraines,[1] at York and Escrick respectively, gave a dry-shod passage across the swampy plain. The low grounds are mainly occupied by 'Warp' clays, which resulted from the melting of a glacier that received tributaries from the valleys of the Tees, Swale, Ure, Nidd and Wharfe.

The city before the arrival of the Romans appears to have been cut off on the east by an extensive tract of woodland, of which traces remain in such names as Sutton-in-the-Forest. Strensall Common is the last remains of the ancient Forest of Galtres.

The open valley of Triassic rocks, which extends north and south from the city, not only gave direction to the Roman roads, but also in later times invited invasion whether from north, south, east or west; and the many battles which have been fought within a few miles of York attest the vulnerability of the site.

Harold Godwinsson, keeping watch near Hastings for the coming of the Norman, was diverted from his main purpose by news of the descent on the Northern coast of a Danish fleet under Harold Hardrada and English Harold's unworthy brother Tostig. The news brought English Harold by a wonderful march up from Sussex, and at Tadcaster he got word that the invaders had defeated the men of York at Fulford, and taking hostages had withdrawn to Stamford Bridge. English Harold followed and defeated the Danes, and Harold Hardrada and Tostig were slain. Historians have wondered why the Danes retired to Stamford Bridge, but an inspection of a geological map would have answered the question—Stamford Bridge is at the convergence of the two moraines, and the Danish fleet lay at Riccall at a convenient distance for reinforcements to be called up, but they came too late.

Prof. A. Hamilton Thompson.—*The growth and development of York in history.*

Prof. E. G. R. Taylor.—*Early literature, in English, on natural waters.*

An analysis of early printed geographical literature, in England as elsewhere, shows that interest was focused on man to the neglect of his physical setting. Even in so-called topographical works the main theme was local history, while in narratives of travel and discovery the writer dealt almost exclusively with personal incidents, and with the manners, customs, conditions and institutions of the peoples encountered. Other branches of geographical literature included disquisitions on the sphere, purely mathematical in character, and technical works for travellers, such as rutters, road-books

[1] For these and other features, *cf.* the *Scientific Survey of York and District*, appendix to this volume.

and guides: of physical and even economic geography there is very little trace.

Natural calamities, such as floods and earthquakes, called forth a vernacular literature from 1570 onwards, and in such works attention was necessarily drawn to physical conditions and phenomena, while the literature of curative springs and wells, beginning at much the same period, is of importance in the history of geographical thought as forming, with rare exceptions, the earliest literature of individual towns and villages and the earliest hydrographical literature, apart from translations from the classics. Some score in all of works of this class appeared before 1650—a date taken roughly as the term of a 'pre-scientific' period of geography.

The content, authorship and geographical aspects of each are briefly examined.

AFTERNOON.

Excursion in and about York.

Friday, September 2.

Mr. F. Elgee.—*Human geography of the moorlands of north-eastern Yorkshire.*

This region consists of a high barren moorland plateau trenched by cultivated dales with isolated farms about half-way down the slopes. Villages are few and chiefly modern. The climate is decidedly wetter and colder than that of adjoining areas. Ironstone is the chief mineral, and has been utilised in the Middle Ages and modern times. Poor coal seams in the moorland sandstones were formerly worked.

The earliest inhabitants were Mesolithic food-gatherers whose flint implements occur on the sandy central and North Cleveland watersheds. There is little sign of further occupation until the Mid-Bronze Age, when the region was settled in suitable areas. Sites are well preserved in Eskdale, Ryedale, etc. Their distribution foreshadows that of the present farms. The Late Bronze and Early Iron Age cultures are absent. Romano-British settlements are unknown. Celtic fields and place-names indicate a scanty British population, possibly post-Roman, for the region was shunned by the Angles. The Domesday survey only shows settlement in Eskdale. The occupation of other dales by Scandinavian stock probably took place after 1086. The character and history of the moorlands indicate that their inhabitants were often refugees.

Mr. G. H. J. Daysh and Mr. E. Allen.—*Features of the industrial geography of the north-east coast.*

The North-East has an occupational specialisation in close relationship to the natural facilities afforded. The population is gathered in proximity to the coast, with particular concentration at points where natural opportunity for development has been available. Such points have required artificial improvement to render them useful for industry, and have in turn exercised control upon the location of the industrial sites and the extent of the built-up areas. The major type of industrial specialisation, and the degree to which it has been developed at any one of these particular groupings, have been clearly determined by their individual relationship to the natural resources of the region as a whole. Examination of the economic life of the area shows conclusively its basis in the winning of coal. Coal-mining is the largest single occupation, and coal shipments provide the largest item of trade. Basic industries have been developed, and in each a fundamental connection with coal may be discerned. There is important regional specialisation within the area. Its southern portion contains almost the whole of its iron and steel industry and constructional engineering. Other activities tend to be developed along each of the three main rivers, with the Tyne taking the first position in importance. During the prolonged economic difficulties of the post-war period the Tyne gained relatively to the Wear and Tees, notably in shipbuilding and marine engineering. This makes complex the question as to where future development in the North-East may be anticipated. Successful industrial activity does not depend upon natural advantages alone; organisation too is important. The spaciousness of Tees-side does not provide, therefore, either an obvious or a simple answer, though it may well be that it is in this that the answer may finally be found.

Mr. W. B. Crump.—*The wool-textile industry of the Pennines in its physical setting.*

Much of the cotton region of Lancashire had formerly a share in the woollen and worsted industries that are now restricted to the West Riding. This wider textile region of the Pennines viewed as a whole is almost co-terminous with the Millstone Grit and Lower Coal Measures where these are adjacent. The industry thus had at its service abundant soft water and water-power, iron and coal. Its market-towns, to which the cloth was brought for sale, were, with one exception, situated upon or near to the Lower Coal Measures. The higher, wilder country of the Millstone Grit, scored by innumerable cloughs and narrow valleys, was their hinterland; wool was spun and cloth was woven in its upland villages and scattered farmsteads along the flanks of the moors. This is the historic weaving district, and cotton has inherited the tradition. Fulling-mills driven by water-power began the descent into the valley bottoms before 1300, and more so after the dissolution of the monasteries. After 1780, when first scribbling-mills and then spinning-mills sprang up on every little stream and canals threaded the valleys, the descent became an avalanche. But manufacturing still clung to the uplands, for weaving was long done on the hand-loom, and when the power-loom came the manufacturer could often find an outcrop of coal on the hillside to drive his steam-engine.

Mr. H. C. K. Henderson.—*The distribution of occupations in the West Riding, with particular reference to textiles.*

The source material for this paper consists of the 1921 Census, the List of Mines and the large-scale maps.

The method adopted has been to construct circular graphs to a scale relative to the total number of persons occupied in each of the districts quoted in the Census. Angular divisions represent the proportions employed in the several groups of occupations—by this means it is possible to delimit the extent of respective activities of the population; in this case, that of the textile industry is of most interest. Thus it is found that the region of textile workers is essentially to the west of the coalfield, and that, once the mining region is entered, the textiles die out just as suddenly as the mining increases in importance; similarly, southwards there is a sudden change in the leading industry from textiles to metallurgy. Makers of textile goods assume importance in three small areas—around Leeds, Huddersfield, and to the west of Halifax.

For obvious reasons, a base map of a limited number of related facts was essential as a background to the circular graphs—accordingly the latter have been drawn on a map (1 : 63,360) showing the area of the worked coalfield (List of Mines) as distinct from the Coal Measure outcrop, and the significant breaks of slope.

To develop the material on the textile industry further, a second map of circular graphs, using the total number of textile workers as the basis, and having angular divisions proportional to the number engaged in the individual processes, has been prepared, with the object of examining whether processes have any development of regional specialisation similar to that of the Lancashire region. A specialised distribution of finished products has frequently been noted, but attention is here directed to processes, not products.

This map reveals that in some cases a regional specialisation does exist—for example, dyeing is localised in two districts, one around Guiseley and the other in the neighbourhood of Halifax ; again, finishing is confined to two areas, around Guiseley and southwards from Halifax to New Mill ; doubling is mainly in the Calder Valley, while combing is most important in the north-western part of the textile region, as one might expect, since this is the worsted area ; winders are more numerous in the south-western part of the region, while spinners and weavers are present throughout, though in the Calder Valley spinning is relatively of greater importance than elsewhere, and some degree of specialisation in weaving occurs in the districts to the immediate south and west of Leeds.

Comparisons will be drawn with the textile region of Lancashire, which has been mapped and studied on similar lines.

Afternoon.

Excursion to Howden, to study ‘ Warping ’ in the Vale of York.

Saturday, September 3.

Excursion to the Vale of Pickering, Scarborough and Flamborough Head, returning *via* the Wolds.

Sunday, September 4.

Excursion to Boroughbridge (Isurium), Richmond, Swaledale, Wensleydale and Ripon.

Monday, September 5.

Dr. Vaughan Cornish.—*Æsthetic principles of town and country planning.*

The hygiene of Town and Country Planning has long been studied in a scientific way, but in regard to æsthetic amenity it has been tacitly assumed that any educated and cultured person is equipped with the necessary knowledge. This assumption is entirely erroneous, for, in fact, the conditions which determine scenic beauty can only be ascertained by systematic study. The aspect of the matter which best rewards investigation is that of *harmonious grouping*, since the character of the new features of construction is largely determined by considerations beyond possibility of administrative control.

In the present paper the author emphasises the preponderating importance to regional planning of (1) architectural elevations which will take their place quietly in the rural landscape, particularly in respect of tone and colour; (2) a large increase of tree-planting and gardening in the towns to relieve the hardness of line and harshness of surface which make the merely architectural landscape inexpressibly fatiguing to the eye, no matter how excellent its design may be; (3) the compact instead of radial arrangement of suburbs, permitting a definite grouping of architectural and natural features; and (4) the reservation of selected areas of wild scenery as National Parks and Sanctuaries for rare species of animals and plants, in order that our predominantly urban population shall not lose touch with that spontaneous aspect of nature which has so profound an influence upon the nobler aspirations of the mind.

Dr. P. W. Bryan.—*Type patterns in the geographical distribution of buildings.*

This paper examines characteristic patterns of settlement. Man engages in activity to satisfy his desires. He adapts and modifies his natural surroundings, or the natural landscape. In the process he is forced by nature to modify his activities to fit into his surroundings. The concrete expression of his activity in relation to nature is the cultural landscape, that is, the natural landscape as modified by man. The cultural landscape takes various forms as man endeavours to satisfy his desire for shelter, cultivated products, raw materials, power, manufactures, exchange, transport, government, recreation, and the gratification of the æsthetic senses.

Of these forms the shelter or building is the most universal. The distribution of buildings in the landscape forms readily recognisable patterns. These patterns vary in response to the number of people, the type of activity carried on, the time-period factor, and the physical setting. The more characteristic of these patterns observed in England and Wales are classified and compared with characteristic patterns in other parts of the world.

Mr. W. Fogg.—*The 'Suq' in Morocco.*

In Morocco, even where sedentarism is dominant, there are no shops in the douars, and no exchanges between douar and douar, and, apart from the few towns of the coast and interior, commercial life takes place at fairs. Of these there are three types: (*a*) 'mouggar,' large annual fairs held on the borders of the Sahara; (*b*) 'amara,' annual religious festivals, which are also fairs; (*c*) 'suqs' or weekly fairs. It is with the latter that the present paper is concerned. They are much more general in development than the annual fairs, and, although their primary function is exchange, it includes the administering of tribal justice and legal settlements. They have fundamental significance in the social and political life of the country also.

The 'suq' is ephemeral, but for the few hours of its weekly existence functions like a European market-town, and, in the life of Morocco, seems to take the place of such. As the 'suq' is not expressed by anything permanent such as buildings, its existence as a characteristic institution of Moroccan life seems to explain a dominant feature of the geography of

Morocco—i.e. the lack of towns in the well-populated parts N. and W. of the Atlas Mountains.

Capt. J. G. WITHYCOMBE.—*Population maps.*

Need for showing the distribution of population on a map.

Practical uses : social, administrative, commercial and political.

Value as an instrument of research enhanced if it forms one of a series of distribution maps uniform in scale and style and so readily comparable.

Convenience and availability of the International 1/1,000,000 Series as base maps for showing distributions of all sorts.

The work done by the Sub-Committee of Section E of the British Association which was appointed to consider the production of a Population Map of Great Britain.

The specimen map of Hampshire on the scale of 4 miles to 1 in.

Reasons for adopting the 1/1,000,000 scale.

Method of compilation. Scale of densities to show both rural and urban conditions on map of the 1931 Census.

Possibility of producing a series of retrospective population maps illustrating the growth and drift of population during the past 120 years.

Dr. E. H. SELWOOD.—*The classification of communities by means of occupations.*

Some indefinite knowledge of types of towns has for years been considered part of geography, but the issue of exact figures of occupations in the census returns has provided the possibility of ascertaining standards for the classification of communities, rural and urban, and the purpose of this paper is to define and classify the communities of England and Wales on an occupational basis.

First it was found necessary to reduce the thirty-three categories so skilfully arranged by the Registrar-General, and by adding occupations of similar character to reach the following list of groups : fishers, land-workers, miners, 'craftsmen,' transport-workers, traders, 'professionals,' 'servants' and clerk-storekeepers.

For ease of comparison the numbers in each group were stated as percentages of the total number of workers in the community.

It was thus found possible to classify the 1,719 communities of England and Wales as :

(*a*) Land-working,
(*b*) mining,
(*c*) 'craft,'
(*d*) transport,
(*e*) 'service,'
(*f*) unspecialised or 'balanced'; with modifications of (*a*), (*b*), (*c*) and (*e*).

The distributions of communities of similar occupational character have been mapped for the country as a whole, and London on a larger scale.

Certain correlations between occupational groups have been found, and the ratio of occupations in urban and the surrounding rural areas calculated. 'Saturation-points' of some groups have been ascertained.

AFTERNOON.

Dr. G. W. TYRRELL.—*The geographical distribution of volcanoes.*

Dr. J. GEORGI.—*Some geophysical results of Alfred Wegener's Greenland Expedition, 1930–31.*

Tuesday, September 6.

Mr. G. V. Jacks.—*Recent changes in the wheat areas of the world.*

During the last twenty years the world's wheat area has increased by over 20 per cent., and production by over 25 per cent.; the increase in population over the same period has probably not been more than 14 per cent. At present there is probably underconsumption, as well as over-production of wheat. The reasons for the discrepancy between supply and demand are very complicated. They may be classed as economic, scientific and political. Economic conditions have played a large part in causing the recent expansion of the great wheat-fields of the world, but other influences have also been at work in varying degrees in different countries. Each of the great wheat areas of the world is considered separately, and the conditions that have affected the cultivation of wheat in them are analysed.

Dr. S. W. Wooldridge.—*The physical basis of the historical geography of south-east England.*

Attention is called to the need for more accurate reconstruction of the geographical environment of the early phases of settlement in S.E. England. The area covered embraces the London Basin, the Weald and East Anglia. In order to secure a framework for such reconstructions a tentative scheme of regional subdivision is proposed. Subdivision is guided by considerations of soil, vegetation and water-supply, and the regions proposed have the character and status of the French *pays*. In the resultant aggregate picture of geographical conditions, attention is drawn to the extent and distribution of areas suited to early clearing and settlement, and of ' negative ' or barrier regions. Particular emphasis is laid upon the almost continuous block of negative country which crosses the area west of London, extending from the Chiltern plateau to the Rother Valley. The mutual relations in space and time of the several important regional centres of early settlement are considered, and a number of archæological and historical hypotheses are examined in the light of the geographical facts.

Dr. Matthews.—*The temperature anomalies of the Chilean coastlands in relation to the classification of their climates, with special reference to Köppen's classification of climate.*

A number of factors combine to give the Chilean coastlands a high degree of abnormality in temperature régime. Among the features of temperature régime three—namely, (*a*) the abnormal defect of summer temperature; (*b*) the very low annual range of temperature; and (*c*) the slow change of temperature with latitude—are of especial significance to the problem of climatic classification.

In brief, while the Chilean coast shows a normal range of climates through desert, steppe, Mediterranean to constantly humid climates, only two of the temperature divisions, out of the total of six recognised by Köppen for the other western margins of the continents, can be found by the use of his unmodified criteria. Thus, the hot desert and steppe of Köppen is not recognisable from the temperature data if only mean monthly temperatures are considered. (Actually these mean monthly temperatures are such that a rigid adherence to the Köppen criteria would entail the inclusion of the Chilean desert in the cold desert, grouping them in absurd alliance with Mongolia !) Again, the olive-growing area of Chile fails to attain to the standard of warmth demanded for Köppen's 'Olive climate'; finally, rigid adherence to the Köppen criterion of a tundra climate would entail the classification of the western coast of Chile south of 52° S. in the tundra climates (as has been done in Köppen's latest map in the *Handbuch der Klimatologie*, Band 5, Teil G), in spite of the fact that frost is rarely experienced along the coast.

It is shown that, by a consideration of mean maximum as well as of mean monthly temperatures, satisfactory delimitation of the temperature divisions of the Chilean climates can be made. But it is also shown that the criteria which apply to certain of the regions are not applicable to other, generally similar, areas—in fact, certain of the Chilean regions have no exactly comparable homoclimes.

In these circumstances, a larger question is raised—namely, the possibility of obtaining a satisfactory climatic classification to apply to both hemispheres. As a basis of discussion new maps of isonomalous lines are prepared. These are constructed for the midwinter and midsummer months for the world, and show departures from the average temperature of the parallels irrespective of the hemisphere in which they occur. It may be called a map of total isonomalies in order to distinguish it from the map of isonomalies in which departures from the average temperatures of the parallels of each hemisphere are mapped. The former is much more significant from the viewpoint of classification, as it throws into full relief the difference between climatically comparable—but not necessarily really similar—areas of the two hemispheres.

Capt. T. E. Longfield.—*The subsidence of London.*

The paper deals with surface subsidence in the London district. This subsidence has been confirmed by a recent, and still continuing, relevelling of London.

The principal lines of levels in this area have been completed, and it is from these that the deductions have been made.

At the same time the opportunity has been taken of comparing the results which were obtained when levelling was carried out in 1865, 1895 and 1914.

A comparatively new method is described by which levels can be transferred across water up to distances of about a mile, as this method has enabled the levelling network to be connected with accuracy across the estuary of the Thames at Dagenham and Tilbury.

In addition to the more or less general sinkage disclosed in the London area a number of cases of purely local subsidence have come to light and are described.

Mr. E. Jacobs.—*The Hull fishing industry.*

This paper gives prominence to certain aspects of the Hull fishing industry. The foundation of the trawl fishing at Hull, by Brixham fishermen, some eighty years ago, is noted. This is followed by a survey of the geographical expansion of fishing operations, and the factors responsible for the same are discussed.

In conclusion, the most recent developments of the industry and its allied undertakings receive comment.

Afternoon.

Excursion to Coxwold, Ampleforth Gap and Rievaulx.

Wednesday, September 6.

Mr. A. Austin Miller.—*The physiographic evolution of the lower Wye valley.*

The meanders of the river Wye were developed on a surface of post-Liassic age, but of this surface no relics can be identified with certainty. During the process of dissection of this stage the river reached maturity at a height of about 500 ft. above the present river-bed, and produced an extensive peneplain at this level, into which the river is remarkably entrenched. A third phase of still-stand at about 200 ft. above present level is indicated by the preservation on several spurs and meander-cores of bevelling at this altitude. The river is now entrenching itself into this stage.

The two latter stages are tentatively correlated with fairly well-defined platforms of marine denudation on the north shore of the Severn Estuary at about 400 ft. and 150 ft. respectively, which are briefly examined.

In the process of adjustment the river has effected minor changes in its course and abandoned some entrenched meanders at different levels.

Mr. D. L. Linton.—*Some aspects of the physiography of southern Scotland.*

Thirty years ago Mackinder put forward the thesis that in the south-eastward-flowing portions of certain Scottish rivers we may see the remnants of an original consequent drainage system whose streams flowed continuously from the Minch to the Scottish Border. In doing so he realised that such eastward-flowing streams as the Aberdeenshire Dee and Don, the Tummel, the Earn, the Forth, and the Tweed found no place in this scheme, but he did not therefore abandon it. Later workers adopted this idea completely. Mort suggested an Argyllshire source for the Galloway rivers; Gregory found no difficulty in carrying a reversed Lower Clyde eastwards to the North Sea at Berwick; Peach and Horne found themselves forced to draw conclusions as to the origin of the Tweed not in accord with the accepted principles of river development.

This preconception as to the nature of the river system from which the present Scottish drainage has developed, led in the southern uplands to a failure to realise two important points. The first is the very great extent to which the original drainage has been modified by the growth of subsequent streams. The second is that in addition to the classes of streams already recognised in the region, viz.:

(*a*) the south-eastward or south-south-eastward-flowing streams, such as the Nith and the Gala, of supposed consequent origin;
(*b*) the unexplained east-flowing Tweed, matched by the Forth and the South Tyne just beyond the limits of the region;
(*c*) the subsequent streams such as Ettrick and Yarrow,

there exists an important series of right-bank tributaries to the Tweed flowing from south-south-west to north-north-east.

In the present communication evidence is brought forward to show that the Tweed must be regarded—together with similar major east-flowing rivers—as a consequent trunk stream, receiving both left- and right-bank consequent tributaries, of which the Gala and Jed are types. Further south a second series of minor consequents flowing south-south-east and including the Nith, Esk, and Rede, were received as left-bank tributaries by the east-flowing Tyne, while to the north the Forth had a similar origin and function.

Mr. A. N. Harris.—*Factors controlling port sites, with special reference to western India.*

A brief review of the physical geography of W. India. The ancient ports were situated in regions of relatively great productivity and attracted the trade-routes to them. The most productive regions were the Indus Delta country, the Cambay country and southern India, so that the ports had wretched sites which were doomed to decay. The process of preparing the sites of the modern ports of Bombay and Karachi was a relatively slow one, in which both nature and man were concerned, and it was not until comparatively recent times that the sites were made fit to support great ports.

The changes in the regions in which port sites are located may be attributed to the fact that in ancient times ports were in regions of increment, owing to the difficulty of land transport, whereas in modern times improved land transport has obviated the necessity of ports being within the region of surplus production, but a first-class site is required.

Exhibit.

Exhibition of Dr. Tempest Anderson's collection of photographs of volcanic phenomena, in a room adjoining the Section-room.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Thursday, September 1.

Prof. J. Coatman, C.I.E.—*International migration in the twentieth century.*

Any discussion of migration nowadays must recognise that the problem which it presents is a complex one, composed of many factors, biological, political and economic.

For our present purpose the chief interest is on the economic side, but since this side cannot be studied in isolation we must take at any rate the main features of the biological and political sides into account.

Biological.—Differential birth-rates and effect on population, growth and pressure. Effects on the flow of migration. How birth control affects the problem.

Political.—Migration policies of the chief countries concerned, both countries of migration and receiving countries.

Economic.—The economic aspects of population growth. What countries can sustain growing populations by reason of natural resources, potential industrial development, etc. What countries must find outlets for their surplus people.

Where are the possible outlets and what sorts of outlets will they provide—i.e. for settlers on the land, or in industrial or other urban pursuits ? The present and future balance of agricultural and industrial occupations, and the effects of changes in this balance on our subject. Present-day trends in the flow of migration. Economic consequences of migration on both the countries of migration and the receiving countries. Migration is primarily an economic problem, and like all other major economic problems has become an international problem. Possible direction and limits of international action in regard to migration.

Prof. L. Robbins.—*Consumption and trade fluctuation.*

The paper commences by an examination of the view that trade depression is caused by insufficient buying by consumers. An attempt is then made to outline positively the influence of variations of consumption on the course of trade activity.

Friday, September 2.

Presidential Address by Prof. R. B. Forrester on *Britain's access to Overseas Markets.* (See p. 119.)

Dr. F. C. Benham.—*Some theoretical aspects of Public Finance.*

Public finance as a science.

The traditional defence (e.g. by Edgeworth) of progressive taxation. An alternative defence.

Public finance and Equilibrium Theory, with comments on—

(*a*) Wicksell's ' Solution.'
(*b*) Pigou's views on ' Taxes and Bounties to Correct Maladjustments.'
(*c*) The Marshall-Wicksell argument for certain State undertakings.

The special question whether an income tax differentiates against saving, with particular reference to the views of Irving Fisher.

Monday, September 5.

Discussion on *The Location of Industries* (Dr. Brinley Thomas ; Mr. J. Jewkes) :—

Dr. Brinley Thomas.—*The volume and direction of the movement of labour into south-east England since 1920.*

The general trend of new industrial development in this country, as is well known, has been in favour of the South-East during the last decade. Though a substantial body of information is available from Ministry of Labour and Population Census figures, these sources do not enable us to examine the volume and direction of the movement of labour that has taken place. The statistical results embodied in this paper are founded on a special return made available through the courtesy of the officials of the Ministry of Labour, which shows for each office (excluding the smallest rural ones) in the S.E. Division the number and origin (by Division) of all ' foreign ' unemployment insurance books which were first issued outside the S.E. Division as revealed in the exchange of books in July 1932.

The volume of the inflow of insured labour since 1920 is examined, together with the relative contributions from each of the other Divisions. The varying degrees of absorption of adult and juvenile labour in different parts of London and surrounding areas are analysed. Finally a rough attempt is made to relate the labour mobility shown by the analysis with the location of new industries.

Mr. J. Jewkes.

The increasing attention now being devoted to the theory of location of industry is mainly the result of the failure of the attempts to deal with unemployment by the transfer of labour, and the speculations of how far it is possible, or desirable, to encourage mobility of capital to offset the apparently increasing immobility of labour. Those who argue for some control of the geographical distribution of new capital investment may merely point out how dangerous it is to have large parts of the country mainly devoted to one industry, or, in the extreme case, they may support schemes for comprehensive national industrial planning.

Any analysis of such matters involves answers to the questions : How far is the present location of industries rational in the sense of being the most economic which could be devised ? What should be the features of such a rational location ? Is manufacturing industry under private enterprise becoming less or more localised, and is it, in any movements taking place, rendering the task of preventing the maladjustment of labour more or less difficult ?

Prof. G. C. Allen.—*The economic position of Japan.*

The purpose of the paper is to consider, in outline, the main features of Japan's economic structure and to examine, in particular, her position as an international trader during the post-war period.

The extent to which Japan may be considered to possess a 'planned economy.' Instability of her economic system as a result of her rapid industrial and commercial growth. The highly specialised character of her export trade ; her dependence on the American market and on economic 'penetration' in China and Manchuria. Liability of her export trade to extreme fluctuations ; inelasticity of her import demand ; effect of these characteristics on her balance of payments. Rigidity of her economic structure and her difficulty, through financial and social causes, in adjusting herself to changes in world prices and trade.

Japan's international trade and balance of payments after 1914 reviewed in the light of these characteristics. 1914–20, the period of prosperity and the development of an export surplus ; 1920–23, the over-valuation of the yen and its consequences ; 1924–26, the depreciation of the exchange value of the yen and the post-earthquake boom ; the financial crisis of 1927 and the subsequent adjustments ; benefits secured by Japan as a result of 'American prosperity' and of the competitive weakness of the British cotton trade in Oriental markets ; the return to the gold standard in January 1930. The damaging effects of the collapse of 'American prosperity' and of the renewed resistance to Japanese 'penetration' in Asia ; the abandonment of the gold standard at the end of last year. Some political consequences of the economic crisis in Japan.

Tuesday, September 6.

Mr. C. R. Fay.—*Reconciliation of producer and consumer within the Co-operative Movement.*

The reconciliation of producer and consumer has two main sides to it.

The first is the relation of the industrial producer to the industrial consumer. This raises the question of trade unionism and co-operation. Trade unionists should not use the movement as a means of securing rates and conditions which they cannot secure from ordinary employers. If they do, they damage ultimately their own bargaining strength. Concessions made by the C.W.S. as employers call in return for stronger support by the retail societies.

The second side is the relation of the consumers' movement to agriculture, at home and abroad. Numerous problems arise here :

(*a*) Direct farming by the societies and wholesales. This is of small value when it is incidental ; and in fact it is largely a legacy of history, but it may be important in the future, as part of a co-ordinated agricultural policy.

(*b*) The contact of the home farmer with the movement. No contact is of any value unless it is on a quality basis. Organisation is as necessary to the producing farmer as trade unionism is to the wage-earner.

(*c*) The attitude of the movement towards organised marketing on a national or regional basis. This is a vital problem in the milk industry to-day. The movement must adapt itself to commodity selling, but must not sell out to it. The societies and their wholesales must retain their traditional unity. The new orientation of producer and the State *versus* the consumer needs careful watching, both in marketing and in fiscal policy.

(*d*) The relation of the movement to agricultural co-operation overseas—e.g. in Denmark, Canada, New Zealand, and elsewhere. Here, elasticity is better than a rigid contract, which obstructs the blending of consumers' demand.

(*e*) Intertrading and the international mobilisation of co-operative credit. Intertrading between wholesales has no dangers. Intertrading between organised producer and organised consumer is greatly obstructed by tariffs. International mobilisation of co-operative credit must not be allowed to freeze the banking resources of the consumers' movement. Special aid to agriculture is the task of the several States concerned.

Dr. E. Roll.—*Effects of the world depression on the Banking Systems of Central Europe.*

It was the peculiar sensitiveness of its credit systems to economic and social tension and political interference which made Central Europe the storm-centre of the panic of 1931.

It is well known that the crisis of confidence began in the autumn of 1930 when the results of the German elections revealed a state of great political instability. Since then, events in all Central European countries, as well as the adopted remedial measures, show considerable similarity. We find that in all countries the banks lose a considerable proportion of their deposits, varying from 11 per cent. in Czechoslovakia to 30 per cent. in Austria, Hungary and Germany, and reaching even greater proportions in Rumania. These losses are accompanied by decreases in the gold and foreign exchange reserves of central banks, by increases in the note circulation, and by considerably increased stocks of discounted bills. In some countries the traditional liberal credit policy was sufficient to stop the run, in others more radical measures had to be introduced. They comprised as a rule very stringent regulations for dealings in foreign exchange, the guaranteeing by the State of the deposits of insolvent banks, together with a radical re-organisation—again with State help—of their capital structure.

In Germany, owing to the scale on which difficulties appeared and remedies had to be applied, these measures amounted to a virtual transformation of the entire character of the banking system. An unprecedented writing off of losses—by means of capital reductions, amalgamations and

State subsidies—had to take place. In addition the Reich had to provide funds—in the form of fresh share capital—to enable the banks to carry on. The Reich now possesses the majority of shares in two and an important holding in the third of the largest Berlin banks. Combined with the increased importance of previously existing public banks, this new development gives the State virtual control over the entire German banking system. It is impossible at the moment fully to gauge the significance of this increased influence of the State; nor is it possible to predict with certainty the developments in the immediate future. It is, however, fairly certain that a return of the banks to their full private status will not be possible for a long time. Moreover, political developments have already lifted this question out of the realm of economic considerations. As for the ability of the State to manage the banking system, it is more than doubtful whether the Reich will be able to undertake the issuing and promotion business, although the pure deposit banking might be administered publicly. It is not impossible, therefore, that we may see a new specialisation arise; and the most important result of the events of last year may be the final disappearance of the 'mixed' type of German credit bank.

Wednesday, September 7.

Prof. J. R. BELLERBY.—*Inflation; the international remedy.*

It is widely agreed that the remedy for depression in this country involves a recovery of 30 per cent. or more in wholesale prices. This in turn would entail the expansion of credit and possibly of currency. Under every definition these measures would be termed 'inflation': let us then boldly describe the remedy by its true name and set our minds to the task of developing it. Its difficulties and possible ultimate dangers need careful examination.

The most serious risk is not that inflation may be overdone, but that we have lost all power to set it in motion. The traditional methods of expanding credit by reducing the Bank Rate and buying securities are apparently ineffective. There is a ban on public works. And no State action seems now possible for creating that psychological effect which might set the wheels of industry in motion. There remains one suggestion, which is put forward here for criticism. In essence, it is that new money should be created by the banks and transferred, viâ the Government, to to the needy as a gift outright.

Mr. J. MORGAN REES.—*Some assumptions underlying the problem of equilibrium between Production and Consumption.*

Equilibrium is defined for the purpose of this paper as that production of goods and services which can be consumed at a given price level such as would occupy the maximum productive powers and give maximum employment.

The classical economists and the problem. Certain underlying assumptions no longer valid. Economic realities and the persistence of dis-equilibrium. Do these realities force economic analysis towards an ethical basis?

Where initiative rests. Responsibility should be conscious for maintaining a balance. The monetary system and the relation between price levels, bank rates and unemployment. The power of money and credit; policy of central banks towards stabilisation of price levels.

Difficulties which prevent general adjustment between production and consumption. International monetary policy and the regulation of industry. Past failures of all attempts at regulating agricultural production. A world central bank and what it could do. Control of currency and credit. Regulation and distribution of international loans. Assuming failure to secure international co-operation, what the Bank of England could do. Consequences of a managed currency and control of investment: some degree of planning and a managed industry. The worst method—tariffs.

Competition and prices not automatically self-adjusting or sufficient to secure equilibrium. Need for the professionalising of modern business.

DEPARTMENT OF INDUSTRIAL CO-OPERATION (F*).

Thursday, September 1.

AFTERNOON.

DISCUSSION on *The preparation and uses of statistics for the business executive* (Chairman: Dr. W. H. COATES; Mr. A. G. H. DENT; Dr. E. S. PEARSON; Mr. F. W. PAISH):—

Mr. A. G. H. DENT.

In most business problems the judgment of executives has to be based on relevant statistics. The essential statistics needed are internal to the company and external, the former dealing with operating results; the latter with markets, competition, the industry itself, and the general economic position.

The statistician's task is to analyse and interpret raw material figures, presenting a report which is intelligible to an executive who has not had specialised training in the handling of figures. The objective is to assist him to operate and control efficiently; to base decisions on the most accurate presentation of figures; to understand existing conditions, and to foresee important changes. Executive judgment begins where statistical presentation ends.

A statistical report should consist of concise statements backed up by figures and charts. The advantages of the graphic system are: ease of reading and preparation, simplicity, compactness and comprehensiveness, wide scope and vivid presentation. This system enables an executive to grasp otherwise unco-ordinated masses of figures rapidly.

The most important field for statistical work is the company budget, in which demand, orders received, sales invoiced, accounts receivable, expenses, net profits, etc., are estimated ahead, interpreting company policy. This is the figure fabric of a company's existence, and needs to show clearly the relationship between groups of figures, the effects of varying policies, and of probable external changes.

There is need for an adequate statistical treatment of accounts figures, which may be considered as raw material data for studies. New forms of statistical control are developing, such as 'Higher Control,' which co-ordinate and relate company figures and give the managing director a complete inter-related picture of company operations and their results. Commencing with orders, the data can be worked through to the final net profit, relating balance-sheet, profit and loss account, operating position, showing operating ratios, long-period movements and current figures.

The technique of statistical analysis is applicable to special investigations, to market studies and to such company statistics as purchasing, covering raw material prices, stocks, production and consumption ; applying equally to personnel activities, where data of wage rates, employment, cost of living, salaries, etc., have to be marshalled and understood.

In statistical presentation consideration should be given to the correct use of the term ' average ' and to frequency distributions. In the charting field the straightforward line chart, the moving annual total, the ratio or semi-logarithmic scale chart, Z chart, and ordinary bar and circle charts represent important methods of presenting data now in use.

Dr. E. S. Pearson.—*Statistical methods in the quality-control of output.*

A characteristic feature of modern industry lies in the attempt to make the same thing again and again, yet it needs but little consideration to realise that there is no field in which this result has been or is, indeed, ever likely to be completely achieved. Whether we measure the ' sameness ' of a thing by linear dimensions as in the diameter of a shaft or the length of a screw, by tensile strength as in cotton thread or steel wire, by electrical resistance as in parts of telephone equipment, or by one of many other methods, we find that the recorded measures are not identical. And these differences are not merely due to errors in measurement, but exist in the things themselves that we have produced. We may record an average value, but we are also forced to recognise the existence of variation about that average.

An analysis of this variation will often, however, enable causes of trouble —or lack of control—to be located and consequently eliminated. It is possible to summarise the results of such analysis in certain simple control charts which indicate the position and extent of the trouble and the effect of its removal.

Mr. F. W. Paish.—*The selection and interpretation of business statistics in the light of recent research into the causes of the trade cycle.*

Friday, September 2.

Afternoon.

Discussion on *The selection, training and placing of administrative personnel, including the study of the ' Case Method ' as an instrument in education and training for management* (Chairman : Dr. J. A. Bowie; Mr. Jules Menken ; The Hon. J. F. A. Browne) :—

Mr. Jules Menken.—*The Case Method.*

The Case Method uses problems drawn from the experience of business firms for instruction in the principles of business administration. Cases, which are problems in written form, constitute the basis of class discussions designed to develop the habit of analysis and quality of judgment increasingly required in modern business.

The successful use of the Case Method involves a large number of factors, including the selection and training of teaching staff and case collectors, the development of confidence amongst firms which supply material, the planning and organisation of the subject-matter treated, the collection of the right facts and their presentation in a suitable way, and, last but by no means least, students sufficiently mature in mind and experience to participate profitably in case discussions.

Teaching by the Case Method is likely to be slow. The method is relatively unsuited for the orderly communication of systematised knowledge, particularly where the variables involved are comparatively few. On the other hand, the method is very flexible ; and where, as in business, variables are numerous and independent, where appropriate relative weights must somehow be attached to factors themselves incommensurable, there the Case Method provides one valuable instrument for developing a suitable technique of analysis and attack, and for training the qualities of practical judgment which business decisions require.

The Hon. J. F. A. Browne.—*Some suggestions for co-operation between the universities and industry and commerce in the matter of placement.*

The scope of this paper is not to consider those who have been trained as specialists in some subject, such as chemists, physicists, or engineers, but rather those who have taken a university degree in more general subjects, and who leave the universities not specifically qualified for any definite vocation.

Some consideration of what leaders of industry and commerce look for in recruitment, and of the great variety of opinions held by them as regards the qualifications of university men.

What the universities claim for the university man.

Some suggestions for discussion and consideration of various aspects of the problem on both sides: What industry has already done ; a more specific description of its requirements ; more systematic selection ; the problem of the small firm ; what the universities have already done ; the functions of Appointments Boards ; the danger of more specialised training.

A general appeal for the consideration of the university woman.

Monday, September 5.

Afternoon.

Discussion on *The techniques, possibilities and limitations of the measurement of human effort as a basis of monetary reward* (Chairman : Dr. C. S. Myers, C.B.E., F.R.S. ; Dr. C. H. Northcott ; Dr. G. H. Miles) :—

Dr. C. H. Northcott.—*Possibilities and limitations.*

Financial reward may be expressed in relation to time or to quantity. Effort is most easily correlated with reward in terms of quantity of production. But human activity, if spontaneous, is irregular and variable ; it becomes measurable when standardised and mechanised. Within what limits do industrial processes permit of measurement ? Less and more scientific methods of measurement. Consideration of possibilities and conditions.

Limitations arise from :

(1) Degree to which motivation of human effort may be affected by financial rewards ;

(2) Reflex effect of proposals upon motivation.

Consideration of incentives of non-financial kind, and of the safeguards necessary in financial incentives to secure full effort.

Tuesday, September 6.

AFTERNOON.

DISCUSSION on *Fashion cycles* (Chairman : Mr. EDWARD A. FILENE) :—

Mr. R. F. WILSON.—*Colour and colour cycles.*

Historical considerations. Colour as a factor in interpretation of national group-psychology. The part played by colour in religion, war, commerce, etc. Similarity of human emotional responses (individual and collective) to certain colours throughout the ages. Relation of cycles of colour influence to changes in national outlook. International reactions in uses of colour. Effects of improved international communication on extent of areas affected by colour cycles. Influence of æsthetic appreciation upon national commerce. Influence of recent industrial-economic changes and technological progress upon colour cycles. Influence of personal prestige and publicity upon new cycles. Effects of modern living and trading conditions upon the nature of ' cycles of colour.'

SECTION G.—ENGINEERING.

Thursday, September 1.

Dr. G. W. C. KAYE, O.B.E.—*The suppression of noise.*

Noise is generally regarded as an attendant evil of present-day civilisation, though the problem is really one of long standing. There is, however, a steadily increasing volume of public opinion which is making its influence felt beneficially in many directions.

The problem of noise suppression is largely bound up with that of noise measurement, and although the latter is one of some complexity, bound up as it is with physiology and psychology, the physics of acoustical measurement has made great strides in recent years owing to the exactitude and facility of electrical methods. By such means, noises can be analysed into spectra, and their loudness can be measured by the microphone. Alternatively, noises can be matched aurally against some calibrated standard of loudness.

The unit of intensity now generally adopted in noise measurement is the decibel, which corresponds approximately to a 25 per cent. increase in energy. Such a scale of geometrical progression is a rough fit with the sensation scale of loudness. The decibel has the further advantage of corresponding approximately to the least change of loudness which can be detected under ordinary conditions. The auditory range of loudness embraces about 120 decibels.

The best way of suppressing noise is to silence it at its source, failing which a policy of isolation is likely to be more effective than one of absorption. All three expedients have been resorted to, each with partial success, in the modern aeroplane liner, so that in the aggregate the noise heard by the passenger, which was formerly intolerable, is now but little louder than he would experience in a train.

For the study of noise and associated problems new acoustic laboratories are being erected at the National Physical Laboratory. Each of the experimental rooms is as completely isolated as possible, the massive double walls are on independent foundations, and the rooms are asymmetric both in plan and elevation.

Mr. R. Borlase Matthews.—*Rural electrification and the grid.*

As the greatest field for the use of electric power from the grid is in rural areas, a rural area is defined and its prospects are analysed. Three hundred and twenty authorised undertakers are concerned with supplying electricity in rural areas. For various reasons, however, the farm load has been comparatively neglected. As the institution of the grid ensures a low price for current at the smaller centres, this should facilitate rural development. The general principles associated with the supply of rural areas are dealt with, the Mid-Lincolnshire and Rutlandshire Rural Electrification Scheme (covering an area of over 1,600 square miles) being taken as an example and some particulars thereof given.

The possibilities of considerably reducing the cost of rural distribution lines are briefly discussed, followed by a consideration of the possibilities of the farm load, in which emphasis is laid on the fact that the future of British farming will undoubtedly lie in intensive cultivation rather than in the adoption of modern prairie methods. To-day farming is carried on too much after the fashion of a weaver with a hand loom, i.e. with antiquated methods and machinery, yet farmers in the aggregate already use more power than that employed in all the other industries combined. Hence, the suggestion is made that, in view of the existence of the grid, this power should be electric. As the 300 ordinary uses of electricity on farms are now generally well known, brief reference is made to the new and larger farm apparatus such as the 30-h.p. rain cannon, 150-h.p. hay-drying and disintegrating plants, 250-h.p. electric ploughs, and 80-h.p. combined harvester-threshers. Reference is also made to electric soil heating, to moving platforms for continuously milking cows, to the auxiliary industries (e.g. those concerned with the manufacture of alcohol, beer, flour, starch, sugar, etc.) and the like.

In conclusion a brief reference is made to the necessary policy in connection with propaganda activities and tariffs.

Dr. C. C. Garrard.—*The electric propulsion of ships.*

This paper does not set out to prove the economic advantage of electric ship propulsion. The fact that (excluding war vessels) ships built, or building, with turbo-electric propulsion have a total shaft horse-power exceeding one million, and Diesel-electric vessels with a total of more than 100,000 horse-power, renders such proof unnecessary. Ninety per cent. of all these vessels have been built in the United States. This is to be attributed in part to the stimulus afforded by the adoption of electric propulsion for the capital ships of the American Navy. The recent reversion of the battleship *New Mexico* to geared turbines was not due to any dissatisfaction with the electrical equipment, but to quite other reasons. The decision to adopt electric propulsion for any vessel is not so much a question for the electrical engineer as the naval architect, who must take into account the whole of the ship as a means of transporting passengers and merchandise. The effect upon the revenue-earning capacity is more important than the reduction in fuel cost. In the case of liners, generally speaking, electric propulsion results in greater efficiency, while for vessels of the self-unloading type, which require large amounts of power in dock, it is a necessity. In other cases, the ease of control and manœuvre is a determining factor. With electric propulsion bridge control is possible. The author advocates the greatest possible use of automatic control, and maintains that the great reliability such gear has shown in land practice will be repeated at sea. The propulsion equipments of the *Viceroy of India*, *Monarch of Bermuda*, and E.M.V. *Cement Karrier* are considered in some detail, as well as the various systems of electric propulsion and the circumstances which determine a choice between them.

AFTERNOON.

Excursion to Blackburn Aeroplane and Motor Co., Ltd., Brough.

Friday, September 2.

PRESIDENTIAL ADDRESS by Prof. MILES WALKER, F.R.S., on *The Call to the Engineer and Scientist.* (See p. 119.)

Mr. A. P. M. FLEMING.—*An engineer's review of the Soviet enterprise.*

Dr. Miles Walker's Presidential Address discusses some of the problems associated with world economic conditions, and suggests the part that the engineer can play in their solution. His proposals have suggested to the writer the desirability of considering what bearing the huge experiment at present conducted in Soviet Russia has on these economic conditions. This review of the Soviet enterprise is made from a first-hand study of conditions in Russia, primarily from the standpoint of the engineering objectives and the plan and achievements thus far.

The Soviet plan envisages the development of the natural resources of one-sixth of the earth's land surface, comprising practically all the kinds of material wealth necessary for human well-being, and the distribution of these resources to the 150 millions of people confined within its borders. The plan to achieve this result within a comparatively short time, and the considerable measure of success that has attended the beginnings of the operation, justify very serious consideration of the scheme and the method in which it is carried out, especially when one appreciates that the economic difficulties that confront the rest of the world are largely those that relate to the distribution of the existing ample productive facilities. The carrying out of the Russian enterprise rests essentially upon an engineering basis, and especially upon the provision of an abundant supply of cheap power. The underlying basis is summed up in Lenin's formula that ' Electrification plus Soviets equals Socialism.' The basic factors in the engineering aspect of the enterprise include the pursuit of hydro-electric developments on a large scale, the establishment of the manufacturing facilities for engineering plant, the setting up of metallurgical and other enterprises required for the supply of raw materials, and the application of the most advanced methods of engineering to agricultural developments, transport and communication. Associated with, and ancillary to, all these is the development of education, and particularly the training of personnel to replace the vast numbers of foreign experts that have been employed in connection with these developments. Consideration is given to the subject principally from the engineering aspect, and without reference to its political significance.

Some comparison is made between the methods adopted in the Soviet enterprise and elsewhere.

Dr. F. W. Carter, F.R.S.—*Magnetic noise in dynamo-electric machines.*

The paper deals with vibrations in dynamo-electric machines caused by the movement of the magnetic field with the rotor of the machine ; and particularly with such as result in the objectionable howling noises which certain machines emit. The vibrations are shown to be due to one or other of the members having a toothed magnetic structure, which causes periodic variation in the field, and consequently in the mechanical traction on the structure. The conditions favouring vibration are elucidated, and the relation between the frequency of vibrations and the numerical data of the machine determined. It is shown, moreover, that certain harmonics in the periodic magnetic forces which act on the teeth are essential to the vibration ; and methods for computing the forces are discussed, applicable particularly to synchronous machines. In an appendix a comparison is made between two machines from the point of view of vibration, and it is estimated that one has some eighty times the potency of the other in producing sound. In a second appendix certain features of the sound from travelling wave sources are discussed, and it is shown that the sound produced is not effectively broadcast unless the pulse of distortion which produces it travels around the machine with speed greater than that of sound in air.

Prof. E. G. Coker, F.R.S., and Dr. Ruth Levi.—*French and British cleavage tests of timber.*

The need of maintaining a sufficient supply of useful timbers is a matter of world-wide importance, and the numerous scientific and other questions which arise have led to the establishment of a number of State laboratories for the study of these problems. Among these the mechanical properties of timber take an important place, and numerous standard tests have been devised which are in process of co-ordination, in order that the results from all sources shall be strictly comparable.

This co-ordination is especially difficult for a material like timber, which has unlike properties in different directions, and although the grain of timber is one of its most prized characteristics, yet its presence renders a scientific classification of its mechanical properties a task of the utmost complexity.

At the suggestion of Sir Alfred Ewing, many of these timber tests have been investigated by photo-elastic means, using transparent and isotropic materials.

This procedure affords stress distributions of more simple types than occur in actual test members of anisotropic bodies like timber ; nevertheless they afford considerable aid in ascertaining the actual nature of the practical tests employed, and also help to explain some of their anomalies.

Cleavage tests are usually made on notched specimens of timber so designed as to ensure fracture along the grain at a place of minimum cross-section. This does not always happen, and photo-elastic investigations of French and British standards prove that the minimum cross-sections are not places of maximum stress intensity.

The paper describes these experimental observations in detail, and shows that various cleavage tests now made are not properly co-ordinated.

The suggestion is made that a better form of test might prove to be a simple tension test with the grain of the timber arranged perpendicularly to the line of the load.

Saturday, September 3.

Excursion to Leeds district to visit :—

(1) Savile Pit and Whitwood Silkstone Pit (Messrs. Henry Briggs, Son and Co., Ltd.) for an inspection of a new method of supporting underground roadings and of surface arrangements.

(2) Yorkshire Coal Owners' Association Rescue Station, Wakefield, for demonstrations of breathing apparatus, model underground galleries, etc.

(3) Kirkstall Super-Power Station (using pulverised fuel) of the Leeds City Electricity Dept.

(4) *Yorkshire Post* printing works.

Monday, September 5.

DISCUSSION on *Railway traction* :—

Sir SEYMOUR B. TRITTON, K.B.E.—*Steam power.*

The technical press having dealt exhaustively with details of the modern steam locomotive and the high speeds recorded, it is impossible to introduce novel proposals, but a *résumé* is set forth for discussion.

The general design has altered little from the earlier types, but details have been altered out of all recognition.

The energy obtained by explosion in the internal combustion engine is compared with the elastic drive of steam.

The tendency of present-day propulsion is by prime mover running at high speed with a reduction gear to the driven member. Examples : marine turbine, the road motor-car, and, on rails, locomotives of the ' Sentinel ' type.

Development of the powerful steam locomotive on these lines is questionable.

The boiler—the vital part of the locomotive—and its development to its present form seems to have reached the limit, and the water-tube boiler, in the author's opinion, is the form in which most progress can be made, though other forms using very high pressures are referred to.

The progress made with the boiler has been followed by that of valve gears, especially of the ' poppet ' type.

The use of special steels and alloys is essential to the development of the steam locomotive if its weight is to be kept within permissible limits of the restricted ' loading gauge ' of this country.

Sir HENRY FOWLER.—*Oil engine power.*

At the inception of what is called the internal combustion engine, its application to railway transport was naturally considered by engineers. It will be remembered that Sir Frederick Bramwell, about fifty years ago, looked to it supplanting the steam engine in every direction. Our President, Sir Alfred Ewing, dealt with this in his address last year.

The use of a heavy and cheaper oil by Diesel and others made the matter a more practical proposition, whilst recent developments have given us a more flexible engine. A great deal of work has been done on the subject and many interesting experiments carried out. The proposition offers considerable advantages in many directions. The greatest difficulty, undoubtedly, is the provision of a perfectly satisfactory transmission and power unit at a price which makes the problem a feasible one from an economic standpoint. Many experiments have been and are being carried out in various parts of the world, and the matter is receiving increasing attention from all interested.

Mr. F. LYDALL.—*Electric power.*

The paper deals with the use of electrical energy for the propulsion of trains. The energy may be transmitted to the trains from an external source by means of track conductors, or may be derived from storage batteries carried on the trains. Both alternatives are distinguished from other forms of traction by the absence of steam or gases resulting from combustion; electric traction is, therefore, practically indispensable for underground railways.

On the subject of battery traction, reference is made to the Drumm battery and its application to railway work on the Great Southern Railways of Ireland. The possibility of using similar batteries for other service conditions is considered.

The justification for electrical operation of surface railways depends upon either an increase in the net revenue, such as results from the electrification of suburban railway systems, or a reduction of the working expenses, as in main line schemes. The special features of suburban electrification are well known. The reduction of working expenses in main line operation is dependent upon a number of factors, the three principal items, which together make up fully 75 per cent. of the working expenses, being (1) fuel or electrical energy, (2) wages of drivers and firemen, (3) maintenance of locomotives. Each of these three items is discussed in some detail.

AFTERNOON.

Excursion *via* Northallerton to Darlington for an inspection of permanent way, rolling-stock, rail-cars and track-widening operations of the L.N.E. Railway and of the Works of the Cleveland Bridge and Engineering Co. Ltd.

Tuesday, September 6.

JOINT DISCUSSION with Section A (Mathematical and Physical Sciences, *q.v.*) on *The theoretical and practical aspects of the control of humidity in industrial processes.*

Prof. W. CRAMP.—*A new system of lighting at the coal face.*

Modern mining conditions involve the use of much complicated machinery at the coal face. Such machinery cannot safely and efficiently be worked without adequate light. The usual illumination is far too small, yet the only satisfactory way of augmenting it is to supply lighting circuits from the power mains—an arrangement hitherto precluded in gassy pits because of obvious dangers. The present proposal is an attempt to render such a supply safe, flexible and convenient. The system, which may be demonstrated, is arranged as follows:

(1) From each phase of a lighting transformer fed from the power mains a series circuit is connected between phase and neutral, the neutral wire being earthed.

(2) In each such circuit the primaries of a number of special transformers are connected in series without switches. The secondary of each transformer feeds one lamp in an appropriate fitting.

(3) The transformers are constructed so that the lamp, tail, secondary and yoke can easily be withdrawn as one unit; and this is the method of extinguishing or removing a lamp.

(4) The characteristics of the transformers are such that no matter whether a lamp be in place, withdrawn, or even short-circuited, the primary circuit is not substantially disturbed.

(5) The most vulnerable portion of the circuit then becomes the lamp. It is proposed to use a fitting provided with a glass which will withstand the shock of an explosion or of shot-firing, in which case the secondary voltage would be either 12 or 25. If this is not considered satisfactory, recourse can be had to the special lamp recently designed by Dr. Wheeler.

The advantages of the system are: simplicity of connection, low voltage on each primary and each secondary, and the removal or extinction of any lamp without opening a switch and with no risk.

Mr. J. Gilchrist and Dr. R. H. Evans.—*Elasticity and hysteresis of rocks and artificial stone.*

In this paper is described a new method of investigating the elastic properties of rocks, part of which consists in allowing a column of the material to stand for a long time under a given load, and then to vary this through a small range. The strain so obtained is termed the short range strain, from which we can calculate the short range modulus. In general, for stone and concrete, the short range strain decreases with increasing load, and the modulus increases. This short range strain, with certain limitations for concrete, is a constant magnitude found always on returning to the same average load; it is independent of time. The sum of the short range strains integrated between two given loads differs from the actual strain obtained when observations are made in the ordinary manner. The difference between this integral short range strain and the actual strain is a time effect. The authors suggest that this conception of a short range strain combined with the time effect gives clearer ideas of the stress-strain relations of the materials in question. For example, the elastic hysteresis loop can be explained in terms of these two effects.

Afternoon.

Visit to L.N.E.R. Carriage Works, Signalling School and Museum, York.

Wednesday, September 7.

Prof. F. Bacon.—*Cracking and fracture in rotary bending tests.*

The primary aim of the experiments described has been to reproduce in laboratory tests the features found on the fractured faces of rolls, shafts and axles which have failed in service by the gradual spreading of cracks. The investigation arose from the desire to interpret the various markings of simple geometric form often found on the freshly fractured faces of the chilled iron rolls used in the hot mills of sheet and tinplate works.

Two fatigue-testing machines are described which have been specially developed to study (*a*) the various stages of the crack-spreading process; (*b*) the modifications caused by the contact pressure of loaded rollers; (*c*) the influence of periodically varying the limits of successive cycles of alternating stress.

Attention is drawn to certain constantly recurring features of service breakages which have been successfully reproduced in the laboratory tests. It is shown that some of these are related to the direction of rotation. Various methods of crack detection are illustrated and compared, and the possibilities of fracture study as an aid to diagnosing causes of failure are discussed. Some examples of corrosion fatigue are included in which the corroding agent is a mixture of wet steam and air.

A collection of the author's photographs will be placed on view previous to the reading of the paper.

Dr. H. Cotton and Mr. F. A. Hough.—*The pulling into step of a synchronous-induction motor.*

The investigation of the transition from induction motor to synchronous motor running involves the solution of a differential equation necessitating a very laborious step process, in consequence of which the mathematical solution of the problem has been confined to a few special cases. In America solutions have been made by means of the integraph, a machine which is not available in this country, and which also has the disadvantage that it is a purely mechanical contrivance giving the operator no insight into the real nature of the problem under investigation.

The present research deals with a solution obtained from the examination of the motion of a mechanical model whose equation of motion is the same as that of the synchronous-induction motor. Cinematograph films were taken while the model was in motion and the angular position at any instant determined from these. The advantages of the method are: (*a*) the constants of the model can be altered at will, so that the performance of any motor can be imitated; (*b*) the motion to be examined is a slow slip motion and not the high speed of an actual motor, on which the slip motion required is superposed; (*c*) the model can be made very cheaply; (*d*) other phenomena—e.g. re-synchronising after falling out of step—can be investigated in addition to the pulling into step.

There were many difficulties to be overcome before a suitable model was developed, and these are described in the complete paper.

Dr. T. F. Wall.—*The economical control of the speed and power factor of three-phase induction motors.*

The problem of the economical control of the speed and power factor of three-phase induction motors by cascade connection with alternating current commutator machinery has become one of rapidly increasing industrial importance. The investigation of this problem is greatly facilitated by the use of the complex quantity method of treatment. In the first part of the paper some of the characteristics of the standard equation for the circle diagram are considered, when this equation is expressed in terms of complex quantities with the slip as the variable. In the next part of the paper it is shown how the most favourable circle diagram for the purpose in view may be chosen at will and the motor operated on a shunt characteristic with the same circle diagram and having any desired no-load speed. In the last part of the paper the conditions are established for one method of operating an induction motor so that a considerable drop in speed is obtained as the load comes on. This system is suitable for cases in which heavy variations of the load occur and a flywheel set is used to screen the network from the fluctuating load.

REPORTS OF COMMITTEES:

(1) *Earth pressures.* (See p. 287.)

(2) *Electrical terms and definitions.* (See p. 289.)

(3) *Stresses in overstrained materials.*

SECTION H.—ANTHROPOLOGY.

Thursday, September 1.

DISCUSSION on *Who were the Romans?* (Prof. H. J. ROSE; Prof. P. S. NOBLE; Prof. J. L. MYRES; Dr. D. RANDALL-MACIVER):—

Prof. H. J. ROSE.—*Early Rome, the evidence from religion.*

To reconstruct the earliest religion of Rome is practically impossible, and recent researches have but emphasised the difficulty of the task by pointing out the importance of certain rather neglected pieces of evidence. It may, however, be said with some confidence: (1) That so far as the cults can tell us anything of so remote a period, they testify to a mixed people, for (*a*) some deities, certainly very early, have for their province the fertility of the soil, while others deal with the increase of cattle, thus suggesting a people part pastoral and part agricultural; (*b*) there are to be found, alongside of survivals from the Stone and Bronze Ages, definite Iron Age features. (2) That the level of civilisation was not very high, all the worship suggesting a barbarous folk, mostly polydaimonistic, having very little industry or trade. (3) That the people were nevertheless sufficiently advanced to be receptive of foreign influence and able to assimilate it, as is shown by demonstrably early borrowings (*a*) from other Italian peoples; (*b*) from Greek sources; (*c*) probably also from Etruria, though here the extent of the indebtedness is a highly controversial point.

Prof. P. S. NOBLE.—*Linguistic evidence.*

Prof. J. L. MYRES.—*The plebs.*

AFTERNOON.

Rev. A. RAINE.—*The beginnings of York.*

The object of this paper is to examine the evidence for and against the existence of a pre-Roman York.

(*a*) Was there a British tribal headquarters on the site of York?

(*b*) Was there any kind of British occupation?

(*a*) seems ruled out by the fact that Aldborough (Isurium Brigantium) occurs as a tribal headquarters before A.D. 100, and as it was the usual Roman policy to leave native local government undisturbed, it is probable that in the pre-Roman period Isurium was the centre of native government in the district.

(*b*) Was there any kind of British occupation? The evidence is against this. Few British objects have been found on the site of York. No certain British interment has been discovered. The British name underlying the Roman form 'Eburacum' is a descriptive name and not the name of a settlement. The geographical evidence points to there being a river-crossing on the site of York in pre-Roman times; indeed, here was the only possible crossing-place for a great distance to the north or south of York. There is known to have been a British trackway leading to the river. If the site of York was a tribal crossing-place, it affords a cogent reason why the Romans chose the site for a legionary fortress.

Mr. I. A. Richmond.—*Recent discoveries at Birdoswald, Hadrian's Wall.*

Since 1927 excavations at Birdoswald (Camboglanna) by Mr. F. G. Simpson, M.A., Hon. F.S.A. Scot., and the writer have been devoted to studying the sequence of the three frontier works of Roman date that approach one another at this point and are overlaid by the milliary cohort-fort which was laid out in connection with the last of them, Hadrian's Stone Wall. The first procedure was accurately to define the periods of occupation of the Stone Wall fort. These proved to be four, running from *c.* A.D. 124 to *c.* A.D. 196, from *c.* A.D. 208 to 297, from *c.* A.D. 297 to 368, and from *c.* A.D. 368 to 383, the second and third being defined by epigraphic evidence, the others by numismatics. The stratified pottery related to these periods now forms a firm basis for dating elsewhere.

Below the Stone Wall fort, excavation has now revealed three occupations. The earliest preceded the Vallum and was destroyed by it. The second, a small fort of Trajanic type, is contemporary with the Vallum and goes typologically with the forts of the Stanegate. The third overlies the demolished Vallum and is in turn cut through by the ditch-system of the Stone Wall fort: it should therefore be the fort going with the Turf Wall. Work this season is expected to reveal the form of these structures and to define more clearly their period. At present they provide an unrivalled example of complicated but beautifully distinct stratification.

Mr. F. Elgee.—*The camp on Eston Hills.*

This is perched on the edge of a sandstone cliff at Eston Nab (800 feet), in the extreme north-east of Yorkshire. It consists of a semicircular rampart and outer fosse about 350 yards in circumference. Excavations undertaken by the Cleveland Naturalists' Field Club, 1927–29, point to a Bronze Age date. Fragments of a coarse, reddish-brown pottery associated with small pieces of calcined human bone, flint implements, stone pounders, etc., and found on the site of hearths, are similar to those of the Late Bronze Age in the Heathery Burn Cave, co. Durham. No hut sites were discovered, but on the cliff-edge about half-way between the rampart ends there was a burial-place with cremations, a decayed Bronze Age food-vessel, leaf-shaped flint arrow-heads, scrapers and flakes. No objects were found at the bottom of the fosse excavations, which were impeded by a thick infilling of heavy sandstones falling from a wall, the foundations of which can be traced on the inner side of the rampart. No Iron Age objects were found, and this accords with their general absence from north-east Yorkshire, where Bronze Age, especially Mid-Bronze Age remains are the dominant feature.

Mr. Philip Corder.—*Roman Malton and some neighbouring sites.*

The Roman fort at Malton is situated half-way between the legionary headquarters at York and the coast, on the eastward extremity of the Howardian hills. It is connected with Lincoln by the road which crosses the Humber at Brough.

The earliest occupation, probably under Cerialis, covered at least 22 acres. Shortly after this a permanent fort of 8½ acres was established, perhaps by Agricola, and presently received a massive revetment of stone. The consolidation of the northern frontier by Hadrian led to the withdrawal of the garrison, but occupation of the site was resumed early in the third century. Towards the end of the century the fort was deliberately abandoned, but again during the fourth century there was continuous and intensive occupation; indeed, it is probable that Malton served as base to the coastal signal stations during its closing years.

Two sites in the neighbourhood are of special interest. In 1926–27 boys from Bootham School excavated two pairs of pottery kilns at Crambeck, about 5 miles from Malton, where manufacture began late in the third and continued throughout the fourth century. The products of this pottery had a very wide distribution in the northern military area. In 1929–30 an extensive villa site was excavated at Langton, 4 miles south-east of Malton. Here a small fortified enclosure of the first century was succeeded by a definitely civil occupation, which probably began in the third century and was intensive in the fourth, particularly during the last thirty years of the century.

Sir Flinders Petrie, F.R.S.—*Copper and Bronze in Palestine.*

The excavation of Ancient Gaza in 1932 has been on the palace site and the cemeteries. The latest palace is limited to the XVIIIth dynasty of Egypt, as no later remains were found. The earliest is after the Copper Age of the Vth–VIth dynasties, as the pottery of that age had entirely ceased. As it was contemporary with the great fosse round the hill, which is of North Syrian type, the invaders from that region, who formed the VIIth–VIIIth dynasties, were probably the builders of the first palace. Three other palaces are between the first and last, probably belonging to the XIIth and the Hyksos age of the XVth and XVIth dynasties. The earliest palace was about 150 ft. wide, built with dressed slabs of sandstone for the wall basement, 6 ft. wide. Much foreign painted pottery was found, mainly in the early palace levels; it can be classed by the levels. Of earliest period is the cemetery of the Copper Age, with ledge-handle jars, and copper daggers of large size.

Friday, September 2.

Presidential Address by Dr. D. Randall-MacIver on *The place of Archæology as a science, and some practical problems in its development.* (See p. 147.)

Discussion. (Mr. R. U. Sayce.)

Mr. J. W. Crowfoot.—*Excavations at Samaria.*

The Harvard expedition to Samaria which discovered the famous Hebrew ostraca of the ninth century suspended operations in 1910, and no archæological excavations have been conducted on the site until 1931, when the present joint expedition started work.

The city stood on an isolated ridge in the centre of the northern kingdom, easily defensible and commanding the main road from north to south. There are, however, no springs near, and in consequence, except for a small settlement in the Early Bronze Age, it was apparently unoccupied until about 880 B.C., when Omri chose it as the capital of his kingdom. It is with the remains of the Israelite period during the next 150 years that this paper deals.

The place was defended in Israelite times by two great walls. Of the lower of these, which may be called the City wall, only fragments have been found: it followed the irregular outline of the ridge and it was built mainly upon a natural terrace against the rising rock. A magnificent section of this wall was uncovered in 1931: the foundation course was laid in an excavated rock trench, and the upper courses were built of carefully dressed stones laid with an accuracy and regularity to which there is no parallel of this date in Palestine. Of the upper Palace wall more has been found: the main portion of it was set out in the form of a rectangle enclosing more than eight acres of ground. Red guiding lines can still be traced on some of the rock trenches, showing with what precision it was planned: the dressing, bonding and jointing of the masonry show equal fineness of execution.

Of the buildings within these walls very little of the Israelite period has been found: the only architectural details which have come to light are three early caps of the Proto-Ionic Cypriote type.

The most illuminating relics of the time, however, are a series of small ivory plaques which were discovered in the last campaign. They come from the decorations of furniture, probably from beds or thrones or cabinets: the motifs are drawn indifferently from various fields, Egyptian, Assyrian, Anatolian and the like, and they are brilliant examples of the eclectic art which has been connected in turn with Cyprus, Phœnicia and Syria. The nearest parallels are the ivories found in 1928 at Arslan-Tash, near Carchemish, on one of which an inscription of Hazael, King of Damascus, occurs. They provide the most vivid illustration of the wealth and luxury in Samaria which was denounced by the Hebrew prophets.

Afternoon.

Miss Kitson Clark.—*Some invasions of Yorkshire.*

The superficial geography of Yorkshire is particularly marked, and has greatly influenced the history and prehistory of the county. Distribution maps of selected periods show that the same causes lead to the same effect. At the same time they make clear the difference between penetration by a primitive race and invasion by a civilised nation. Comparison of the Early Iron Age, the Roman and the Anglo-Saxon Ages illustrates this point in Yorkshire.

Dr. A. Raistrick.—*Roman West Yorkshire.*

This paper puts on record several finds of Roman coins, fragments of pottery, etc., that have been discovered at various times in Craven, West Yorkshire—i.e., roughly, the country between Wensleydale and Nidderdale on the north, Ribblesdale on the west, and the Elslack-Ilkley Roman road on the south. Some of these finds have received casual comment in the past;

but none have yet been adequately recorded. The finds of coins are from several localities in upper Wharfedale, between Kettlewell and Grassington, from some of the caves, Dowkerbottom, Victoria, Kelco, etc., and in Nidderdale. The possible dates of the coins found reveal a curious hiatus —present over the whole area—separating two main periods in each of which there are several coins to represent each emperor's reign. The coins lie in the two groups of dates A.D. 54–187 and A.D. 250–380, with no representatives of the gap A.D. 187–250. The remains of mining activity lie in the earlier group of dates, three pigs of Roman lead from the area having dates A.D. 81, 81, and 98. The tracing of this gap over wider areas and its interpretation are reserved for further work, though it would seem to offer strong corroboration of the rebellion on the Pennine area, suggested by Collingwood and Haverfield, around a general date A.D. 155. The second important feature of these finds is the support they give to the suggestion of a Roman road down Wharfedale from Bainbridge camp to Ilkley camp. The sites of the finds have been mapped, and cluster markedly around a line along which at various points, Grassington, Cray, Hebden, and Appletreewick, ancient road foundations have been excavated at depths up to 10 ft. below present ground level, many of the finds being actually on this line of old road. Over Stake, and near Cray, this old road is still well preserved, and affords a pleasant by-pass from the busier modern roads. Along this line are large areas of Romano-British settlement, at Kettlewell, between Kettlewell and Coniston, at Grassington, and near Appletreewick, from which quantities of pottery and other objects have been excavated. This road would pass by Addingham and Middleton to Ilkley, and continue after crossing the river as the long-known Roman road along Otley Chevin to the camp near Adel.

Mr. A. L. ARMSTRONG.—*Discovery of rolled Aurignacian tools in a boulder clay of North Lincolnshire.*

Dr. AXEL BOETHIUS.—*Domestic architecture under the Roman Empire.*

Visit to places of interest in York.

Saturday, September 3.

Excursion to Pickering and Sleight Moors, Whitby and Scarborough, to examine relics of early man and evidences of glaciation.

Monday, September 5.

JOINT DISCUSSION with Section C (Geology, *q.v.*) on *The contacts of geology: the Ice Age and early man in Britain.*

Miss A. I. RICHARDS.—*The Babemba tribe of N.E. Rhodesia.*

Mrs. ROBERT AITKEN.—*The Kivas at Hano.*

Hano, near the Hopi village of Walpi, Arizona, is a settlement of Tewa and Tano elements from New Mexico. Hano kivas are influenced in form, use and ownership by Hopi custom. The existence of two kivas only in Hano at present is fortuitous, and not connected historically with the

New Mexican moiety system ; there is evidence for the existence of a larger number in recent times.

Miss E. D. EARTHY.—*The tribes of Moçambique.*

The Moçambique tribes have been classified by Aires d'Ornelas, Pereira Cabral, Schapera, Junod (*Thonga*) and Torday.

The classification accepted in the Anthropological examination for the post of *Administrador* (native commissioner) is as follows :

Divisions of the Bantu race living in the colony of Moçambique, from north to south : *Macua*, *Mocaranga*, *Thonga*, *Zulu* (Portuguese spelling employed in this list) :

Macua : Subdivisions—*Macuas, Malomués, Makondes, Mavias, Borores.*
Mocaranga : Subdivisions—*Massengas* (*Asenga*), *Maraves*, *Macanjos*, *Maganjas*, *Massingires*, *Machonas*, *Manicos*, *BaNyai* (and *VaNdau*).
Thonga : Subdivisions—*BaTonga*, *MChopes* (*BaChopi*), *Maguambas*, *Mabaluecos*, *Valengues* (*VaLenge*), *Matembes*, *Maputos*, *Mabaloios*, *Cossas*, *Bilas*, *Rongas*.
Zulu : Subdivisions—*Vatuas*, *Mafites*, *Matabele*, *Angonis*, *Ajaus* (*Yao*).

Pereira Cabral uses the alternative term *Landin* for the *Ronga* (not for the *Angoni*), and the tribal name *Ronga* for the *Thonga*.

The *BaZaruto* of the Islands are not mentioned in any classification, but are ethnologically important.

The *VaNdau* of Sofala are scattered remnants of the *BaRozwi* and *MaKaranga*.

There are a few Bushmen families living on the banks of the Aluize (Inhambane district).

Some tribes are noted for their initiation ceremonies and scarification.

Most are clever at handicrafts (pottery, basket-making, wood-carving, metal-work).

The main occupations are hunting, fishing and agriculture.

Dr. M. A. MURRAY.—*The Royal Tail-Festival in ancient Egypt.*

The 'totem' of the invading dynastic kings was the falcon ; the indigenous ruling house had a cattle-totem. When therefore the foreign conqueror intermarried with the native royal house he had to join his wife's tribe and adopt her totem. The Tail-festival was the initiation of the king into the Cattle-tribe, when a tail was affixed to his girdle to show that he had become a bull.

Prof. V. SUK.—(i) *Human races on the basis of serological tests.*

The present paper is the outcome of over 3,000 precipitation tests and over 4,000 blood groupings.

1. On the basis of the precipitation tests the biological value of the different races is discussed. For the present study the serum from Eskimos, Kalmucks, Gipsies, European Jews and different Europeans—'nordic,' 'alpine,' 'dinaric,' etc.—was used ; we had fifteen antisera and twenty-five sera at our disposal, and dilutions up to 1 in 20,000 were used. As a result of these studies the following conclusions were arrived at : all the different European 'races,' like the 'nordic,' the 'alpine,' the 'dinaric,' etc., 'race,' are *not true races at all*, but only types or not fully established races in process of making. Only those distinct and geographically separated groups, the Eskimos and the Kalmucks, and the Eskimos and the Europeans

as a whole gave well-marked differences. Hence 'nordic,' 'alpine,' 'dinaric,' etc., have not the *immunologic specificity* of the old races like Mongols, Negroes, etc.

2. The results on blood groups are based on more than 4,000 cases, and the general results of our work on blood groups with regard to the different anthropological traits, as, for instance, colour of eyes, colour of hair, seem to lead to the conclusion that the racial significance of blood groups is but very small and that, at least, it has been grossly overrated. Our previous studies on the decay of teeth amongst different races led us to the investigation of the condition of teeth with regard to blood groups. Amongst the 3,000 records on blood groups from Brno we had 700 young men between the ages of eighteen and twenty-two whose teeth we were able to examine. Generally speaking, we found the highest percentage of faultless teeth amongst people with blood group I (θ agglutinogen), and the same holds true for sets of teeth with very little decay. This investigation gives a strong hint that blood groups seem to belong to the constitutional qualities, and therefore can be found all over the world.

(ii) *Eyebrows and eyelashes in man.*

The present paper is the outcome of nearly 600 observations on eyebrows and eyelashes made by one of our students, Mr. Rozprým, of the Anthropological Institute, Masaryk University in Brno, Czechoslovakia. Mr. Rozprým studied the different forms—colour of eyebrows and eyelashes in relation to sex and age, and also with regard to heredity, and arrived at the following conclusions: (1) There are several forms of eyebrows which do not change with the age of the subject. (2) The position of the eyebrows in relation to the upper orbital margin depends on age, for with advancing age the eyebrows sink below the upper margin of the orbit. (3) Amongst the common forms of eyebrows a distinct sexual dimorphism has been observed, the 'even' form being found in 70 per cent. in women and the 'double' form in 71 per cent. in men. (4) The colour of the eyebrows occurs in the same shades as the colour of the hair, is independent of the form of eyebrows, and is hereditary. (5) There are only very few forms of eyelashes, yet the noticeably long and curved eyelashes are *decidedly an infantile form*, fall out during the age of puberty and are replaced by an adult form. There is no correlation between the colour of eyelashes and the colour of eyebrows and of hair, for quite blond types have dark eyelashes. The longest eyelashes are in the upper lid and in front of the pupilar opening of the eye. It would be of great interest to follow up this study amongst different races of mankind—Negroes, Mongols, Ainus, Weddahs, etc.; in other words, to study it in races with very little and very much hair. And in addition to this a thorough survey of these characters in apes and monkeys should be of very much interest and value.

Afternoon.

Joint Discussion with Section D (Zoology, *q.v.*) on *The Primates and early man.*

Dr. Cyril Fox.—*The frontier dykes of Wales.*

A survey of the running earthworks of the Welsh Marches has been in progress for seven years.

These earthworks, linked with natural obstacles, form a continuous frontier from the estuary of the Dee to the estuary of the Severn, a distance as the crow flies of some 120 miles. They are closely related to the natural division between highland and lowland, and are the work of the lowlanders.

The chief work is Offa's Dyke. This is duplicated in the north of the frontier by Wat's Dyke, which extends for some 30 miles. In addition, short cross-valley and cross-ridge dykes are widespread in the central region crossed by the main work.

Evidence supporting the attribution of this main work to King Offa, 757–796, has been obtained by excavation. It is held to be probable that the whole series are Mercian, and of the period *c.* A.D. 700–850.

Interesting facts bearing on the distribution of forest and agricultural land in the eighth century in the Welsh Marches, and on the constructional technique of these running earthworks have been obtained in the course of the survey and will be referred to.

Mr. J. P. Williams-Freeman.—*The Chichester earthworks.*

Miss G. Caton-Thompson.—*Recent discoveries in Kharga Oasis.*

Field work has established a long Palæolithic sequence covering Acheulean, Acheuleo-Levallois, Middle Palæolithic (pre-Sebilian), Aterian, Capsian to Capso-Tardenoisean, and Neolithic. The pre-Sebilian is an interesting and apparently new *facies* of Mousterian culture. These industries were all found *in situ*, in dead springs, gravels, or silts, enabling close relative dating for local physiographic stages throughout the Pleistocene. Thus tufa deposits, hitherto undated in Egypt, are shown to synchronise with Acheulean to pre-Sebilian times, but to extend no later. Moister conditions undoubtedly prevailed from the Acheulean to Aterian (early Upper Palæolithic) period, when reversion to a norm of aridity, witnessed for pre-human times by breccias and loess-like deposits, and suitable to lat. 25° N., becomes marked. The oncoming of the dune-belts occurs between Aterian and Capsian times. Neolithic man, whose great flint-mines and hearth-mounds were explored, was finally driven from the depression by failure of the Pleistocene springs, discovered in 1930–31 and re-examined last season. The region appears to have been abandoned until the sixth century B.C., when the Persians refertilised it by means of deep artesian borings, and inaugurated the classical period of Kharga's prosperity.

Tuesday, September 6.

Mr. J. G. D. Clark.—*The Mesolithic Age in Britain.*

Mr. A. Leslie Armstrong.—*The pre-Tardenois and Tardenois cultures of North Lincolnshire.*

Researches in North Lincolnshire have revealed a series of stratified sections and occupation sites, forming a continuous sequence of industries, embracing late Upper Palæolithic and the whole of the Mesolithic periods. The earliest of these is a late Developed Aurignacian (Creswellian) station, discovered by Mrs. E. H. Rudkin, on the western escarpment of the Lincolnshire Cliff, above Willoughton, excavated in February of this year, and which yielded a wide range of characteristic tools and other evidence.

Sheffield's Hill, near Scunthorpe, is a similar occupation site, but of later date than that of Willoughton, evidencing the final phase of the native Developed Aurignacian culture upon which the early Tardenois culture was imposed. Risby Warren, Scunthorpe, as a result of eleven years' systematic research, has provided evidence of a stratified sequence of occupation levels ranging from the latest phase of Developed Aurignacian (Creswellian) at its base, free from Tardenois influences, to the earliest Neolithic; also successive Neolithic and Bronze Age occupations. Tardenois culture is represented by several horizons and can be broadly classified as early and late. By reason of the extent of this site, the abundance of stratified material and the numerous occupation zones representative of the whole Tardenois period, it is claimed that Risby Warren is the type station for this culture in England.

Rev. H. G. Williams.—*Pygmy flints from the Cleveland Hills.*

Introduction.—How I first became interested in prehistoric flints in 1927. Bransdale and Farndale the scene of my researches. How I was led to discover my first pygmy site at Farndale Head: abundance of flint on this particular part of moor. Ignorance at first. Specimens sent to British Museum and information received. Interest aroused and greater and more intensive search made. Most of pygmies found on surface. Later on flint found under turf by digging. Best specimens, however, on surface. Turf in most places not deep. Sand underneath and pygmies lying on sand or just in turf. Further discoveries made about half a mile to the east of the site. Odd chippings found, but in no great quantity. A site discovered on Blakey Ridge. Cores and flakes fairly abundant, but implements scarce. Flint here mostly white. A few implements found near Danby by Mr. R. W. Crosland and forwarded to Middlesbrough Museum. Further discoveries made in Bransdale. Pygmy flakes found above Stork House on moor, but not abundant. Apparently sites on this moor, but unable to locate them. Only two or three good specimens found, the best being a knife and a 'needle.' In 1931 more chippings found in another direction by one of the dalesmen. No search made. To sum up: little digging done, finds mostly on surface and comprising the following: cores, knives, small triangles, 'needles,' gravers, scrapers, points, etc., few micro-gravers and burins, and two or three thumb flints (small).

Mr. F. Buckley.—*Mesolithic artifacts from the Pennine Chain.*

Not much of the Pennine Chain has yet been thoroughly searched for traces of Mesolithic occupation. Conclusions must therefore be drawn from excavations on specially favoured sites—e.g. at both ends of the Standedge Ridge (Yorks.), where the whole Chain narrows down to a single ridge. Mesolithic man was bound to pass that way, if he avoided the valleys. In the peat are found stray Bronze Age and Neolithic tools; in the soil under the peat the occupation sites of various Mesolithic peoples have been excavated. These contain the relics of two distinct races of Tardenois folk, called locally the 'Narrow Blade' and the 'Broad Blade' industries. The former made numerous small geometric tools, perhaps as teeth for harpoons; they used open-air encampments and wandered freely over all the hills. The 'Broad Blade' people made few geometric tools, but many pointed blades. They travelled only along the watershed ridge, and erected huts or wigwams on their camping sites. The Micro-Graver is common to both industries; small Angle Gravers and True Gravers are found. The hearths have yielded wood remains, giving data as to tree distribution in Mesolithic times.

Discussion on papers previously communicated.

AFTERNOON.

Rev. Dr. E. O. James.—*Folklore and archæology in north-west Spain and Portugal.*

Certain legends of the Santiago type connected with pilgrimage centres in North-West Spain and Portugal collected during recent visits to the district are discussed in relation to their archæological setting. In Galicia and the adjoining region south of the Minho falling in Portugal, there is evidence of important ancient settlements, connected in many cases with mining operations and megalithic monuments, having had a continuous occupation from the early periods of the Bronze Age to Christian times. Around these centres a sacred tradition has collected, the analysis of which throws some light on the anthropological and historical causes which gave rise to the sites and have made them places of pilgrimage throughout the ages. The development illustrates how a tradition may be raised to new activity by the impact of extraneous cultural influences and so acquire a new functional value.

Rev. Canon J. A. MacCulloch.—*Were fairies an actual race of men?*

Were fairies ghosts of an earlier race ? They are connected with burial-mounds, and parallels exist between fairies and ghosts. On the whole, they are distinct in origin, though the Brownie (house-fairy) may be an exception. Were fairies an actual race transmuted—Neolithic men, Picts, or an earlier pygmy folk ? Pygmies in tradition and fact. Their likeness to fairies. Folk-tales about dwarfs and, to a less extent, about fairies suggest an actual people. Examples—dislike of a higher civilisation ; migration legends ; underground dwellings ; dislike of iron ; stone weapons and fairies.

Some traits of dwarfs and fairies suggest an early race. Others are animistic in origin. Even where groups of elfin beings (Polynesian, Melanesian, African) seem to be transmuted human folk, they have non-human traits. An early pygmy race cannot be the sole cause of belief in fairies. Traits of elfin beings are also those of supernatural groups with no human ancestry.

The fairy creed suggests animistic or pre-animistic ideas attached now to groups of imaginary beings, now to races viewed traditionally. Man regards the beings of his belief as like himself. There has been interaction between animistic beliefs in imaginary beings and traditions of earlier races regarded more and more from an animistic point of view.

Mr. I. C. Peate.—*Welsh folk culture.*

Welsh culture is essentially a peasant culture, and is based to a large extent upon love of craftsmanship. The craftsmen have always been considered the pillars of the rural society, and their craft is a tradition handed down from father to son through countless generations. A case in point is that of the wood-turners, who still produce wooden utensils of designs strongly reminiscent of prehistoric prototypes from, e.g., the Swiss lake shore dwellings. In the same way, the Welsh quilters work upon patterns which revert to medieval times, if not earlier, while many of the customs associated with carpentry, etc., are almost certainly of pre-Christian origin and may be compared with similar practices in Brittany. The same emphasis upon craftsmanship is to be noticed in the spiritual life of the people. Poetry has been looked upon as primarily a craft practised by a select class of bards who had to conform to strict regulations and undergo set tests. The development of the Welsh strict metres affords an interesting study in literary craftsmanship of an extremely high order. In post-Reformation times this love of craftsmanship found expression in (amongst other things) the perfection of pulpit oratory and in the development of the *Eisteddfod* as a venue for folk expression.

Dr. A. H. Smith.—*A survey of Yorkshire place-names.*

Wednesday, September 7.

Mr. O. Davies.—*Mining in Greece in pre-classical times.*

The paper makes an attempt to collect our knowledge on the sources of gold, silver, copper, tin and iron in Greece in the Bronze and early Iron Ages. It embodies a number of the author's own discoveries in this field on Greek soil, and also investigates how far these metals at various dates were imported from abroad. Some attempt is also made to discuss the methodology of the subject, particularly in regard to testing the source of ancient specimens of copper by means of the impurities they contain.

Mr. M. E. L. Mallowan.—*The prehistoric civilisations of Nineveh. British Museum Excavations, 1931–32.*

During the season 1931–32 Dr. Campbell Thompson, Director of the British Museum Expedition to Nineveh, financed by Sir Charles Hyde, entrusted me with the task of making a prehistoric sondage of Quyunjik. Mrs. Campbell Thompson and my wife assisted us in drawing the pottery.

We dug down through no less than 92 ft. to virgin soil. Of the total depth, 72 ft. represented the prehistoric period, an accumulation probably greater than any yet dug in the Middle East.

Our classification of the material comprises five distinct cultures: Ninevite 1–5.

Ninevite 5.—The latest culture; wheel-made painted pottery, remarkable incised pottery, Sumerian seal impressions, *c.* 3000 B.C.

Ninevite 4.—Erech red slip ware, seal impressions of the Jemdet Nasr period, *c.* 4000 B.C.

Ninevite 3.—Infant burials in urns, grey burnished pottery, seal impressions with exquisite animal drawings, earliest Ninevite examples of metal.

Ninevite 2.—Brilliant painted pottery in three colours on a burnished slip. These show affinities with the early ware of Carchemish and Tall Halaf, but the pottery from the latter site is probably a late stage of a development not found at Nineveh. The earlier stages bore affinities to the Samarra ware.

Ninevite 1.—Coarse plain and incised ware, cannot be placed much later than 5000 B.C.

SECTION I.—PHYSIOLOGY.

No meetings of this Section were held, in view of the XIVth International Physiological Congress at Rome.

SECTION J.—PSYCHOLOGY.

Thursday, September 1.

DISCUSSION on *The interim report of the committee on the reliability of the criteria used for assessing the value of Vocational Tests.* (Mr. E. FARMER.)

JOINT DISCUSSION with Section A (Mathematical and Physical Sciences, *q.v.*) on *The quantitative relation of physical stimuli and sensory events.*

AFTERNOON.

(Section meeting in two divisions.)

Division 1.

Dr. J.W. COX.—*Some experiments in formal training in the acquisition of skill.*

(1) *The problems.*—The 'transfer' problem is generally stated: 'How far does the training of any mental function improve other mental functions?' The answer may depend on (1) the kind of 'training,' which may vary from mechanical unaided repetition ('practice') to skilled instruction ('training' proper), (2) the function trained, (3) the relation of (2) to the 'other' function, and (4) the *modus operandi* of the 'transfer.' The experiments were planned to examine these problems in the field of manual assembly operations.

(2) *General method.*—I. *The 'practice' experiment.*—(*a*) All subjects were tested initially on a number of manual operations of varying complexity. (*b*) They were then divided into groups, each of which practised daily a different operation. (*c*) On completing their 'practice' all were re-tested as in (*a*). A further 'control' group did (*a*) and (*c*), but not (*b*).

II. *The 'training' experiment.*—The same procedure was then followed by a new group, with the exception that (*b*) now took the form of 'training' based on introspective analysis of the former 'practice' and of approximately the same length, and a further period of 'practice' at another operation followed (*c*).

(3) *Subjects.*—Experiment I. *'Adults':* 33 practisers, 17 controls; *Schoolboys:* 40 practisers, 38 controls. Experiment II. *'Adults':* 36 trainees, 18 controls.

(4) *Results.*—Graphical and statistical examination of scores indicated a 'transfer' effect in II, but nowhere in I. Trained subjects also did better than controls of equal initial ability in the subsequent 'practice,' both as regards 'ability' and 'rate of progress.'

(5) Discussion on the interpretation and significance of the results in relation to the above problems.

Mr. H. E. O. JAMES.—*The estimation of the directions of sounds.*

Dr. J. D. SUTHERLAND.—*Quickness and intelligence.*

The use of time-limit tests with instructions to work at high speed has raised important questions—viz. the validity of such measures as measures of intelligence, and the related problem of a factor of quickness existing independently of intelligence. Previous work shows that the time-limit does not invalidate the measure. On the second question evidence is conflicting, but data are presented showing that such a factor does not exist in any noteworthy amount.

Division 2.

Dr. F. W. Edridge-Green, C.B.E.—*The relation of the classification of the colour-blind to the tests for colour-blindness.*

The classification of mankind according to the number of colours seen in the spectrum—namely, heptachromic, hexachromic, pentachromic, tetrachromic, trichromic, dichromic, and absolutely colour-blind—is a very real classification and does not involve any theory. In addition we have those with a defect of light perception—namely, shortening of the red or violet end of the spectrum or defect in light perception of any portion of the spectrum. These defects are quite distinct from those in which the luminosity curve is normal. For practical purposes we are only concerned with the dichromic and trichromic—namely, those who see two or three colours in the spectrum respectively, and those who have shortening of the red end of the spectrum, preventing them from seeing a red light at the requisite distance.

A properly constructed lantern and spectrometer are perfectly efficient tests, especially when combined. This applies to all grades of colour vision, even a comparison between the normal and supernormal.

It is obvious that a man cannot pick out a colour which he cannot see, neither will he be able to recognise the colour of the light when shown in the lantern.

Mr. W. O'D. Pierce.—*Individual differences in colour discrimination.*

The National Institute of Industrial Psychology, at the request of a colour printing firm, undertook the investigation of individual differences in colour discrimination. An account of the preliminary work has been given by Mr. Hudson Davies in *British Association Report* (1928), p. 606. The colour test described has been given to over 400 individuals; of whom 147 were experienced colour workers, 81 were without colour discrimination experience, and 40 worked under unusual dark room conditions.

The results on the test show that the experienced workers always give better *average* results than workers without colour experience. A high correlation was found between the ranking on colour discrimination and results on the test for industrial colour workers. Dark room experience was found to lower the colour discrimination of the worker. Previous training in discrimination was found to aid workers in carrying out the test. The results show that although experienced colour workers do better on the test, the colour discrimination of many of these workers was much lower than the discrimination of the best untrained workers. The workers tested were drawn from the artificial silk, cotton, wool, and colour printing industries. The results obtained show that the test can be used to select workers to meet the varying requirements of these different industries.

The test indicates the following types of individual colour differences: (*a*) Differences in total colour discrimination for red, yellow and blue colours; (*b*) Differences in the score on each colour series with the same total colour discrimination; (*c*) Differences in the variations made on repetition of the test: some subjects improve steadily, other subjects vary without improvement and some subjects give relatively constant scores;

(*d*) Variations in the after-image responses of different individuals to colour stimulation. The after-excitation effects were shown to lower the colour discrimination of some subjects.

Dr. M. Collins.—*Variations of colour memory with wave-length.*

A series of experiments has been carried out over a period on colour memory. Colours of different wave-length, ranging over the entire spectrum, were learned and tested at intervals for immediate and permanent memory. Difficulties in learning were encountered at various wave-lengths. If the results are graphed, the graph shows a peak of difficulty beginning at λ 670 and rising higher at λ 660, a greater peak about λ 545 with its summation at λ 535, and a third smaller peak in the region of blue. Representative colours in the red, green, blue and yellow regions were also tested under conditions of dark adaptation, the eye being dark-adapted (*a*) for five minutes, (*b*) for thirty minutes.

Friday, September 2.

Dr. W. Brown.—*Suggestion, hypnotism and the will.*

The contrast between will and suggestion is brought to a point in the so-called law of reversed effort—' Where the will and the imagination are in conflict, the imagination always wins.' In this statement the word ' will ' must refer to ' effortful wish,' rather than to the completed act of will, and it is found that suggestion treatment can often strengthen will-power by contributing to an adequate control of the imagination, enabling the individual to envisage and imagine success with an adequate degree of vividness. Autosuggestion, in a state of mental and physical relaxation, can in some cases bring about a remarkable facilitation of the will-act, followed by permanent effects. This is due to its influence on deep-seated springs of action in the subconscious.

In a still more striking way hypnotism may in certain instances reorientate subconscious psychical forces to produce a transformation of character and a corresponding enhancement of will-power in certain directions.

Prof. R. H. Wheeler.—*A comparison of Gestalt with other modern trends.*

Part I deals with the historical background of *Gestalt* psychology, emphasising the reasons, both theoretical and experimental, why a revolution is occurring in the science.

Part II contrasts *Gestalt* psychology with associationism, conation psychology, Freudian psychology, neogenetic psychology, self-psychology, and behaviourism. In this section, also, it is explained why *Gestalt* psychology has been so universally misunderstood and, therefore, misrepresented by its critics.

Part III contains a brief summary of the principles of the new psychology, and an effort to correlate it with developments among other sciences, including physics, general biology, physiology, neurology, and social science. Many modern writers are sensing a new era in human thought which will express itself in the recovery of orthodox scientific and social theory from its present chaos. *Gestalt* psychology is presented as one phase of a new enlightenment, going back in part, but not wholly, to the point of view of the ancient Greeks.

Mr. R. Knight.—*How animals behave.*

Most people believe that some animals, like dogs, cats, horses, elephants and monkeys, have minds of a sort. But this belief is a precarious inference, not a fact which we directly observe. Scientists, like Köhler and Lloyd Morgan, who attempt to justify it, usually argue, not from physiological similarities between men and animals, but from observations of animal behaviour. They urge that some of the responses of animals to new situations, and to training, are such as could arise only from mental activity. In this way Köhler tries to show that chimpanzees possess 'insight,' and Lloyd Morgan to persuade us that some animals enjoy not only sensation and perception but also retrospection, reflection, and forethought. This method of reasoning, however, is full of pitfalls, and a critical examination of the crucial examples put forward by those who believe in animal minds makes it plain that they are inconclusive. And, on the contrary, recent experiments in the training of animals, carried out in the Department of Comparative Psychology in Aberdeen University, showed once again how comprehensive trial-and-error is in animal behaviour, how large a part is played by conditioned reflexes, how adequate is the Pavlovian thesis, and how easily animals can acquire an entirely undeserved reputation for intelligence and other mental characteristics.

Afternoon.

(Section meeting in two divisions.)

Division 1.

Joint Discussion with Section L (Educational Science) on *Industrial psychology and psychological selection in York* (Dr. V. Moorrees; Dr. Northcott; Dr. C. W. Kimmins; Sir Richard Gregory, Bart.) :—

Dr. V. Moorrees.—*Some aspects of psychology as applied at the Cocoa Works in York.*

Dr. Northcott.—*A statistical note on the results of psychological selection at the Cocoa Works, York.*

During the years 1923–31 inclusive, 1,287 individual girls have been engaged by Rowntree & Co., Ltd., after psychological tests. Of these, 122 or 9·5 per cent. proved inefficient and were dismissed. Analysing these 122, we find 58 were engaged on the responsibility of the Employment Department, without the concurrence and in some cases against the advice of the psychologist. The remainder were recommended but proved to be failures, 21 of them on grounds mainly of character and temperament, the others being straight contradictions between forecast and result. Before the application of psychological tests, 19·5 per cent. were proved, on the experience of 2,002 girls engaged in 1919–22, to be misfits. Psychological selection has practically halved the number of misfits, and, judged purely by degree of variance between forecast and workroom results, has been right in 95 per cent. of instances.

Mr. J. A. Fraser.—*Incentives to learning an industrial process.*

A study was made of five groups of workers engaged in learning a pattern-assembling process under industrial conditions. The groups commenced learning at different times, and were subjected to different conditions of incentive.

Data were obtained relative to the effect upon rate of learning of :

(*a*) a time-rate basis of payment ;
(*b*) an appeal made to the workers for increased output ;
(*c*) a monetary reward paid to one worker who responded to the appeal by increasing output by 40 per cent. ;
(*d*) the introduction of a piece-rate system of payment ;
(*e*) the age and previous earnings of the workers.

The following conclusions are suggested :

(*a*) that, as an incentive to learning the industrial process concerned, a time-rate basis of payment was ineffective ;
(*b*) that an appeal elicited a favourable response from one worker only ;
(*c*) that anticipation of a monetary reward did not produce a favourable response from all workers, nor was a favourable response always immediate ;
(*d*) that the introduction of a piece-rate system of payment produced immediately a favourable response from most workers ;
(*e*) that the effectiveness of an incentive was, to some extent, dependent upon the age and social responsibilities of the workers.

Division 2.

Mr. R. J. Bartlett.—*The difference threshold for lifted weights.*

Working with arithmetical and geometrical series of weights by methods of fractionation, ranking and standard comparison, it was found that :

(1) The nature of the field is of prime importance. Actual results from small containers differ greatly from those from large containers weighted similarly, but obey the same laws.
(2) Apparently, for any given set of containers uniform in size, shape and appearance, there is a zone of weight to which we are accustomed and adapted. In this zone Weber's law holds.
(3) The threshold is a summation of ' constant error ' and ' scatter error.'
(4) Outside the ' Weber zone ' the ' constant error ' is the more important factor.
(5) The ' constant error ' is a regression towards a value, within the ' Weber zone,' coincident with the ' expected weight ' of the given container.
(6) With practice the regression diminishes and the ' Weber zone ' extends.
(7) The law of regression, using geometric units, is of the form $y=cx^3$, where y is the regression, x the deviation of stimulus from the datum value of (5), and c a constant.
(8) This cubic law holds for published results of the lower values for brightness, sound intensity, and pitch.
(9) The ' scatter error ' about the ' best equal value ' approximates to Weber's law, but would seem to decrease slowly as the stimulus scale is ascended.

Dr. J. O. Irwin.—*A critical discussion of the single factor theory.*

The theory of the single General Factor (Spearman's ' g ') has been used extensively in the field of mental tests. While the vanishing of the ' tetrad differences ' is a necessary and sufficient condition for the existence of a single general factor, three theoretical difficulties arise. The first is the difficulty of the sampling problem, but this is not discussed in the present paper. The second difficulty is that the condition that the ' tetrad differences ' should vanish is not sufficient to determine ' g ' uniquely. Some experimental work is given to show the effect this would be likely to have in practice. The third difficulty is that if new test scores are formed by linear combinations of the old, even if the ' tetrad differences ' vanish for the new scores, the latter will not necessarily lead us to the same value of ' g ' as the old. Those linear transformations for which ' g ' is invariant should have a particular psychological importance.

Dr. S. J. F. Philpott.—*An approximation to a theoretical curve of output.*

It has been suggested by the present writer (' Fluctuations in Human Output,' *B.J.P. Mon. Supp.*, 1932) that the curve of output can be expressed as the sum of a large series of waves. Necessary conditions seem to be that the periods concerned shall be whole number multiples of a common unit, and that the waves converge on a common trough somewhere near the origin of the curve.

In arriving at an approximate outline for such a curve, waves were assumed of periods 2 to 360 times the common unit, inclusive. Amplitude measures were, however, not calculated in the ordinary way. With so large a number of waves, it seemed sufficient to assume that the mean amplitude over any given short length of curve should be inversely proportional to the number of waves therein coming to the centres of troughs.

Comparisons between the curve so obtained and actual output curves show that there are definite points of resemblance.

Sunday, September 4.

Visit to the Retreat Mental Hospital.

Monday, September 5.

Presidential Address by Prof. B. Edgell on *Current constructive theories in Psychology*. (See p. 169.)

Prof. W. McDougall, F.R.S.—*A third report on a Lamarckian experiment.*

Since my second report, made in 1929, the stock of rats trained to a specific task has shown further increase of facility, the thirtieth generation making in the curve of training twenty errors per rat, where the ancestral stock made 148 errors. This report is mainly concerned with experiments designed to test two questions: (*a*) Can this increased facility be due to ' social ' transmission ? (*b*) Can it be due to favourable selection ? The experiments of the former group are of three kinds: (1) omitting training of one or more generations; (2) rearing under foster-mothers; (3) cross-breeding females of untrained stock with males of trained stock. The latter experiment consists in practising strongly adverse selection on eleven generations during training. Facility continues to increase under training in spite of adverse selection.

Dr. T. G. Maitland.—*Disorientation and vertigo.*

Tuesday, September 6.

Dr. E. Miller.—*Temperamental differences in the behaviour disorders of children.*

It is important in the study of behaviour in children to determine what is due to the emotional disturbance and what is due to the constitutional peculiarities of the child. Every child is born into the world with a temperamental bias, which colours its responses to life and its situations.

Apart from this general consideration it is necessary to discover who are the candidates for the varieties of behaviour disorders—that is, whether subjective or neurotic disorders are found amongst one or other temperamental groups or types, and whether delinquency occurs in those with a specific temperamental make-up. A research is described which attempts to discover whether descriptive clinical categories agreed with the findings during test situations of temperamental peculiarities. Mobility, prudence, and persistence were taken as temperamental types of reaction appearing from a study of the history of a case and from the behaviour during tests situations (Binet Simon and Performance Tests). It was found as a result of observations and scoring during test periods that age correlated poorly with mobility, but well with prudence and persistence. Further, that prudence and persistence correlated with one another well, but mobility less well with prudence and persistence. While there was a general agreement with these test period findings and the clinical investigations, there was room for the working out of tests for temperament of a more or less quantitative type based upon clinical observation, which would show up basic temperamental endowment independent of the specific emotional disturbances.

Miss L. G. Fildes.—*The relation between educational backwardness and behaviour difficulties in children.*

Children who exhibit markedly antisocial or asocial behaviour are apt to suffer from educational backwardness (i.e. to be more behind in their school work than their mental ability warrants) much more than socially adjusted children. Clinical examination of over a thousand cases of problem children reveals backwardness in over 50 per cent. of the cases.

Attempts to analyse the reasons for this situation suggest two main types of relationship between backwardness and difficult behaviour :

(*a*) Cases in which the backwardness itself, determined by environmental factors, is the cause of unacceptable conduct ;

(*b*) Cases in which the backwardness is only one form of maladjustment, and is not its main determinant.

Suggestions for the prevention and handling of backwardness rest on a realisation of the causative factors in any particular case.

Dr. C. S. Myers, C.B.E., F.R.S.—*Recent evidence of the value of vocational guidance.*

Nearly every civilised country is adopting 'improvements' in vocational guidance, founded on scientific experiment and systematic method. But hardly any of those countries which have introduced these 'improvements' have taken steps to ascertain and to demonstrate exactly how far they are really superior to the older, more haphazard methods. In Great Britain more determined attempts have been made than elsewhere to fill this important gap in our knowledge. Eight investigations have recently been conducted, and are here considered—seven of them wholly or conjointly by the National Institute of Industrial Psychology, three of them incomplete, and seven of them with the express object of ascertaining the value of the newer methods of vocational guidance as compared with the older. In three of these eight investigations 'control' groups were formed, consisting of individuals who received only the *current* methods of vocational guidance. These were followed-up in their after-careers and compared with the results of a similar follow-up of strictly comparable 'experimental' groups who had been vocationally guided according to the *newer*, more systematic, more scientific methods. Whether control groups were formed or not, comparisons were also made between those persons who took and those who rejected the advice received. The criteria used in these comparisons included (*a*) the number and duration of the posts occupied by those advised during the follow-up period, (*b*) their degree of satisfaction with their work, (*c*) the degree of their employers' satisfaction with their work, (*d*) their wages earned, etc. Five investigations relate to elementary schools, two to public and other secondary schools, one to a junior technical school and a technical college.

The numerical tabular data, obtained from these eight investigations and presented in this communication, afford striking evidence of the value and vast superiority of the *new* methods of vocational guidance. Indeed, in several instances the average results of the *current* methods of guidance employed in this country appear to be more favourable when the advice received is rejected than when it is followed.

Dr. A. Macrae.—*Demonstration of modern vocational guidance methods.*

Dr. G. H. Miles.—*Some psychological problems in market research.*

Afternoon.

Dr. Ll. Wynn Jones.—*The prediction of common reactions as a psychological method.*

Studies of free association by means of the Jung or Kent-Rosanoff word lists proved useful in the diagnosis of conduct. The former is intended for locating complexes, the latter for ascertaining the frequency of unusual associations when care has been taken 'to avoid such words as are especially liable to call up personal experiences.'

In the present preliminary study the Kent-Rosanoff list was employed and the instructions were radically modified. The subjects on hearing the stimulus-word were to write the word which they considered would be given by most individuals. The results of this modification are: (1) The test may be administered as a group test; (2) Inhibitions due to complexes are reduced so that the recording of the reaction-times may be discontinued, a procedure which is questionable in the Kent-Rosanoff test; (3) Various methods of marking were tested and there were available for comparison three scales by Leeds graduates: Verbal Tests of Intelligence (Tomlinson's West Riding Scale), Gowda's Non-Verbal Tests of Intelligence, and Karve's Fluency Tests; (4) There is a need of frequency tables for special use with school children, irrespective of whether the Kent-Rosanoff or the present procedure of asking the subject to predict the reactions of his fellows is employed. Especially is this the case with 'problem' children.

Prof. W. McDougall, F.R.S.—*A new statement of the native bases of intelligent and instinctive behaviour.*

These two closely allied questions are still very obscure and controversial. We may distinguish broadly two kinds of units of innate organisation underlying all instinctive capacity—namely, on the one hand, propensities, and, on the other hand, abilities, some predominantly cognitive, others predominantly executive or motor in function. Abilities are merely 'machinery' without driving power; they become differentiated and multiplied through all learning processes. The position of any creature or species in the scale of intelligence is in the main a function of the number and variety of its innate abilities; the richer its endowment of native abilities, the more adaptable will be its behaviour.

The lower animals have few abilities, and each ability is 'geared' closely to some one propensity; such an innate and fixed conjunction of an ability and a propensity constitutes in the strictest sense an 'instinct.'

In the higher animals more numerous native abilities are linked more loosely to the propensities, so that any propensity may activate any ability. In man this is carried to a further point, and the slow maturation of his native abilities obscures their nature and renders the expressions of his native propensities highly unspecific and variable.

Dr. R. W. Pickford.—*Some observations on reading compound passages.*

SECTION K.—BOTANY.

Thursday, September 1.

Dr. T. W. Woodhead.—*Yorkshire plant ecology.*

Yorkshire provides a greater variety of habit conditions than any other county, and consequently has a very varied flora. The vegetation will be considered in relation to the following natural divisions. In the west, the Pennine Uplands, which include Upper Teesdale with Mickle Fell rising to 2,596 ft., the calcareous North-Western Dales, and the Millstone Grit and Coal Measures area of the Middle and Southern Pennines. The Permian ridge extending from north to south, and cut through by the rivers from the western dales, and its significance in plant migration. The great Central Plain, overlaid by glacial and post-glacial deposits, and to the north-east the Oolitic Hambleton and Cleveland Hills and the eastern dales. To the south the Vale of Pickering, and beyond the chalk wolds and wold dales; to the south-east, the gently undulating Plain of Holderness covered by glacial and alluvial deposits; and a coast-line ranging from precipitous cliffs to sand dunes and mud flats. The distribution will be considered of northern and southern species which reach their limit in Yorkshire, also the effect of the maximum glaciation and that of the last Ice Age on the history of the vegetation.

Dr. G. E. Du Rietz.—*The problem of bipolar plant distribution.*

In New Zealand, Australia, and southernmost South America isolated populations are found of several boreal species, some of which occur also on high tropical mountains. Analogous types of distribution are found also in many genera and higher taxonomic units. Long-distance migration under present geographical conditions cannot explain all these bipolar populations, nor can the theory of transtropical migration during the Pleistocene glaciations, since fossil evidence shows that many bipolar distributions are much older. We must obviously go back at least to the more continuous connection between boreal and austral floras, probably formed by the high mountain-ranges of the Tertiary period. Some bipolar populations show evident traces of a transtropical connection along the American Cordilleras, others across the Malayan archipelago, still others along both these transtropical bridges. The occurrence of a bipolar population both in the Australasian and the Magellanic regions is no proof that both transtropical bridges have been used by this population, since there is ample evidence also of a trans-antarctic connection. Though there is an evident relation between bipolar distribution and the Alpine Orogen, or the great Mesozoic-Tertiary fault system, there are also facts suggesting that epeirogenetically uplifted highlands bordering the alpine geosynclinales may have formed transtropical bridges of still greater importance for the development of the present bipolar populations.

Mr. T. K. Rees.—*Algal associations of a salt marsh.*

Whilst investigating the general ecology of marine algæ in the Lough Ine district, Co. Cork, a close study was made of a small salt marsh situated at the extreme south-west corner of the lough. The marsh, which consists of eight islands separated by mud, is peculiar in that there is a sudden transition from a Zosteretum to a general salt-marsh association (9 sp.) limited by a Juncetum. The following algal communities occur :

1. *Pan association* subdivided into (*a*) Fringing benthos ; (*b*) Plankton ; (*c*) Loose-lying colonial community ; (*d*) Myxophycean community of decaying vegetation.

2. *Scattered association of Salt-marsh Fuci*, including limicolous forms of *F. vesculosus*, *F. spiralis* and *Pelvetia*.

3. *Catenella-Bostrichia association*, growing on roots or rhizomes or colonising bare mud. Rarely pure, frequently mixed with—

4. *Gelatinous Myxophyceæ association*, widely distributed, especially on or between marsh Fuci and Catenella-Bostrichia.

5. *Association of Filamentous Algæ* on bare soil, subdivided into a Myxophyceæ sub-association dominated by Oscellatoria-Lyngbya, and a Chlorophyceæ sub-association dominated either by *Rhizoclonium implexum* or *Enteromorpha torta*.

6. *Rivularia association*, either pure or merging into 2, 3 and 4.

7. *Algal epiphytes on Zostera*.

8. *Vegetation of vertical banks*, with four distinct zones : (*a*) Oscillatoria-Ulothrix ; (*b*) Vaucheria ; (*c*) Vaucheria-Rhizoclonium ; (*d*) depressions and overhanging banks dominated by *Catenella repens*.

The main ecological factors appear to be biotic.

Dr. A. Raistrick and Dr. K. B. Blackburn.—*Peat investigations in the north of England.*

These investigations so far have followed three main related lines: First, a statistical investigation of tree pollen caught and preserved in the peat, used as evidence of the phases in post-glacial afforestation of the area as a whole ; secondly, the examination of individual peat deposits and bogs with the object of elucidating their botanical history, using the pollen of plants that have grown *in situ*, and the plant remains preserved in the peat.

The deductions from the tree pollen work provide a time-scale which can be applied to the individual peat deposits. The stratigraphy and distribution of the peat areas make possible a linkage with late glacial and post-glacial physiographic conditions. The peats so far examined include hill-top peats, woodland peats, pond peats, and shore-line peats. Our results agree well both among themselves and with the results obtained in similar work on the Continent. It is not proposed in this paper to discuss the stratigraphical aspect of the work.

Mr. N. Woodhead and Mr. L. M. Hodgson.—*Pollen analysis of Snowdonian peats.*

Detailed analyses of seventeen peats situated in the Nant Ffrancon valley and its tributary corries have been made. The peats vary considerably in depth and extent, but show a homogeneous texture with 'forest' layers in most of the upland areas. They show an abundance of tree pollen, and their pollen diagrams agree in the main with those established for the Pennines. The deepest peat in Cwm Idwal has *Pinus* and *Betula* dominant, in the lowest layer so far investigated, with *Alnus* and *Corylus* in association. *Alnus* ousted *Pinus*, but soon died out completely, giving place to a *Pinus* association remarkable for its high frequency (71 per cent.). This maximum occurred, according to Scandinavian authorities, in the late Boreal time, the upper limit of which is marked by decreasing *Pinus* and increasing *Alnus*. The latter reached a second maximum in the moist Atlantic period, but *Pinus* seems to have lingered in Caernarvonshire long after it had died out in the North of England. As on the Pennines, *Betula* supplanted *Alnus* in the drier conditions of the sub-boreal period, but *Alnus* remained abundant in the wetter parts of the valley.

Corylus appears more or less uniformly at all layers in all the peats. *Quercus* pollen is uncommon. In view of the present distribution of *Fraxinus* in woods near the sea, it is interesting to note that its pollen has been found only in the lower-lying peats near the coast.

Historical records show that the Forest of Snowdon was laid waste in the reign of Elizabeth, and the valley is now almost treeless.

Afternoon.

Excursion to Askham Bog.

Friday, September 2.

Joint Discussion with Section D (Zoology) on *Biological balance in fresh water* (Dr. W. H. Pearsall; Dr. W. Rushton and Mr. H. D. Slack; Dr. R. W. Butcher; Mr. R. S. A. Beauchamp and Mr. P. Ullyott; Dr. L. Lloyd; Prof. F. Balfour-Browne; Dr. G. S. Carter; Mr. J. T. Saunders; Prof. H. S. Holden) :—

Dr. W. H. Pearsall.—*The water-algal balance.*

Dr. W. Rushton and Mr. H. D. Slack.—*Observations on the relationships between the flora and fauna in the upper part of a chalk stream.*

The paper records the results of weekly and bi-weekly samplings from selected stations in a four-mile stretch of the River Test (Hampshire) over a period of eighteen months, with a view to gaining information which will lead to an improvement of the fishing conditions.

The work has been concerned mainly with the relationships of the micro- and macro-flora to the fauna, especially the Trichoptera, Ephemeridæ, Mollusca, and Gammarus, both as sources of food and for purposes of protection.

Methods tending to the encouragement or discouraging of certain forms of life are being studied experimentally. These are discussed, and the further lines of study they suggest are indicated.

Dr. R. W. Butcher.—*The effect of organic effluents on the biological balance in running water.*

Four characters of organic sewage effluents may be considered to react on the biology in running water: (1) Deposition of fine silt; (2) deoxygenation of the water; (3) bringing in of nutrient matter; (4) the increase or introduction of salts that affect the biology in other ways than nutrition.

Silt is trapped by masses of plants in swift waters, or deposited in slow waters. This deposit increases the fertility of the river-bed, and helps locally with deoxygenation of the water.

Deoxygenation of the water affects the fauna much more than the flora. Serious deoxygenation exterminates most of the animals except chironomids and tubificids. Lesser oxygen deficiency increases the fauna of clean and foul mud and reduces considerably the fauna of stony stretches. Although deficiency of oxygen also kills fish, it is not known what is the minimum amount of oxygen in which a fish can survive.

The extra nutrient matter supplied by organic effluents has a very marked effect on the flora. Sewage fungus is abundant in waters rich in organic matter. Certain algæ, such as *Cladophora glomerata*, *Navicula radiosa* and *Cocconeis placentula*, are very abundant when organic matter is present in smaller amounts.

Other salts contained in sewage that affect the flora and fauna are chlorides, sulphides and calcium salts.

Summarising, organic effluents, when dilute, alter the character of the flora and fauna, but at the same time increase the volume. Especially do they cause the growth of the sewage-fungus community and the advent of chironomids and *Tubifex*. If still stronger, they deprive the water of oxygen, reduce the fauna and increase the volume of sewage fungus. In extreme cases polluted waters have hardly any dissolved oxygen, but show a heavy growth of sewage fungus and a fauna dominated by *Chironomus* and *Tubifex*. When an organic effluent ceases partial recovery is rapid, but absolute recovery probably takes some years, especially with water-borne fauna.

Mr. R. S. A. Beauchamp and Mr. P. Ullyott.—*Factors affecting the distribution of Planarias.*

In England the commoner species of stream-living Triclad are *Planaria alpina* and *Polycelis cornuta*. Both these animals are stenothermal for cold, and at no stage in its life-history can either resist the effects of drying. Consequently they are only found in streams which have a permanent supply of water.

In hard water *Planaria alpina* and *Polycelis cornuta* occupy successive stretches of the uppermost reaches of the stream. This zonation, which is controlled by temperature, indicates the presence of calcium, since in soft water it does not occur.

Of the two species *Planaria alpina* is the more sensitive to the organic content of the water, so that this species is sometimes absent from streams colonised by *Polycelis cornuta*. The reason for the absence of *Planaria* *alpina* is not its non-viability in such water, but because its behaviour changes under these conditions. The animal becomes persistently negatively rheotactic, and so is never able to colonise streams with an organic content above a certain value.

The presence of *Planaria alpina* may be taken as an indication that the supply of water is not only constant, but also of very low organic content.

Dr. L. Lloyd.—*Polytoma as an indicator of oxygen deficiency.*

Previous applications of the aerotaxis of certain micro-organisms as indicators of the oxygen tension in water have been by microscopic methods. The reaction here described, being macroscopic, has a more practical interest. The organism employed is obtained in culture in a medium heavier than and not readily miscible with water. A sample of the culture is placed in a narrow upright tube and the water to be tested is run on to this to a chosen height. The organisms gather in blanket-like formation at the junction of the fluids, and this mounts the tube at a speed which is influenced by the oxygen tension. *Spirillum* is present in the culture employed and accompanies *Polytoma* in the blanket. Nitrates and nitrites in the water cause a proportionate lag in the climb. Variations in the activity of the cultures prevent as yet absolute readings being obtained, and the test is read in relation to controls of a standard water. The test is thought to be a possible biological alternative to the Oxygen Absorption Tests as applied to contaminated waters, and is probably more selective in its action than the chemical reagents. Details of the technique are demonstrated and various tests set up which show the delicacy of the reaction. A grading of waters by means of the *Polytoma* reaction is contrasted with that obtained by their chemical analysis.

Afternoon.

Prof. S. G. Paine.—*Bacteria in relation to the decay of stone.*

During recent decades biology has been found to enter many fields where its influence was least expected. In soil chemistry it has helped to explain much of the phenomena which result in the conversion of rock into fertile soil, and now we find our building stones, though for the most part removed from conditions where bacterial action is possible, yet subject to destruction by soil bacteria in much the same way as the native rock. At the Glasgow meeting of the Association, R. M. Buchanan showed that bacteria were associated with decaying stone; Stutzer and Hartleb, in 1899, suggested that nitrifying bacteria may contribute to the disintegration of cement, and the nitrifying bacteria were believed by J. E. Marsh (1923) to be responsible for a considerable part of the decay of college buildings at Oxford. The present paper embodies the results of seven years' investigation of the problem of stone decay under the ægis of the Building Research Department of the Scientific and Industrial Research Board. Common air and water organisms are nearly always present in decayed stone in surprisingly large numbers. It has also been clearly shown that organic matter present in rain-water is sufficient to allow of the development of acid bacterial products which attack progressively the substance of the stone. The presence of nitrifying bacteria has been established, and perhaps most significant of all a new autotrophic bacterium capable of oxidising sulphides, sulphites and thiosulphates has been discovered. Much of the formation of the sulphate incrustations previously believed to be due to sulphur dioxide of the atmosphere will probably be found to be due to the action of these micro-organisms.

Prof. Dame HELEN GWYNNE-VAUGHAN and Mrs. WILLIAMSON.—*Variations in the formation of the fruit in the Ascomycetes.*

The fructification of the Ascomycetes may be homothallic or heterothallic in origin ; it may originate in a normal sexual process, or the sexual apparatus may have partly or wholly disappeared. In either case nuclei formed by the union of those from one or of two complementary mycelia may pass into the ascogenous hyphæ. The sheath may be formed from branches of a single mycelium, from branches originating separately from two mycelia, or from branches derived from a region where two mycelia have fused. Variations are present in the types of gametangia and of ascogenous hyphæ.

Mr. C. G. C. CHESTERS.—*An interesting Phycomycete associated with a diseased condition of Antirrhinum.*

The fungus described in this paper was obtained from the roots and stems of diseased Antirrhinum seedlings. The actual disease was caused either by *Rhizoctonia Solani* or by *Phyllosticta Antirrhini*, and this fungus was present as a secondary organism. Later it was obtained in quantity from nursery soil. Its exact systematic position is doubtful, but there is evidence that it occupies a position close to the Zygomycetes, in that its ' resting-spore ' is formed by the conjugation of two hyphal branches. The mature ' resting-spore ' is somewhat similar in appearance to that of one of the higher members of the Chytridiales, but so far no motile stage has been observed in the life-history. The normal means of reproduction is by the germination of intercalary spores. The mycelium produced in culture is white and forms a thick skin on the surface of the medium, from which dense aerial hyphæ arise. These bear numerous intercalary spores. Within the medium and in the neighbourhood of the inoculum nests of branched hyphæ give rise to structures which are here termed ' resting-spores.' When mature each of these consists of a thick-walled terminal spore borne on a thin-walled swollen stalk, which is attached to the mycelium by a branched hypha. So far the resting-spore has never been observed to germinate. The fungus grows well as a saprophyte in soil and can infect weakly or etiolated Antirrhinum plants.

Mr. A. H. CAMPBELL.—*Black lines in timber caused by Xylaria polymorpha.*

A preliminary attempt has been made to classify the black lines associated with wood-rots into groups, in order to provide a basis for research and to facilitate the statement of results.

The black lines formed in the substratum by the genera *Nummularia*, *Ustulina*, *Hypoxylon*, *Daldinia* and *Xylaria* comprise such a group.

The black lines formed by *Xylaria polymorpha* have been investigated morphologically and culturally and their actual formation has been observed. As a result the suggestion is made that the black lines are the marginal zones of entostromata in the substratum comparable to those occurring in *Diaporthe*.

An account is given of a *Xylaria polymorpha* black line superimposed upon the zone line formed by the attack of *Fomes applanatus* on beech wood.

Semi-popular lecture by Dr. E. J. BUTLER on *Tropical plant diseases, their importance and control.*

Saturday, September 3.

Excursion to Newtondale, Beck Dale, etc.

Sunday, September 4.

Excursion to Lake Gormire and Sutton Bank.

Monday, September 5.

PRESIDENTIAL ADDRESS by Prof. J. H. PRIESTLEY on *The growing Tree.* (See p. 185.)

Dr. R. N. ALDRICH BLAKE.—*The influence of nutrition on the relative root and shoot development of forest tree seedlings.*

The majority of plants, among them seedlings of five representative conifers and of *Casuarina equisetifolia*, respond to increase of the supply of nitrogenous salts by a decrease of relative root weight. There are indications that this generalisation may be extended and that relative root weight is depressed by an increase of the supply of all nutrients normally obtained from the soil. American work shows that plants with a high carbohydrate/nitrogen ratio have relatively heavy roots, and *vice versa.* Root-branching of Corsican pine seedlings is less dense the greater the supply of ammonium nitrate.

This response of the plant to nutrition can be explained readily on teleological grounds, but as yet there has been advanced no satisfactory analysis of the reaction along causal lines.

For the forester this reaction of the tree seedling to nutrition may be of considerable importance in connection with problems of manuring in forest nurseries.

Dr. L. CHALK.—*Multiperforate end-walls of vessel segments.*

Scalariform perforations are common among the less advanced woods, and are associated with long vessel segments and oblique end-walls. Reticulate-scalariform and foraminate perforations may be regarded as variations of the scalariform type.

Amongst the more highly specialised woods—e.g. in the Bignoniaceæ—there occurs a type of perforation which is superficially very similar and for which the term pseudo-reticulate is suggested. These perforations occur in only a few of the vessels, the others having simple perforations; the segments are very short and the end-walls are horizontal. Their reactions with stains are unusual. Two types can be distinguished. Their origin and function are discussed, and some suggestions made for revising the terminology applied to perforations.

Mr. B. J. RENDLE.—*The study of wood anatomy as a link between botany and forestry.*

The paper deals briefly with the development of wood anatomy along various lines, following the early descriptive period which culminated in Solereder's *Systematic Anatomy of the Dicotyledons.*

In studying the anatomical structure of wood, whether from the point of view of systematic botany, plant physiology, silviculture or timber-utilisation, it is necessary to distinguish clearly between characters which are due to the influence of environment (biological characters) and those which remain unaffected by variations in conditions of growth (inherent characters). Certain of the anatomical characters of wood are eminently susceptible to climatic and edaphic influences. Intensive research in wood anatomy is required to formulate correlations between silvicultural factors and the technical properties of timber, and to establish the systematic anatomy of wood on a sound basis. A recently formed organisation designed to advance the study of wood anatomy by international co-operation between interested persons and institutions is outlined.

Tuesday, September 6.

Dr. H. Bancroft.—*A contribution to the geological history of the Dipterocarpaceæ.*

A collection of fossil dicotyledonous woods from the slopes of Mount Elgon, an extinct volcano on the borders of Kenya and Uganda, contains a considerable proportion of specimens showing typically dipterocarpaceous structure, the outstanding features of which are secretory canals and heterogeneous, uni-, bi- and narrowly multiseriate rays.

The Dipterocarpaceæ are represented in Africa at the present day only by *Monotes* and *Marquesia*, two genera in which the wood-structure is divergent from that typically associated with the Dipterocarpaceæ, having (in the material so far examined) no secretory canals, and uniseriate rays only.

The Elgon fossils, which are apparently of late Tertiary age, are therefore of interest, as indicating a former distribution of the true dipterocarpaceous type, more extended than at the present time.

Prof. H. S. Holden.—*A fossil plant of doubtful affinities from Autun.*

The material of the plant described consists of small linear-lanceolate leaves with recurved margins, these being traversed by an unbranched tangentially flattened midrib composed of spiral tracheids. The stomata flank the midrib and are confined to the lower side. The leaves are believed to have a petiole with a monodesmic trace, circular in transverse section, the xylem of which consists wholly of spiral tracheids. The name *Bertrandia autunensis* is suggested as appropriate.

Dr. H. Duerden.—*Tracheidal variation in ferns.*

An examination of the xylem elements of certain fossil and living ferns shows that the pit-closing membrane is present between the pits on all the walls in *Metaclepsydropsis duplex*, *Diplolabis Römeri* and *Botryopteris cylindrica*. In *Stauropteris burntislandica* the membrane is absent between the pits on all the walls, whilst in *Pteridium aquilinum* it is absent from the pits on the oblique end-walls only. In *Osmunda regalis*, *O. cinnamomea* and *Todea barbara* the membrane is present between the pits on some of the walls, but the pits on many of the walls are true perforations, the closing membrane having disappeared.

Miss M. G. Ashton.—*The development, morphology and anatomy of the winter bud of Glaux maritima* L.

Glaux maritima L. perennates by a winter bud fixed by long storage roots, and arising as an axis of the second or third order. Such buds arise on *non-flowering* plants and seedlings, in the axils of lower leaves and cotyledons. They have one root and develop into either *non-flowering* plants with buds—axes of the second order—or, when strong enough, into *non-flowering* plants with horizontal axillary runners—axes of the second order—bearing triarch adventitious roots at their nodes, and axillary buds—axes of the third order. These give rise to flowering plants with stronger runners and buds. After the flowering of the plant, these buds produce three or four endogenous roots, and rotate until they are at right angles to the axis of the runner. Each bud receives two traces from the continuous xylem of the runner and has a prominent lateral bud in the axil of the lowest leaf, opposite to the region of attachment, which will form next year's runner. Cambium and phloem are abundant in the stem region, but there is little xylem. The roots are pentarch, with no root hairs or xylem plate. On development of the bud into a plant, the roots form xylem plates and triarch laterals. The base of the stem develops continuous xylem, which, higher up, gives place to eight discrete bundles, four cauline and four leafy.

Prof. J. Doyle and Mr. W. T. Saxton.—*Contributions to the life-history of Fitzroya patagonica J. D. Hook.*

Fitzroya, a Chilean genus with one species, is one of the rarer conifers whose development has not previously been worked out. Its general morphological relations with the Callitrinean forms lend particular interest to its study.

The megaspore mother-cells, formed early in autumn, are variable in number, but commonly numerous, although only one develops. The pollen tube growth is precocious, deeply invaginating the top of the female gametophyte while the latter is still in the vacuolated stage. The peculiarities in the 'endosperm' development of *Cryptomeria* as described by Lawson seem here to be repeated. The archegonial complex is rather loose and indefinite and lateral archegonia occur. The early pro-embryo completely fills the archegonium, walls being formed at the end of the second post-fertilisation division. Later embryo stages show considerable variation. In general, *Fitzroya* presents an interesting link between the strictly Cupressinean type and the Callitrinean type.

Some abnormalities in the stamens which seem to bear on the morphology of that structure in conifers are illustrated.

Afternoon.

Excursion to the Wolds, Pocklington, etc.

Wednesday, September 7.

Miss W. Parke and Dr. M. Knight.—*Life cycles of certain members of the Mesogloiaceæ.*

The problem of the 'over-wintering' of algal species described as 'summer annuals' has been investigated in the case of *Mesogloia vermiculata* Le Jol. and *Castagnea virescens* Thur. Cultivation of spores from unilocular sporangia have resulted in the growth of minute plantlets of ectocarpoid habit bearing plurilocular sporangia. The zoids from the latter may repeat the filamentous phase for some weeks or even months, but eventually, in the early spring, some of the plantlets produce plurilocular sporangia, the liberated zoids from which behave as gametes, fuse in pairs and give rise to a plantlet of disc habit from whose surface finally arise groups of upright threads whose interweaving re-establishes the macroscopic summer form. There has thus been demonstrated a microscopic phase which may serve to maintain the existence of the species during the winter and at the same time represent the alternate haploid gametophytic phase of the life cycle.

The results of culture experiments have been confirmed by careful collection of material in the open field throughout one complete year. Stages corresponding to those obtained in cultures have been obtained from the localities where the summer form of the plants is normally distributed.

Dr. E. Ashby.—*The physiology of hybrid vigour in maize.*

The aim of the experiments was to find a physiological interpretation of hybrid vigour in certain strains of maize. Populations of inbred lines, their reciprocal F_1 crosses, the F_2 and the F_3 generations were grown, and the relative rates of increase in dry weight or wet weight followed through the grand period of growth.

The F_1 hybrids in every instance showed hybrid vigour, and were therefore heavier than their parents. They did not, however, show any increase in relative growth rate, or efficiency index. The efficiency indices were, in fact, inherited from one parent, the higher efficiency index being dominant. In the F_2 and F_3 populations there was less hybrid vigour and the efficiency index segregated out.

Hybrid vigour was not due to increased efficiency index ; but was found to be nothing more than the maintenance of an initial advantage in embryo weight of the hybrids.

Reciprocal F_1 crosses exhibited different degrees of hybrid vigour, though they had the same efficiency indices. This too is due to an initial difference in their embryo sizes.

Dr. N. L. Penston.—*Some aspects of potassium distribution in plants.*

Dr. T. Whitehead.—*On the respiration of healthy and leaf-roll potatoes.*

Infection with the virus of leaf-roll has no *direct* effect on the respiration, in oxygen or in nitrogen, of potatoes at any stage in the life-cycle. Immature tubers, whether healthy or diseased, respire at a higher rate than do mature tubers after storage. After sprouting, the rate rises rapidly to a maximum in the young plant and falls gradually with tuber formation.

In comparing the respiration of healthy and leaf-roll plants at each stage it was found that the diseased immature tubers show a higher rate than comparable healthy ones, but this falls to the same, or slightly lower, level in mature tubers before sprouting. Whilst still in the sprouting stage the healthy plant shows the higher rate but, with the unfolding of the leaves, the rate of respiration of the diseased plant quickly exceeds that of the healthy and remains higher when tuber formation has begun. When, however, very young plants are allowed to assimilate, the healthy plant respires at a higher rate than the diseased until the latter accumulates a definite excess of carbohydrates in the leaves, after which the diseased plant again respires at the higher rate.

It is suggested that these differences can be correlated with the failure of autolysis in the infected seed-tuber, and the accumulation of excessive amounts of translocatory carbohydrates in the diseased foliage.

DEPARTMENT OF FORESTRY (K*).

Thursday, September 1.

CHAIRMAN'S ADDRESS by Mr. T. B. PONSONBY on *A system of forestry for the British Isles.*

British woodlands must be economic, beautiful, and they must hold game. The existing system of clear-cutting followed by replanting results in monotonous and unpicturesque woods, which are very inefficient as game reserves, and their value as an economic investment is decidedly doubtful.

The Selection type of forest is more beautiful and of greater sporting value. Its economic value only is in dispute and is here discussed.

In the hands of experts, the Selection wood can give returns, both as to quantity and quality, that are as good as, or better than, those yielded by the even-aged methods. The objection raised against the system by competent critics is not based on any sylvicultural insufficiency, but on the high standard of management required.

An outline is given of management suitable as the basis of large forests worked on the Selection system, and an indication given for the management of smaller areas.

It is very important to obtain some measure of natural regeneration which we, along with all countries which have adopted 'clear' cutting methods, have so unfortunately lost. It is only by natural regeneration that we can obtain trees suitable to each of our very varying districts. The agricultural analogy for the importation of exotic seeds does not hold good in that it is not possible to alter the soil conditions, both chemical and physical, in the forest in the same way as can be done in agricultural land.

DISCUSSION. (Mr. A. C. FORBES, O.B.E.; Dr. A. S. WATT.)

Mr. R. C. B. GARDNER, Secretary British Wood Preserving Association.—*Timber preservation on estates.*

The durability in service of oak and larch appears to depend to a great extent upon the conditions under which they have been grown, and it is not safe to rely too implicitly upon the reputation for durability which these timbers have acquired. Examples will be given which bear out this contention. Where supplies of these timbers have become depleted satisfactory use can be made, by adequate preservative treatment, of many timbers which are not naturally durable, such as birch, beech, alder, elm and poplar.

Treatment under pressure gives the best results, but eminently satisfactory results can be obtained in the open tank by the heating and cooling method. This method can be carried out also in a simple and inexpensive plant for the treatment of the butt-ends of fence posts, which will be fully described.

Statistics of the life in service of most of the home-grown timbers, both treated and untreated, and under varying conditions of soil and rainfall, are given, together with slides showing the forms of pressure, open-tank and butt-treatment plants, in use on estates in Great Britain. Creosote and water-soluble salt preservatives will be described, and their advantages and limitations for various classes of work will be indicated.

AFTERNOON.

Excursion to Castle Howard.

Friday, September 2.

DISCUSSION on *Exotic Conifers and the factors governing their introduction* (Mr. F. R. S. BALFOUR; Mr. A. C. FORBES, O.B.E.) :—

Mr. F. R. S. BALFOUR.—*Conifers in Scotland.*

Deals first with the two arborescent native species. In former days there were great forests of Scots pine in many Highland straths, notably in the Great Glen of Scotland, in Deeside and Strathspey. Yews are undoubtedly indigenous, of which there are great trees in most Scottish counties, often connected in fact or fancy with historical events.

Instances of tree-planting from the records of the early seventeenth century are given.

The first exotic conifer to be introduced was Norway spruce, followed by the Silver fir from Central Europe and early in the eighteenth century by the Tyrolese larch. At about that time coniferous trees from the New England colonies first made their appearance.

In the first half of the nineteenth century came the introductions from the Himalayas, Caucasus and other regions of the Northern Hemisphere of the Old World.

The expedition of David Douglas to the Pacific coast of North America in 1825 and following years was the most important event in the history of conifers in Scotland. Mention is made of the fine species introduced by Douglas and subsequently by other explorers from that region.

The value of the tree species introduced by other Scotsmen is discussed, the first being James Cunningham, who went to Amoy in 1698, and the last, George Forrest, who died in S.W. China in January 1932.

Mr. A. C. FORBES, O.B.E.—*The silvicultural value of exotics in Ireland.*

Down to the end of the seventeenth century the Irish forest flora was the poorest of any part of Europe, except possibly that of the far North. Great Britain received additions to her native flora during Roman and Saxon occupations, and trees like the English elm, Spanish chestnut, walnut, and sycamore, had become acclimatised and widespread in Britain before a tree was planted in Ireland.

Few, if any, broad-leaved species thrive better in Ireland than in Great Britain. In the case of conifers, the reverse is often the case. Conditions generally favour the growth of many Western American species. The Irish climate compares favourably with that of Wales, Cornwall, and Devonshire for producing Douglas fir, Sitka spruce, Tsuga, Thuya, Japanese larch, etc., but sea-winds off the Atlantic check the height-growth of many species at a comparatively early age.

Of the many species which can be grown in Ireland, only twelve or fourteen are of economic importance, and three-fourths of these are exotics. A serious problem which faces the forester is to decide where conifers should replace broad-leaved trees, and how far indigenous species should be replaced by exotics. In solving this problem diseases, hitherto unnoticed or disregarded, will probably receive increasing attention.

Dr. J. BURTT DAVY.—*The cricket-bat willow problem.*

At the request of the Forest Products Research Laboratories, an investigation into the systematy of the cricket-bat willow has been commenced by the author. Complaints had been received from growers that, after spending time and money on the production of willow timber, many sound trees were rejected by buyers, as unsuitable for bats.

Preliminary investigations showed that soil, soil-moisture, or climate could not be the cause of the trouble, since trees growing on the same soil, and alternately with trees accepted by buyers, were rejected, although perfectly healthy, sound and straight, and of the right size.

There were indications, however, that the differences in quality might be correlated with botanical differences. It was found that at least four different strains of *Salix alba* var. *cærulea* occur in plantations of cricket-bat willows.

Methods of cultivation are described. Attention is called to the need for further systematic and for genetical work, and for thorough practical tests of the timbers of the different strains, of both sexes.

The paper is illustrated by lantern-slides showing the habit-characters of the tree, the conditions of cultivation, and the catkin peculiarities of the several strains.

AFTERNOON.

Excursion to Ribston Hall Estate.

Saturday, September 3.

Excursion to Rievaulx and Gilling.

Sunday, September 4.

Excursion to the Forestry Commission, Allerston.

Monday, September 5.

(Meeting with Section K, Botany, *q.v.*)

Tuesday, September 6.

Miss M. M. CHATTAWAY.—*Tile-cells in the rays of the Malvales.*

Certain genera of the Malvales have rays containing a peculiar type of cell (' Ziegelsteinformige,' Moll and Janssonius) which has not been observed elsewhere. These cells are apparently the result of more frequent tangential divisions than the normal ray cell, and differ from the erect cells of heterogeneous rays in shape and position in the ray. They are devoid of contents and can be divided into two types. Type A, *tile-cells* two or more times as high as the procumbent cells ; usually not more than four cells correspond to one procumbent cell (radial section); conspicuous on radial and tangential sections, but not on transverse. Type B, *tile-cells* equal in height to the procumbent cells ; often eight to twelve cells corresponding to one procumbent cell (radial section); conspicuous on radial and transverse sections, but not on tangential.

An attempt has been made to follow the development of these cells from the cambium in fresh material, and to discover their function in the rays of the Malvales. Comparison with genera from other families in which rays without procumbent cells occur shows that their cells differ in structure from tile-cells, and probably also in development and function.

Dr. W. B. R. Laidlaw.—*The enemies of the Elm Bark Beetle and their significance as a bionomic control.*

This paper gives a brief résumé of the Elm Beetle, its appearance, life-history and type of damage. The causes of its attack are discussed more fully on the basis of its being a primary or a secondary pest, along with its relationship in this respect to the attacks of the Dutch Elm Disease (*Graphium ulmi*).

The natural enemies recorded are mentioned, those noted in Britain being dwelt on briefly.

In conclusion, the different types of bionomic pest are considered, the Elm Beetle allotted its apparent place, and the consequent importance of its enemies discussed. It is considered that, although food is the prime factor in the presence and increase of this pest, yet parasites and predators, essentially a secondary factor, may on occasion prove the most important one in the control of the pest, when the problem of dealing with the food factor becomes impracticable.

Mr. P. Harris.—*Research in woodworking.*

This paper deals with the experimental work in this connection being undertaken at the Forest Products Research Laboratory, Princes Risborough; describes the methods employed in carrying out the tests, and indicates where further research would be profitable.

Woodworking research is concerned with investigations into the effect of variation in shape, setting and speed of the cutting tool and rate of movement of the wood on the finish produced, the energy consumption of the machine and the life of the cutting edge. This involves a study of the principles underlying the cutting action of tools and the influence thereon of the elastic properties of the wood. The fundamental knowledge so obtained is of assistance in determining the optimum conditions for machining individual species of timber to ensure economy of working. Determination of the behaviour of the timber when worked under these conditions allows comparison of its working qualities with those of a well-known timber, such as home-grown oak, for hardwoods or imported red or yellow deal for softwoods. Measurement of the energy consumed in certain of the machining operations, estimation of the quality of the finish by means of special recording apparatus, and the opinion of the operator concerning the finished surface and the relative ease of working, provide the data in these investigations.

Dr. M. H. O'Dwyer.—*Recent advances in the chemistry of the hemicelluloses of wood.*

For many years hemicelluloses were considered to be true carbohydrates, but in 1926 the author showed that hemicelluloses from English beechwood contained, in addition, uronic acid anhydrides. On further investigation a certain percentage of methoxyl (2 to 4 per cent.) was found in each hemicellulose examined. About 0·4 per cent. methoxyl is present in a substance of a lignin-like character obtained after hydrolysis of the hemicelluloses with 72 per cent. sulphuric acid. There are indications that part, at least, of the remainder is attached to the uronic acid molecule.

In the preparation of the hemicelluloses the importance of a knowledge of methods employed in drying the wood, its moisture content at time of preparation as well as sylvicultural details, such as the identification of the species and the age of the wood, cannot be too strongly emphasised. The author found that the percentage amounts of hemicellulose A obtained from English oak decreased rapidly as methods of drying the wood became more drastic. There was also a difference of 60 per cent. in the response to acetylation of hemicellulose A from beechwood of 80 and 140 years growth, showing that the nature of the hemicellulose alters with the age of the tree.

AFTERNOON.

Excursion to Buttercrambe.

SECTION L.—EDUCATIONAL SCIENCE.

Thursday, September 1.

THE FILM IN EDUCATION :—

Sir BENJAMIN GOTT.—*Introduction.*

The film must be used to help the teacher, not to replace him ; he must be supplied with good apparatus of as simple a kind as possible, and there must be a plentiful supply of good and suitable films easily accessible. We must bring the teacher and the film-maker nearer together—they must understand each other, not simply wait for the other one to do something. It is hoped that a Film Institute may be set up to help this work, and the reception given to the report of the Commission on Educational and Cultural Films seems to show that there is a wide recognition of the necessity for help and advice in the matter of films in education. It is hoped that such an institute may act as a clearing-house for information on the production and distribution of educational and cultural films, including information as to research undertaken abroad. There will be work of many kinds for such an institute to do in creating a demand for films of a good kind and in advising teachers as to sources and conditions of supply, types of films available, and the apparatus and conditions of projection. The institute must bring the producer and the teacher together and show how they can help each other. There is a great work to be done, and it can only be done successfully if we all pull together. I do not presume to say what subjects require films or what kind of film each subject requires ; each of you knows what help he would be glad to have, and we must all be ready to say what we want and to co-operate in the preparing of the films we should like to have. It is important for school purposes that the films must not be too long, or the pupils' interest will flag, and the teacher must look upon it as a help, not as something which is taking his place for a time.

We have fallen on unfortunate times financially, and cannot expect a supply of apparatus for every school just now, but I would stress the necessity of seeing that in all new school buildings for older pupils there should be provided the wiring and other arrangements which are necessary for film apparatus when it can be provided, and I hope we shall be able to get education authorities to see to this. In the meantime there are methods of hiring the necessary apparatus, and in view of the rapid improvements in scientific apparatus to-day this may be a wise procedure.

Mr. A. C. CAMERON.—*The film as a cultural force.*

The film has a threefold place in national life : as an instrument of visual and oral instruction, as a means of entertainment, and as an art form.

It claims the serious consideration of educators, not merely as a visual aid but as a cultural influence for good or ill which we cannot neglect.

A teacher who uses a film in his class-room is linking up his lesson with the outside life of his pupils and is drawing into service the experience of their leisure. An adult population which reads few books has turned to the cinema as its staple solace and enjoyment. A generation of film-going children is learning to pick up quickly points and illusions on the screen. It is part of this current that we want to turn into the channels of the class-room, as one aspect of childhood's relation with the film.

But it is in public cinemas that the film has its strongest hold on national life, and therefore its great cultural and social influence both on children and adults; and its constructive use is a form of national planning from which the finest intelligences of the country should no longer hold aloof.

Mr. R. Gow.—*The teaching film.*

If the cinema is to be developed for class-room teaching, it would seem desirable to establish the technique of the 'teaching film' as soon as possible. The production of films is costly, and misdirected experiment is likely to prove wasteful. It is possible to approach a subject in education in a variety of ways, and, similarly, it would be possible to produce an educational film in a variety of styles. Just as one text-book cannot hope to please every teacher, so one teaching film may not be generally acceptable. But the supply is necessarily limited by the expense, and the needs of the teacher must be closely studied.

So far, experiment has been chiefly concerned with attempts to prove that there is a place for the film in the class-room. Future experiment must concern itself with the *kind* of film for the class-room. The extent of co-operation required of the teacher must be decided. The proper use of sound must be thoroughly explored. In short, we shall have to ask ourselves once again: 'What is the aim of teaching?'

Mr. F. A. Hoare.—*Educational cinematography.*

Never before has the prospect of real progress in the educational use of cinematography been so hopeful as it is to-day. Coincident with the experimental work carried out by the Historical Association and that conducted jointly by the National Union of Teachers and certain Local Education Authorities with sound films in schools, the large-scale investigation of the Commission on Educational and Cultural Films has proceeded. The publication of the Commission's Report in June this year has been followed by Governmental action and by Parliamentary provision for the establishment of a Cinematograph Fund under the Privy Council Office 'for the purpose of encouraging the use and development of the cinematograph as a means of entertainment and instruction.' The exercise of a wise discretion in the development of this project should provide a powerful stimulus to the film industry.

Educationists have come to regard the cinematograph as an additional visual aid in education, directly in the line of succession with such well-established instruments as the blackboard, picture, chart, diagram and the lantern slide, or the more novel episcope and epidiascope. The educational function of the sound film is, however, more than merely illustrative. It is the modern method of imparting knowledge and conveying facts, and by reason of its dynamic nature it renders the old method of picture and printed word somewhat obsolete. It is also pre-eminently the medium for correlating class-room work with the life of the world outside school. The sound film of a coal-mine or factory, for example, if properly made and faithfully reproduced, provides, by an illusion of reality, vicarious experience of the real things of life without which the pupil and the student must continue to suffer from the cramping effects of a limited mental horizon. Geography, economics, science, history, and nearly every subject of the curriculum stand to-day in urgent need of this vitalising and invigorating quality, which the cinematograph can impart and without which their school treatment must tend to be 'a sterile commerce with abstractions.'

If this claim can be justified, as those who have experimented believe, the problem of films and projectors assumes a new importance. Quality is the first essential if the reproduction of events, processes and personalities upon the screen is to be realistic and can be absorbed by the student into his personal experience. This modern mechanical equivalent of the ventriloquist's art has reached its present stage of perfection by the continuous efforts of equipment makers and studio technicians, so that the spectator loses consciousness of the mechanism and submits to the 'illusion of reality.' Technical advances in photography and in the recording of sound both on film and on disc make an interesting scientific study. Their practical outcome, from the educational standpoint, is the present standard and sub-standard equipment now available to schools. Have these technical advances made possible the universal adoption of cinematography in schools? Is the expenditure involved in securing the best films and reproducing equipment (i.e. the best technically and educationally) economically justified? In the writer's view both these questions must be answered in the affirmative. The engineer and the film producer have co-operated in the production of an educational device whose power we can hardly estimate. The way for the educationist is now opened up.

Mr. J. W. Brown.—*The film in adult education.*

1. *Influence of mechanical aids in general.*

Recognition of gramophone, film, broadcasting, as forces in national life. Special contribution of film to education; it cannot, however, supplant the teacher.

2. *Adult Education audiences*—Classification in terms of needs.

Film for higher technical instruction, and scientific record in work of university standing; film for use in technical schools, demonstrating application of mechanical principles, etc.; film for use in industry to demonstrate processes to the worker and to train apprentices, etc.; film for training in a special subject—e.g. agriculture; film for propaganda; teaching or interest film; film of special artistic merit or cultural interest for local film groups or societies; general interest film for special bodies—e.g. Educational Settlements, Institutes, etc.

3. *Development of use of Film constructively in Adult Education.*

Demand from bodies of all kinds for film of general interest and for teaching films will justify the production of special films. Work of extra-mural departments of universities and adult educational associations in organising the demand for films and advising on their production, etc. Value of film in discussion group.

4. *Difficulties of securing Films.*

Need for Film Institute which would perform an important function in arranging to distribute at reasonable cost suitable films to bodies requiring them, either direct through its central film library or indirectly through a trade organisation.

5. *Methods of other countries.*

6. *Commission on Educational and Cultural Films.*

Recommendation for establishment of permanent central organisation which would advise and aid production.

DISCUSSION on *The film in education.* (Dr. F. CONSITT ; Miss MARY FIELD.)

DEMONSTRATION of silent and sound sub-standard films by the Western Electric Co., Ltd., R. C. A. Photophone Ltd., and Ensign Ltd., of films arranged and recorded in collaboration with British Instructional Films Ltd.

DISCUSSION on *The film in education.* (Prof. J. L. MYRES ; Mr. J. L. HOLLAND, with reference to report of the committee on educational and documentary films.)

SUMMATION. (Mr. G. T. HANKIN.)

AFTERNOON.

Visit to St. Peter's School.

Friday, September 2.

PRESIDENTIAL ADDRESS by Mr. W. M. HELLER on *The Advancement of Science in Schools : its magnitude, direction and sense.* (See p. 209.)[1]

THE SCOPE AND EQUIPMENT FOR SCIENCE TEACHING IN SENIOR SCHOOLS (INCLUDING RURAL SCHOOLS) :—

Mr. F. J. THORPE.—*The teaching of science in senior schools, with special reference to work in a county area.*

Increased attention to history of Science has evoked a philosophy of science teaching based on that study. The slogan ' Science is Measurement ' has gone, and the ' Heuristic Method ' broadened into emphasis on the uniqueness of Science as first-hand investigation into everyday problems presented to appeal to the child's sense of values though not necessarily to the adult's. Lesson plans devised on these lines must commence with everyday problems or with model-making, the work must be generally experimental and individual and the instructions so framed that the maximum of personal effort is required from the pupil. An attempt should be made to form a provisional hypothesis and test this by further experiments and applications. Qualitative investigations are more suitable than quantitative for pupils from 11 to 15 years of age. Careful records should be made and precise use of terms developed, as this forms part of the cultural value of science. In scattered county areas this work has to be attempted in existing school buildings. An ordinary class-room may be adapted with little expense.

[1] In the absence of the President owing to an accident, the address was read by Mrs. Cosslett-Heller. The Chair of the Section was taken by Dr. A. W. Pickard-Cambridge.

As specialist teachers are not always available, the work should be under supervision and help given by refresher courses for teachers and by grouping the schools round some central institution of higher education.

Miss A. A. Scorrer.—*Science for senior girls.*

Value of and necessity for science teaching in schools now recognised.

Extensive choice of matter—must be related to experience, hence variety in type of course.

Historical development of science teaching among girls—early popularity of nature study—introduction of practical subjects, cookery and laundry, opened up new matter for science lessons—health teaching a further extension, leading to hygiene and human physiology.

Effect of Prime Minister's Committee's Report on Natural Science in Education (1918).

Modern conception of general science course.

Recommendations of Hadow Reports.

Examination of typical syllabuses in use.

Equipment—specialist teacher—specially provided room—apparatus—books.

Capt. F. W. Merritt.—*A course for older scholars in rural schools.*

Content of the Course.—Simple study of the physics and chemistry of air, water, and soil. Simple experimental lessons on mechanics and physics. Elementary study of the conditions of the healthy growth of plants and animals. Simple hygiene. Personal hygiene. Care in handling foodstuffs, milk, etc. Differentiation of the course for girls ; relation of the science teaching to the work done in the domestic subjects room.

The danger of attempting to cover too much ground.

Experiments in practical science which have been successfully undertaken by children of average intelligence, and their application to rural pursuits and industries.

General observational work (not done by formal lessons).—Daily weather and meteorological records. Continuous study of a particular tree, plant, or hedgerow. Interest in local geology, wild flowers and grasses.

Equipment.—Account of an actual rural science practical room. The minimum of apparatus required. Home-made apparatus. Provision which may be made for rural science teaching in schools where (*a*) no practical room is available ; (*b*) no gas available.

Mr. F. Boothroyd.—*The science of things around us.*

Practical Nature of Course.—Utilisation of interest in environment ; direct appeal of working models ; difficulties to be met and overcome in getting models to work ; development of interest in instructive hobbies ; education for leisure hours.

Aims.—Building up a body of useful scientific knowledge ; appreciation of law and order in Nature ; development of keen perception and observation, logical reasoning (inductive and deductive) ; encouragement of initiative and inventive genius.

Method.—Pupils work from sheets or cards of instruction ; individual work by pupils essential ; applications many and directly related to environment of pupils.

Equipment.—Good laboratory for not more than twenty-four pupils per teacher; usual experimental apparatus with addition of useful materials from cars, engines, cycles, clocks, taps, etc.; work-bench with vice and a few simple tools.

Content of Course.—(1) Preliminary training in study of some appliance involving simple scientific principles. (2) Two years' general course in science; study of physics and chemistry of air and water; applications chosen to suit environment of pupils. (3) For third and fourth years, concentration on some branch of science rather than an attempt to give a smattering of all.

Examples of Expression Work.—Working models by pupils (age 10–14) will be on view to illustrate various points in the paper, with examples of note-making and useful working diagrams for teaching purposes.

DISCUSSION. (Mr. W. EASTERBY.)

REPORT OF COMMITTEE:

On the teaching of general science in schools, with special reference to the teaching of biology.

AFTERNOON.

JOINT DISCUSSION with Section J (Psychology, *q.v.*) on *Industrial psychology and psychological selection in York.*

Monday, September 5.

EDUCATION IN YORKSHIRE:—

Sir J. B. BAILLIE, O.B.E.—*Applied science in Yorkshire.*

Applied science in so far as it falls within the Education Section is not concerned either with the achievements or discoveries of applied science or with the industrial developments of applied science. It is desirable at the outset to explain the nature of applied science and the distinction and relation between pure and applied science. They are equally scientific in method, and are mutually interdependent in principle and in fact. The historical development of instruction in applied science in Yorkshire started from the mechanics' institutes, was taken up by the technical colleges and reached its final stage in the incorporation of applied science in the curriculum of the universities of Yorkshire. Technical instruction is inseparable from applied science: but technical education, whether lower or higher, is primarily craft instruction with scientific instruction and investigation occupying a secondary place. Applied science in the restricted sense subordinates craft instruction to scientific training and investigation. Coordination between all forms of technical instruction and applied science is a desideratum. Statistics of attendance and expenditure show a great advance on the extent of technical education in Yorkshire in the last twenty years.

The work of the applied science departments of the universities is carried on in close association with the pure science departments. Applied science in the universities, as well as in the technical colleges, has been intimately connected with the industries of Yorkshire from the first, and has been much encouraged and supported by them. The work of the applied science departments of the universities has been supplemented by and has been co-ordinated with that of the Industrial Research Associations financed by the Department of Scientific and Industrial Research.

Certain directions in which applied science should be further developed in the technological departments of the universities are indicated.

DISCUSSION. (Prof. C. H. DESCH.)

Dr. JOHN STRONG.—*The future training of teachers with special reference to training colleges.*

Three years ago the Board of Education inaugurated a system whereby the two-year training colleges were brought into relationship with the universities. The nexus of this arrangement is the examination for the teacher's certificate. Formerly this examination was conducted by the Board of Education; now it is conducted by local bodies consisting of representatives of local educational interests, including representatives of the relative university. In the Yorkshire area there is an Administrative Board with boards of studies and boards of examiners, the latter consisting of internal and external examiners. The external examiner is normally a professor or lecturer in the university.

The institution of an *internal* examination and the contact with the university is a move in the right direction. The quality of the work done in the Yorkshire training colleges approximates in many cases to that of the pass degree in the universities, and a large number of the students have the ability to take a pass degree. Approximately 70 per cent. of those who entered the colleges this year hold a matriculation certificate or its equivalent, and of these 15 per cent. have gained the higher school certificate.

These facts point to the necessity of providing for these students further facilities for obtaining degrees. This would mean (1) lengthening the course of training; (2) the institution of a degree having a more definite relation to the future work of such teachers; (3) the recognition of some of the work in the training colleges as of university standard.

DISCUSSION. (Mr. R. R. KIMBELL.)

Prof. T. H. SEARLS.—*Extra-mural facilities offered for adult education by the universities and the local education authorities in Yorkshire.*

Mr. G. H. THOMPSON.—*Facilities offered for adult education by voluntary bodies in Yorkshire.*

The paper describes the activities of voluntary organisations, whose main purpose is to stimulate interests of a non-vocational character, and takes no account of facilities provided by professional or technical associations for their members. It directs attention to the change in the character of adult education during this century.

During the latter part of the nineteenth and the early years of the twentieth century, the facilities offered by voluntary organisations were largely miscellaneous in character, and the costs were borne wholly by the voluntary organisation.

Now the chief features of adult education are continuity and intensive study, and a large proportion of the cost is contributed by public or semi-public bodies.

A very notable fact is that this change in character has largely been achieved by working people acting in co-operation with 'learning' in its individual and corporate capacities.

The paper reviews in some detail what is now being done by the chief organisations, and the way it is done. It concludes by attempting to analyse the reasons why the natural and physical sciences have not had a larger share in the modern adult education movement.

DISCUSSION. (Mr. A. S. ROWNTREE.)

Mr. E. WALKER.—*Continued education of adolescent boys and girls in Yorkshire.*

I. THE AREA.

Geographical; economic; population; the Local Education Authorities.

II. THE SCHOOL LEAVER.

(i) His starting point.
(ii) His further needs.
  (*a*) As a citizen.
  (*b*) As a worker.
(iii) Attitude to voluntary education.
(iv) Aims in further education of :—
  (*a*) The pupils.
  (*b*) The Authority.
(v) Duration of continued education.
(vi) Results :—
  (*a*) For the individual.
  (*b*) For the community.

III. EXTENT AND VARIETY OF CONTINUED EDUCATION.

Facilities at various stages : admission, scholarships and exhibitions, range of fees. Specialisation in vocational work ; non-vocational instruction.

IV. SOME PROBLEMS.

(i) The start.
(ii) Inducements to continue.
(iii) Distribution of provision among Authorities : considerations of density of population, accessibility, costs, financial arrangements.
(iv) Correlation of instruction : procedure towards uniformity of syllabuses, standards, administration.
(v) Publicity and co-operation of industry.
(vi) Control of the stream : examinations, progressive specialisation.
(vii) The goal : recognised stages, National Certificates, recognition by industry.

V. SOME SUGGESTED SOLUTIONS.

(i) Administrative.
(ii) Educational.

The aims of the Yorkshire Council for Further Education.

DISCUSSION. (Mr. H. W. LOCKE.)

EVENING.

SYMPOSIUM on *The place of science in the education of boys and girls up to sixteen years of age :*

Sir RICHARD GREGORY.—*General introduction of problem.*

Sir Arnold Wilson.—*From an industrial point of view.*

Mr. Donald Gray.—*From the economic point of view.*

Dr. W. W. Vaughan.—*From literary, cultural and historical point of view, and general survey as Chairman.*

Prof. W. W. Watts.—*From field and open-air (out of school) point of view.*

Tuesday, September 6.

Domestic Science as a Real Educating Instrument :—

Miss H. Masters.—*Domestic science and domestic subjects.*

Domestic science and domestic subjects are frequently used as interchangeable terms, but in the School Certificate they appear as separate subjects and in different groups, and, speaking generally, there seems to be considerable confusion with regard to the exact nature of the subjects covered by these terms. An outline of the main developments which have led to the inclusion of these subjects in the school course is helpful at arriving at an understanding of their relationships to each other and of the attitude usually adopted towards them. There is need for much more general recognition of the educational, as distinct from the utilitarian, value of domestic subjects, and for some modification in the outlook of the teachers of both science and practical subjects. In both these branches there has been a tendency to adhere too closely to traditional methods of approach. Special difficulties peculiar to the teaching of practical subjects, and which have to be taken into account in the training of the teacher, call for some consideration.

The prospects are favourable, but progress lies in the development of a craftsmanship dependent on the merging and not on the separation of science and art.

Miss M. C. Pepper.—*Domestic science and mental training.*

Domestic science compared with the pure sciences—the predominance of craft and the necessity for development of skill.

The problem of teaching the art, developing skill, and at the same time proceeding so as to preserve the spirit of discovery and adventure. How far the teaching of domestic subjects should be by observation and imitation.

Difficulties inherent in the complexity of (*a*) the materials, e.g. foodstuffs ; (*b*) processes, e.g. bread-making ; (*c*) apparatus, e.g. gas-stoves, in all branches of domestic science.

The value of these subjects for mental training inherent in their value as practical subjects developing co-ordination of hand and eye, bodily control leading to quick, accurate movements economic in effort, developing joy in practical work and making it a useful, productive form of self-expression with valuable æsthetic possibilities.

Suggestions for methods of organising and teaching domestic science, based on the realisation of its possibilities as a ‘ real educating instrument.’

Miss M. Weddell.—*The secondary school course in domestic science.*

(*a*) Typical lessons to-day : two methods of approach, ‘ methods of purpose ’ and ‘ methods of exercise.’

Range of syllabuses.

(*b*) Contrast between Domestic Science and other 'craft' subjects.

(*c*) Cultural value to the pupil:
- (1) Interpreting her surroundings, historically, æsthetically, scientifically, socially.
- (2) Developing personal skill, with physical self-control.
- (3) Offering purposes with an immediate appeal, and immediate application.
- (4) Offering social and moral training.

(*d*) Relative value for backward and advanced pupils.

(*e*) Difficulties in its way:
- (1) Ignorance of the subject and its aims on the part of those interested in education.
- (2) Absence of records of experiments in method.
- (3) Isolation of its teachers.

(*f*) An appeal for further discussions and research in such topics as:

Study of its apparatus and methods in relation to fatigue among children.

Tests for craft ability and achievement.

Analysis of the methods of successful craft-teachers.

Further experiments on possible developments—e.g. joint training in speech and craft.

DISCUSSION. (Mr. A. H. WHIPPLE.)

RELATION OF TECHNICAL TO SECONDARY EDUCATION:—

Sir PERCY WATKINS.—*The secondary school: its contribution to technical education.*

For large numbers of their pupils Secondary Schools are the only educational avenues of approach to industrial and commercial careers. The criticism is often heard that many of the pupils do not find their true place in those spheres.

Is it possible that the courses of Secondary Education given in many schools have not adequately recognised the cultural instruments that are available for exercising, quite suitably, the native faculties of those of their pupils who are the most likely to make good recruits for industry and commerce?

The attitude of many schools appears to be: 'Let us give each of our pupils the kind of education we provide in *this school*, and then let each pupil, with that equipment, acquit himself as best he can in the work of the world.' Might not the attitude more properly be: 'Let us discover the special interests and aptitudes of our pupils, and let us provide suitable courses of instruction to meet their diverse needs. Then, let us see whether we can advise each pupil, in the light of his own individual equipment thus obtained, as to the niche in the world that he is likely to fill most happily and most successfully.'

Mr. J. PALEY YORKE.—*The present position and future possibilities.*

'Secondary' education represents a definite generation in the family of Primary, Secondary and University education. 'Technical' education represents several generations within itself and has been regarded as a separate and collateral family. It has been kept in the background as a family of distant relatives of doubtful habits and manners.

This is due to general lack of knowledge of its aims and methods even by many who profess to be educational experts. It has the boring effect of forcing its exponents into the position of apologists. Technical education is not a scheme of acute specialisation at all ages and stages.

There is to-day practically no conscious relationship between Technical and Secondary education. Some of the products of Secondary Schools do proceed to Senior Technical Courses—both full-time and part-time courses—but not by any generally organised scheme of transfer.

So far as Junior Technical Schools are concerned, they have travelled along roads parallel to those of Secondary Schools, but separated by almost impenetrable barriers.

There could and should be a conscious relationship between Secondary and Technical Schools and a scheme of transfer of suitable pupils.

The joyous fact that Junior Technical Schools enjoy freedom from any system of rigid examinations should not be an unsurmountable barrier—but we would not be prepared to sacrifice that freedom.

We claim that ' classical ' and ' modern ' Secondary Schools are not the only educational highways. We are building new highways. They *may* have some of the ugliness of new arterial roads, but they can and will be beautiful. With unbiased and intelligent co-operation they can be planned to provide valuable by-passes and to link up every part of the educational country.

Mr. P. Abbott.—*The co-operation necessary or possible.*

The range of technical education lies between the junior technical school, ages 13–16, and the university graduate. The problems of co-operation are :

(1) Are relations possible between the two types of education at corresponding ages?

(2) Should the work in secondary schools be in any way anticipatory of the work to follow in the higher technical schools?

Discussion. (Mr. J. H. Hallam ; Mr. S. H. Moorfield.)

Afternoon.

Visit to Bootham, Friends', Boarding School for Boys, and The Mount Boarding School for Girls.

SECTION M.—AGRICULTURE.

Thursday, September 1.

Presidential Address by Prof. R. G. White on *Sheep Farming : a distinctive feature of British agriculture.* (See p. 229.)

Mr. W. C. Miller.—*Certain aspects of the genetics of the sheep and their potential economic significance.*

This paper is intended to focus attention on the incorporation of a knowledge of sheep genetics into certain methods of sheep-breeding. The difficulties encountered in determining modes of inheritance of characters in the larger domesticated animals are discussed.

It is suggested that by the use of the knowledge of the genetics of fleece colours in sheep a plan might be adopted which would reinforce the financial returns of the crofter, small-holder, etc., who has not facilities for keeping a large enough flock to constitute the minimum economic unit under present conditions. The plan requires the parallel development of home industries, such as spinning, knitting, and weaving, and aims at the production of pleasing, natural-coloured luxury goods.

Evidence is presented from an analysis of detailed flock records to indicate that abnormally low fertility in the male may be transmitted to his female progeny, and may be exhibited by them as a higher infertility rate than the normal for the flock.

Abnormalities in development of lambs are briefly reviewed, and further evidence is offered to indicate that many deformities appear to behave as simple Mendelian recessive lethals or sub-lethals with adverse effects upon the flock or breed concerned, due to the inability of owners to recognise their genetic basis.

Mr. J. Hammond and Mr. J. Edwards.—*Scientific aspects of mutton production.*

Requirements are discussed in the light of present economic conditions, special attention being directed to methods whereby income per ewe might be increased by more intensive production and more rapid returns. Aspects dealt with are: (1) Fertility of the ewe, how it may be improved by breeding and selection for the twinning character, and by feeding or flushing before conception for an increase in the number of eggs shed. The opinion is advanced that an attempt must be made to secure more than one crop of lambs per year, resulting in a greater return per ewe and a better seasonal distribution of the lamb supply. (2) The growth of the lamb after birth is considered. Emphasis is laid on the need for a continuous and good milk supply, the avoidance of a check in growth during the early stages of development and the provision of young, succulent, protein-rich forage. (3) The development of mutton qualities is discussed. A study of the differing rates of growth of the various parts of the animal's body provides a scientific explanation of the term 'early maturity,' and the process by which this quality can best be achieved is seen to be a consistently high plane of feeding. Such treatment not only satisfies market requirements, but also reveals genetic capabilities, pointing to strains either possessing or lacking the characters sought.

Dr. A. H. H. Fraser.—*Some economic aspects of the Scottish sheep industry.*

The historical development of the industry is traced. Its development has been influenced by political changes, the Union of the Parliaments in 1707, and the suppression of the Jacobite Rebellion of 1745; and by economic causes, such as changes in the value of wool and in the public taste for mutton. The climate and vegetation of the country have constantly checked the full exploitation of economic possibilities. The result, as seen to-day, is a compromise between what man desires and what nature permits.

The system of breeding is described by which the various commercial crosses are derived from the two foundation Scottish breeds, Blackface and Cheviot. It is pointed out that the whole system depends upon the surplus sheep from hill stocks, and the consequent danger of the progressive decrease in the numbers of hill sheep is emphasised.

Suggestions are made regarding the most profitable lines of research in the industry and for improvement in its business organisation.

AFTERNOON.

Excursion to Leeds University Farm, Askham Bryan.

Friday, September 2.

DISCUSSION on *Crop production, with special reference to the increased use of mechanical power* (Dr. H. J. DENHAM; Mr. S. J. WRIGHT; Mr. A. J. HOSIER; Mr. D. R. BOMFORD):—

Dr. H. J. DENHAM.—*Basic problems of mechanised farming.*

The rapid spread of mechanised farming in Great Britain introduces a number of problems in the displacement of labour. These are in many respects parallel to those which existed in the industrial situation at the beginning of the last century, with the difference that there is no appreciable export trade to absorb increased production, but a substantial volume of imports which can be reduced. Mechanised farming can be treated under the two headings of extensive—large-scale—production of a crop of low value per acre, and intensive—small-scale—production of high value per acre. The two forms, and intermediates, may exist side by side on one farm.

Extensive mechanisation on rich land involves displacement of labour, and on poor land finds place for more hands. The opening up of old wheat and cereal land would result in increased employment and would render available more land for crops of higher value. The reduction of labour on large-scale units provides additional resources for subsidiary enterprises.

The main object of mechanisation is to render farming a more rational or economic process. This can be done by making the farmer more independent of seasonal and climatic conditions, and by reducing the amount of seasonal employment.

Specific problems of mechanisation are to adapt machinery originally designed for large acreages and small yields for use in small fields and heavy crops, and to extend the lower limit of the size of unit on which they can be used. The process may be hastened by the return of the agricultural contractor and the development of co-operation.

The reduction of unnecessary transport, as exemplified on the Hosier farm, is an important feature of any mechanised system. This is particularly the case with manure, and the future of stock farming in this country will be largely dependent on the proper observation of this principle.

There is a large field for development in the future in the mechanisation of tropical and sub-tropical crops in the Empire in conjunction with cheap labour.

Mr. S. J. WRIGHT.—*The rôle of the tractor in reducing farming costs.*

The economies which the tractor effects arise from the fact that it allows one man to control a power output equal to that of several teams of horses. On the other hand, both the capital expenditure involved and the comparative lack of flexibility of a tractor as compared with a team of horses make the planning of the whole outfit in relation to the work of great importance.

In other words, while the tractor offers great opportunities for saving, it probably offers still greater opportunities for wasting both time and money.

It is not generally realised that of two tractors of equal power and equal reliability, one may be capable of hauling a three-furrow plough, while the other on the same land may be overloaded with two furrows. This difficulty arises from the fact that every tractor is designed to give a definite working power, while running at certain speeds. If the draught of the plough does not fit in with these, the tractor must always be working at a disadvantage.

For grassland farming the ideal tractor would probably be something utterly different from any of the standard tractors marketed at present. The ruling conditions are quite different from those of arable farming, and the number of 'one-horse' jobs to be done will eventually make smaller power units an essential.

Mr. A. J. Hosier.—*Some problems of extensive farming with mechanised equipment.*

The problems of overproduction and low prices are accentuated by the application of science. Science must be applied to distribution and consumption.

For ten years the author has been doing pioneer work in agriculture, firstly in the successful establishment and mechanisation of open-air dairying, and secondly in the mechanisation of haymaking and the making of stack ensilage.

For the large mechanised poultry farm the author has adopted a folding system whereby poultry can be folded over the land. They are in small houses holding twenty-five hens. By this means the land may be fertilised cheaply. The folding pens are so constructed that cows can be turned out among them without fear of injury.

Mr. D. R. Bomford.—*Some problems of intensive farming with mechanised equipment.*

The paper discusses the economic selection of machinery from the farmer's point of view.

Details of recent attempts to use machinery, particularly as regards row crops.

The national aspect of mechanisation.

Discussion.

Afternoon.

East Riding Agriculture :—

Dr. S. E. J. Best.—*Geographical and historical aspects.*

The East Riding can be divided into nineteen Soil Regions, each with an individuality, though within each, largely owing to glacial action, there are minor variations. This area has a higher percentage of arable land than most counties, with a low percentage of permanent grass, and almost no rough grazing. The percentage areas of the chief cereal and root crops are well above the average for England and Wales, and the yield per acre is seldom below. There are less cattle per 100 acres, and almost as many sheep, though on the Wolds the number of sheep is above the average.

The process of enclosures was slow in East Riding, and by 1850 there were still large common lands, especially on the Wolds. The turnip crop was not established until the nineteenth century, and then the Norfolk rotation and sheep-folding revolutionised Wold farming. Graphs showing changes of agricultural population during the last century reflect agricultural prosperity and depression, and different Soil Regions give characteristic curves. The graph of Wold land population is always slightly below the average ; of good medium-heavy land always above, and the graph of light land cuts across the average.

Mr. J. Strachan.—*The present position.*

(See *Scientific Survey of York and District*, appendix to this volume.)

Saturday, September 3.

Excursion to Wheldrake, Thornton, Southburn, Garton Fields, Sledmere and Malton.

Monday, September 5.

Discussion on *Increasing and cheapening stock production* (Prof. J. A. S. Watson ; Dr. N. C. Wright ; Mr. H. R. Davidson ; Mr. W. A. Stewart) :—

Prof. J. A. S. Watson.—*Reducing production costs of beef.*

The home beef industry suffers under two chief disadvantages as compared with its main overseas competitor. On the one hand, the British national herd includes a large and increasing proportion of the dairy breeds, and hence necessarily produces a quantity of material that is of second-rate value for beef production. This problem should be approached from the broad national point of view, as it is in fact already being approached in Ireland.

The second disability arises out of the shortness of the British grazing season, which varies from five to seven months, while some competing areas approach the ideal of twelve months' grass. In this country the cost of production, in terms of live weight increase, is nearly two and a half times as high in winter as in summer. Roots, which form the basis of the traditional winter ration, are very expensive to produce on account of their high requirements of hand labour. It seems probable that the average cost of producing energy in this form has been higher, over a period of years, than the cost of an equivalent amount in the form of purchased maize, etc. The root crop does not lend itself to mechanisation, which alone could permit any substantial reduction in costs. The paper discusses some possible alternatives.

Dr. N. C. Wright.—*Wastage in dairy cows.*

During recent years a number of investigations have been carried out with the object of ascertaining the length of life of dairy cows, and the causes of premature disposal of milking stock.

As regards length of life, data relating to annual disposals from herds appear to be difficult to interpret and, in some cases, undoubtedly give erroneous conclusions. On the other hand, estimates based on age-distribution studies appear to be fairly reliable. Such estimates indicate that the average milking life of dairy cows extends to about four years, the average total length of life, therefore, being about 6½ years. This indicates that, in general, dairy cows very frequently fail to attain the age of maximum milk production.

With regard to causes of loss, disease plays the largest part, accounting for between 40 to 50 per cent. of the annual disposals of stock. With the exception of Johne's disease, the incidence of which is somewhat localised, the major diseases responsible are reproductive diseases (including abortion and sterility), mastitis and tuberculosis. It is of urgent importance that immediate measures should be taken to combat these diseases. It is suggested that more emphasis should be laid on the need for 'field' investigations, rather than that research into the diseases of dairy cattle should be more or less limited to small-scale laboratory experiments.

Mr. H. R. Davidson.—*Pig recording as a factor in increasing and cheapening pig production.*

Investigations into the financial results of pig-keeping carried out recently show that this branch of production has, on the average of farms, been carried on at a loss, amounting in some cases to from 5 per cent. to 20 per cent. per annum on capital. Detailed costs of production on a well-run commercial herd show that with food at 1*d.* per lb. the cost of producing a bacon carcase is 15*s.* 8*d.* per score. During the five years 1926–30 the average cost of food has been just on 1*d.* per lb., and the average price of baconers 16*s.* 9*d.* per score. It has therefore been possible to produce baconers at a profit of 1*s.* 1*d.* per score, or approximately 7 per cent. on cost of production. The difference between these figures for possible profit and actual loss are shown by recording to be due to (1) a small number of pigs weaned per sow year, and (2) poor age-for-weight results. These account for extra costs of 1*s.* 5½*d.* and 1*s.* 2½*d.* per score respectively, or a total of 2*s.* 8*d.* This obliterates the possible profit and produces a net loss of 1*s.* 7*d.* per score, or approximately 9 per cent. on cost, which is in line with the costing results quoted. The possible improvements which might be brought about by genetic improvement are calculated at 9¼*d.* per score and 5¼*d.* per score respectively. The total of 1*s.* 2½*d.* is not sufficient to outbalance the loss of 1*s.* 7*d.* Poor weaning and age-for-weight results are shown to be largely due to faulty management and feeding, which pig recording demonstrates and thereby helps to cure. While there is much scope for further improvement of pure-bred stock, this is not the major problem in increasing pig production by reducing costs of production. Pig recording, by bringing to light weak points of management and policy, is suggested as the most important single factor in achieving this result.

Mr. W. A. Stewart.—*Adaptation of Swedish systems of housing and recording to English pedigree pig production.*

In Scandinavia pig housing has been carefully studied and tested. Special attention is paid to warmth, lighting, ventilation, cleanliness and labour-saving arrangements. Constructional details are such that it is possible to maintain a high level of hygienic conditions. This results in a relatively low incidence of disease, and in conjunction with other factors helps to secure a high average number of pigs reared per litter. A small 'isolation hospital ' is generally provided for sick or ailing pigs ; in this way the spread of infectious or contagious disease is to a considerable extent controlled.

Certain Scandinavian constructional points have been applied to pig housing in England with satisfactory results.

Pig recording was instituted in Sweden by the Pig Breeders' Society of Malmöhus to ascertain the productive capacity of sows. Records preserve information regarding the number of pigs born and reared per litter, the number and weight of the litter at three weeks old, their average weight, variation in weight, their sex, and the number of teats of each female. Three weeks is considered the best age at which to weigh to give a true measure of the sow's milk yield. Records constitute the only reliable guide to productive capacity and maternal qualities of sows.

Large white sows at Moulton Farm Institute are now recorded on these lines, and the figures obtained have demonstrated the importance and value of recording.

Careful selection of breeding sows according to records leads to a lowering of the cost of production of pedigree breeding stock.

DISCUSSION.

AFTERNOON.

DISCUSSION on *The nature and importance of the clay fraction of soils* (Prof. G. W. ROBINSON; Dr. C. E. MARSHALL; Dr. R. K. SCHOFIELD) :—

Prof. G. W. ROBINSON.—*Clay composition in relation to soil survey and soil classification.*

The significance of the composition of the clay fraction depends upon the extent to which it can be identified with the fraction of the soil resulting from chemical weathering—i.e. the weathering complex. For most purposes, the assumption of this identity does not involve a serious error.

A broad distinction may be drawn between clays with high and clays with low SiO_2/R_2O_3 ratios. There is some justification for regarding a SiO_2/R_2O_3 ratio of 2·0 as critical. Clay fractions with SiO_2/R_2O_3 ratios greater than 2·0 occur under conditions in which removal of silicic acid is inhibited by deficient leaching, as in arid soils ; by impeded leaching, as in ground-water soils ; or by the protective effect of the calcium-ion, as in carbonate soils.

Clay fractions with SiO_2/R_2O_3 ratios of 2·0 or less are found under conditions of free leaching, resulting in desaturation. Where leaching takes place in the absence of acid humus, as in brown earths, red loams, and red earths, the removal of silicic acid results, in soils of primary weathering, in the formation of clay fractions with SiO_2/R_2O_3 ratios less than 2·0. In the presence of acid humus there is a differentiation, owing to the migration of sesquioxides from A to the B horizons.

The study of the composition of the clay fraction may prove valuable in the definition of soil series.

Dr. C. E. MARSHALL.—*The study of the clay particle.*

The accepted definition of clays on the basis of particle size involves the soil worker in three interconnected groups of problems. First, there are the purely physical problems, such as the extension of mechanical analysis into the clay fraction itself. With this as starting-point the study of the more complicated physical properties of the clays, such as plasticity, etc., follows naturally.

Then a group of mineralogical problems of some complexity presents itself. The usual methods of identification and characterisation break down when dealing with clay particles, and a new technique must be devised. The density, refractive index, and double refraction can still be determined, using modified methods. The fact that even the smallest particles of clays show a high double refraction indicates that clays are essentially crystalline, whilst the actual values of the double refraction serve to differentiate between different clay minerals. The study of the double refraction of clays also leads to the conclusion that where the base exchange capacity is high, a large proportion of the cations concerned have definite positions in the crystal lattice.

Lastly come physico-chemical problems associated both with the mineralogical character and the surface properties of the particles—e.g. coagulation and base exchange.

Dr. R. K. Schofield.—*Water films in clay.*

Many of the properties which characterise clay in the agricultural and general sense arise from a special relationship which exists between the solid matter of the individual particles and the water which surrounds them and links them together. The forces at work here are not capillary forces as ordinarily understood, which arise from the pressure difference across sharply curved menisci. Ordinary capillary forces could not give rise to the swelling which takes place when a block of dry clay is moistened.

If the uptake of water by dry clay is controlled by allowing it to come to equilibrium with an unsaturated atmosphere of fixed relative humidity, it is found that the amount taken up bears a close relationship to the base exchange capacity. As base exchange must occur on 'active spots' distributed on (or possibly through) the clay particles, it would seem that the water taken up from an unsaturated atmosphere is in some way associated with these active spots.

Under saturated conditions no direct connection exists between the water content of the clay and its base exchange properties. Here the question as to why the clay particles, which have been separated by the penetration of water between them, should still cohere across this water film deserves special attention.

Discussion.

Tuesday, September 6.

Discussion on *The distribution of agricultural products* (Mr. E. M. H. Lloyd; Mr. F. J. Prewett; Mr. T. G. Henderson; Mr. J. M. Caie; Mr. C. S. Orwin) :—

Mr. E. M. H. Lloyd.—*Planning and world markets; attempts to regulate supplies in the marketing of primary products.*

Attempts to control economic forces by deliberate planning, particularly in the distribution of agricultural products, have been stimulated by the catastrophic fall of prices. Tariffs are supplemented by quotas or quantitative restriction of imports. Prices may be raised by subsidies or by restriction of production. Exports may be stimulated by bounties or limited by monopolistic control. These measures may be statutory or voluntary, but are generally unco-ordinated and on a national basis. Finally attempts may be made by international agreement to limit supplies offered in world markets by export quotas, centralised plan for withholding stocks, and restriction of production, e.g. Chadbourne Sugar Scheme.

Many of these schemes are designed as purely emergency measures. If prices rose, producers themselves might be the first to demand their removal. But some are designed as permanent measures of economic planning, as under the Agricultural Marketing Act in the United Kingdom.

Pre-requisites of successful permanent planning are (1) greater stability in the purchasing power of money (a field offering the clearest scope for world planning) and (2) more accurate, complete and up-to-date economic intelligence. (Statistics of stocks are specially deficient.)

Regulation of supplies is a matter of degree. Schemes may be divided into two main categories: (1) regulation of flow of supplies to avoid short-term fluctuations, e.g. South American chilled beef shipments; and (2) regulation of stocks and production with a view to maintenance of a remunerative price level, e.g. coffee and sugar. Schemes of the former kind present far fewer difficulties than the latter, and where successful represent a permanent advance in the technique of agricultural marketing.

Mr. F. J. Prewett.—*The milk marketing dilemma.*

Milk is a standard commodity, of fluctuating production and constant demand, but, at lowest production, equal to consumptive demand. Variations in production make necessary an alternative utilisation of this seasonably recurring surplus in some less perishable form than milk—that is, in the form of butter, cheese, cream, condensed and dried milk. In addition, there are large parts of the country where liquid consumption cannot account for more than a very small proportion of the milk output, so that manufacture on a large scale is always required. But, owing to the natural protection from imports which the liquid market enjoys, and the consequently higher price that is represented for milk imports in the form of butter, cheese, etc., every milk producer who is marginal, or even outside the range of the liquid market, endeavours to sell on it rather than turn his milk into commodities which come into direct competition with low-priced imports. As a result of this conflict within the home industry, of a protected and an open market, agreements towards 'rationalisation,' which in reality have been confined to the liquid trade, have broken down. No 'rationalisation' will be achieved until the whole dairy industry, liquid and manufacturing, is regarded as a single unit, with milk as the commodity, no matter whether sold liquid or made into butter or cheese. This involves a flat price for all milk, and some sacrifice in money from the favoured producers for the liquid market in order to secure themselves from the encroachment of manufacturing producers, whose mere existence at present depresses liquid prices and makes effective price and supply stabilisation impossible.

Mr. T. G. Henderson.—*Agricultural marketing organisation in Scotland.*

The organisation of farmers in Scotland for the marketing of agricultural produce has lagged behind that for the purchase of agricultural requirements, and that because the former type of organisation encounters numerous factors of great difficulty and no little complexity. The difficulties of adjusting agricultural production to market demand, and the effect of modern inventions in bringing areas of production formerly remote into close touch with the principal markets, however, render the question of marketing organisation a pressing one.

The present position in Scotland is examined in some little detail. Marketing organisations for such commodities as milk, wool and eggs have existed for some time, and the experiences gained are set forth.

Some notice is taken of the general considerations affecting the success of co-operative undertakings.

The use likely to be made of the Agricultural Marketing Act, 1931, is discussed, together with some of the implications which may arise therefrom.

Mr. J. M. Caie.—*The Scottish 'National Mark.'*

The Agricultural Produce (Grading and Marking) Act, 1928, authorises the Department of Agriculture for Scotland to make regulations prescribing 'Grade Designations' and Grade Designation marks for Scottish agricultural and horticultural produce. The commodities in respect of which regulations have been made are eggs, tomatoes, beef, malt flour and extract, ware potatoes and canned fruit. The principle of the schemes is entirely voluntary; this has advantages, but makes it possible for indifference or hostility to restrict their usefulness. Speaking generally, producers are in favour of grading and marking; consumers appear to be rather apathetic; while the attitude of traders varies from cordial support to active enmity. Schemes under the Marketing Act could include provisions for grading and marking; these schemes would be voluntary in origin, but when matured would be fortified with compulsory powers.

THE BRITISH ASSOCIATION STANDARDS OF RESISTANCE, 1865–1932

BY

SIR RICHARD T. GLAZEBROOK, F.R.S., AND DR. L. HARTSHORN.

(From the National Physical Laboratory.)

Ordered by the General Committee to be printed in extenso.

THE original Electrical Standards Committee of the British Association was appointed at the Manchester meeting in 1861. In their first Report (Cambridge, 1862) they point out that they had first to determine 'what would be the most convenient unit of resistance, and second, what would be the best form and material for the standard representing that unit.'

The C.G.S. system of measurement was the outcome of their deliberations on the first question, and they determined to adopt as a practical standard of resistance the ohm equal to 10^9 C.G.S. units of resistance. Experiments were made at King's College by Maxwell and Fleeming Jenkin to obtain the ohm in a material form, and Reports giving the result of these were issued in 1863 and 1864. Experiments were carried out by Matthiessen and Hockin to determine the best form and material for a series of standard coils. The Reports which followed give an account of the process of these experiments, and in Appendix A to the 1865 Report we have their final conclusions and a description of the form of standard coil they recommended. As a material for the wire of which the coil was constructed an alloy containing 66 per cent. silver and 33 per cent. platinum was chosen, for reasons given in the Report. It was agreed that copies of the standard should be made and preserved at Kew Observatory, and the Report for 1867 contains a table of the values of the standards in question. A copy of this is given as Table I. The Committee was dissolved in 1870.

Soon after Maxwell's appointment as Cavendish Professor at Cambridge the coils, with the bridge used for their comparison, were brought to the Cavendish Laboratory and were used by Chrystal and Saunder in their work on Ohm's Law in 1876.

Lord Rayleigh became Cavendish Professor in 1879 and was immediately interested in electrical measurements. Various investigations, particularly those of Rowland at Baltimore, and some deductions from Joule's work, had thrown doubts on the accuracy of the absolute measurements of the British Association Committee. These doubts were confirmed by measurements made at Cambridge by himself and Schuster, and from 1881 onwards there was great activity at the Cavendish Laboratory and elsewhere in connection with the question of electric units.

TABLE I.

COMPARISON OF B.A. UNITS TO BE DEPOSITED AT KEW OBSERVATORY.

By C. Hockin.

The following table shows the value of the different copies of the B.A. units that have been made for preservation at Kew :

Material of Coil.	No. of Coil.	Date of Observation.	Temperatures at which Coil has a Resistance $= 10^7 \frac{m}{s}$	Observer.
			° C.	
Platinum-iridium alloy .	2	January 4, 1865	15·5	C. H.
		June 6, 1865	16·0	A. M.
		February 10, 1867	16·0	C. H.
Platinum-iridium alloy	3	January 4, 1865	15·3	C. H.
		June 6, 1865	15·8	A. M.
		February 10, 1867	15·8	C. H.
Gold-silver alloy . .	10	January 5, 1865	15·6	A. M.
		February 10, 1867	15·6	C. H.
Gold-silver alloy . .	58	April 10, 1865	15·3	A. M.
		June 6, 1865	15·3	A. M.
		February 10, 1867	15·3	C. H.
Platinum . . .	35	January 7, 1865	15·7	C. H.
		August 18, 1866	15·7	A. M.
		February 10, 1867	15·7	C. H.
Platinum . . .	36	January 7, 1865	15·5	C. H.
		August 18, 1866	15·5	A. M.
		February 10, 1867	15·7	C. H.
Platinum-silver alloy .	43	February 15, 1865	15·2	C. H.
		March 9, 1865	15·2	A. M.
		February 10, 1867	15·2	C. H.
Mercury . . .	I.	February 2, 1865	16·0	A. M.
		July 18, 1866	16·0	A. M.
		February 11, 1867	16·7	C. H.
Mercury . . .	II.	February 3, 1865	14·8	A. M.
		August 18, 1866	14·8	A. M.
		February 11, 1867	14·8	C. H.
Mercury . . .	III.	February 11, 1867	17·9	C. H.

During 1879–81 a very careful comparison of the coils was made by Dr. Fleming. It was clear that their relative values had changed appreciably since 1867, and he adopted as a definition of the B.A. unit the mean value of the resistance of all the coils at the temperatures at which they were originally said to be correct. For his comparisons he employed Carey Foster's method, and devised a special form of bridge which after this time was employed for the purpose for many years.

The Electrical Standards Committee was reappointed at the Swansea meeting in 1880, and in the following year 1881, at York, one of the present authors (R. T. G.) became connected with the work; he was formally appointed Secretary at the Southport meeting in 1883, and from that date up to the year 1919 the coils were in his charge. They are still at the National Physical Laboratory. The Committee was dissolved in 1912, when its Reports were collected in a volume published by the Association under the editorship of Mr. F. E. Smith (now Sir Frank Smith, Secretary, Royal Society). Up to that date comparisons of the coils among themselves were continually in progress. Between 1881 and 1884 their values were determined in ohms and also in terms of the length of a column of mercury by Lord Rayleigh and Mr. Glazebrook. In 1888 a further very detailed examination of their values was made by Mr. Glazebrook and Mr. Fitzpatrick. In 1908 Mr. F. E. Smith reported very fully on their values and on the changes which had occurred; while the concluding portion of this paper consists of an account of a comparison made during the current year by Dr. Hartshorn at the National Physical Laboratory and a discussion of the results up to date.

The records show that most of the coils have changed appreciably during their long life, but that the two platinum coils marked 35 and 36 [1] in the original table have remained unchanged.

TABLE II.

RESISTANCE OF MERCURY COLUMN
100 CM. LONG AND 1 SQ. MM. SECTION AT 0° C.
IN B.A. UNITS.

Value found in 1881 by Lord Rayleigh, corrected for temperature of cups .	= 0·953 88 B.A.U.
Value found in 1888 by R. T. G. .	= 0·953 52 B.A.U.

RESISTANCE OF 1 B.A. UNIT
IN TERMS OF LENGTH OF MERCURY COLUMN.

Value found in 1881 by Lord Rayleigh	= 104·842 cm.
Value found in 1888 by R. T. G. .	= 104·875 cm.

The relative changes are known during the period in question, and Table II, based on Sir Frank Smith's Report of 1908, is of importance as showing that during the period 1880 to 1888 the value of the B.A. unit expressed in terms of mercury remained unaltered. The diagram and tables given later in the Report enable the changes which have taken place to be followed in detail.

[1] About 1880 the coils were re-marked, and these coils have since been known as D and E.

TABLE III.

RESISTANCE OF COILS F AND FLAT IN TERMS OF MERCURY.

(LENGTH OF COLUMN OF 1 SQ. MM. SECTION AT 0° C.)

Values found by Lord Rayleigh in the year 1881 :

F at 16·0° C.	= 104·805 cm.
FLAT at 16·0° C. . . .	= 104·871 cm.

Values found by Mr. Smith in 1908 for the resistance of the coils in 1881, assuming them to have altered between 1881 and 1908 by the amounts shown in the British Association Reports :

F at 16·0° C.	= 104·808 cm.
FLAT at 16·0° C. . . .	= 104·874 cm.

The next table (Table III) gives the values of two of the platinum-silver coils examined by Lord Rayleigh in 1881 and Sir Frank Smith in 1908. It shows that, allowing for the recorded alterations in these coils during that period, the value assumed for the B.A. unit was satisfactorily known. The point of most importance which emerged from Sir Frank's measurements of 1908 was the permanence of the two platinum coils. A reference to Table I shows an apparent change of 0·2 in the standard temperature of No. 36 (E) between 1865 and 1867. It would appear from Table IV that this apparent change was not a real one but arose from some error in the 1867 experiments. At any rate Table IV, which is brought up to date

TABLE IV.

Differences between the Values for the Platinum Coils D and E at 16·0° C.

Year.	Difference E—D. Parts in 100,000.	Year.	Difference E—D. Parts in 100,000.
1865	59	1888	60
1866	59	1908	60
1867	—1	1932	59 using 0·1 amp.
1876	63		60 using 0·12 amp.
1879–81	50		65 using 0·2 amp.

Note.—A change in temperature of 0·1° C. causes a change in resistance of the coils of 31 parts in 100,000.

by the inclusion of Dr. Hartshorn's observations of 1932, gives the values observed for the difference E — D between these coils, and shows that with this one exception this difference has lain between 0·00059 B.A.U. and 0·00063 B.A.U. during the whole sixty-seven years of their life. This will appear all the more remarkable when it is remembered that an error of 0·1 in the temperature means a change of resistance of 0·00031 B.A.U., while a variation in the measuring current of from 0·1 to 0·2 ampere produces an alteration of 0·00006 B.A.U., a larger amount than the whole change observed.

The inference is clear that during this period these two coils have retained their values unaltered, and this is confirmed by the following statement of values taken from a later table in this Report:

Values * of Coils D and E in B.A. Units in 1888, 1908 and 1932, obtained from Comparison with Mercury Tubes, assuming the Resistance of 1 metre of Mercury to be 0·95352 B.A.U.

Coil.	1888. R. T. G.	1908. F. E. S.	1932. L. H.
D	1·00013	1·00012	1·00011
E	1·00073	1·00072	1·00071

* See Table VII.

We come now to the detailed account of the recent work at the National Physical Laboratory by one of us (L. H.).

The old standard resistance coils of the British Association, made in 1865 by Matthiessen and Hockin, have been re-measured during 1932, and a comparison of the results with the old values is of considerable interest.

Several features in the construction of the coils make it impossible to obtain the same precision in these measurements as is obtained with modern coils. The coils are embedded in solid paraffin wax, so that the attainment of thermal equilibrium with the bath containing them is not easy. It is, therefore, difficult to obtain the temperature of the coil itself, and as in some cases the temperature coefficient of the material is very large, the accuracy is almost entirely limited by the thermal conditions. Also the coils have no potential terminals. However, preliminary measurements having shown that certain of the coils had probably remained nearly constant over a period of more than sixty years, it was considered desirable to aim at an accuracy of 1 part in 100,000 in the present determinations. This requires an accuracy in temperature measurement for certain of the coils of ± 0·003° C., and although it is hardly likely that this could be realised, the general consistency of a large number of observations has shown that the temperature was usually correct to ± 0·01° C. The coils were immersed in a bath of water, which was surrounded on all sides by cork lagging, and kept throughout the measurements in a constant-temperature vault. The measurements were made by means of a Smith bridge, assembled with standard manganin coils in an oil-bath, kept by means of a thermostat at 20° C. in an adjoining room. The terminal rods of the B.A. coils dipped into mercury cups, and from these cups double leads passed to the bridge in the adjoining room. The resistance of these leads is eliminated from the results by taking two readings in the manner described by Smith. Thus the observer did not have to approach the coils during the resistance measurements. The thermometer dipping into the water-bath was read from a distance by means of a telescope; readings were taken at intervals during each day, as well as before and after the resistance measurements, and it was always ascertained that the temperature had remained constant to 0·01° C. for several hours before each measurement. The mercury thermometer used was graduated in hundredths of a degree, and was calibrated on the hydrogen scale.

A factor of some importance is the heating effect of the measuring current. This has, of course, long been known, but as the magnitude of the effect is surprisingly large for some of the coils, and as no record of it appears to exist, it was measured in each case. The procedure was as follows: The galvanometer circuit was kept permanently closed, and when balancing the bridge the current was reversed, but was allowed to flow for as short a time as possible. Readings were obtained, first with as small a current as would give the required sensitivity, then with rather larger currents. The relation between bridge reading and the square of the current strength was always approximately linear, and thus the resistance corresponding to 'zero current' and to any other values of current was readily obtained. The actual value of current used in the older comparisons is not known, but the usual practice was to connect two quart size Leclanché cells in series with the bridge, which had an over-all resistance of a little more than 1 ohm, when 1-ohm coils were being compared. A trial experiment has shown that the total current obtained in this way is about 0·5 ampere, which means that the current in each coil was about 250 mA. This probably represents the maximum current used in the older comparisons. Its heating effect has been found to cause an error of as much as 5 parts in 10,000 for certain of the coils, but there is no doubt that in the more recent comparisons, particularly those of 1908, there is no question of an uncertainty of this magnitude. An examination of the results suggests that a current of the order of 120 mA. was used on this occasion, and for purposes of comparison this will be assumed to represent the standard condition. The results of the 1932 measurements given in Table V show the values for 'zero current,' 120 mA., and the maximum correction, i.e. the difference between the values for 'zero current' and 250 mA. The values obtained in 1908 are given alongside of those for 1932 with 120 mA. for the purpose of comparison.

A glance at Table V is sufficient to show that there have been no very large changes in the values of the coils in the last twenty-four years. In all cases the change is less than 2 parts in 10,000, which must be considered very satisfactory behaviour, the more remarkable since, so far as is known, the coils are connected to the terminal rods by means of soft soldered joints. In spite of this fact and also of the presence of the paraffin wax in which the coil is embedded, the coils are probably as satisfactory as standards of resistance as when they were first constructed sixty-seven years ago. The paraffin wax has become discoloured, being now yellow with age, and in some cases having acquired a greenish tinge from its chemical action on the copper terminal rods, and on this account the insulation was suspected as early as 1886. However, at that time the leakage resistance between coil and case was measured and found to be of the order of 8,000 to 10,000 megohms. The insulation was again tested in 1890 and found to be several thousand megohms. Measurements made in 1932 gave the following values:

INSULATION RESISTANCE, 1932.

Coil	Insulation Resistance. Megohms.	Coil	Insulation Resistance. Megohms.
A	9,000	E	1,000
B	40,000	F	300
C	1,000	G	4
D	4,400	FLAT	200

The value is definitely low in some cases, but not low enough to affect the resistance measurements by an appreciable amount.

In the following paragraphs the significance of the results is considered from several points of view of practical importance.

Table V.

Results obtained in 1932 for the British Association Standard Resistance Coils of 1865.

Values at 16·00° C. in terms of the B.A. Unit determined by the relation 1 International Ohm = 1·01367 B.A. Units.*

Coil.	Material.	Value for Zero Current. 1932.	Value for 0·120 amp. 1932.	Value, 1908.	Heating Correction for 250 mA.	Temperature Coefficient.
A	Pt–Ir	1·000 55	1·000 67	1·000 50	49×10^{-5}	148×10^{-5}
B	Pt–Ir	1·000 32	1·000 42	1·000 26	44×10^{-5}	148×10^{-5}
C	Au–Ag	1·001 15	1·001 16	1·001 01	4×10^{-5}	70×10^{-5}
D	Pt	1·000 12	1·000 19	1·000 20	28×10^{-5}	308×10^{-5}
E	Pt	1·000 69	1·000 79	1·000 80	40×10^{-5}	306×10^{-5}
F	Pt–Ag	1·001 02	1·001 05	1·000 88	11×10^{-5}	27×10^{-5}
G	Pt–Ag	1·001 01	1·001 04	1·001 03	13×10^{-5}	28×10^{-5}
Flat	Pt–Ag	1·000 48	1·000 50	1·000 53	9×10^{-5}	27×10^{-5}

* In 1892, in accordance with the experiments made at the Cavendish Laboratory, the value of the ohm (10^9 C.G.S. units) in B.A.U. was taken as 1·01358 B.A.U., and became the unit in general use. In 1903 it was shown by Mr. Smith that this unit was equal to 106·291/106·300 international ohms. Thus the international ohm = 1·01367 B.A.U.

(i) *The Platinum Coils D and E.*

From an examination of the available data in 1908 Mr. F. E. Smith concluded that the platinum coils had probably remained constant since 1867, but that all the other coils had changed. The question of constancy is of such importance that a special study has been made of these two coils. About forty observations were made on each coil in the temperature range 15° to 17° C. over a period of four weeks. The results, expressed in terms of the B.A. unit of Table V, could be represented as follows :

Coil D . . $R_t = 1·000\ 12 + 0·003\ 08\ (t - 16·00°\ C.)$

Coil E . . $R_t = 1·000\ 69 + 0·003\ 06\ (t - 16·00°\ C.)$

The mean deviation of all the observed points from the values calculated from these equations was 2·5 parts in 100,000, which corresponds to a temperature difference of 0·008° C. Greater accuracy could not be expected from coils of this construction, and it may be concluded that the coils are at present in a stable condition represented by these equations. The values given in 1908 for the resistance of the coils D and E at 16·0° C. are 8 and

11 parts respectively higher than those given above. However, the above values are corrected to correspond to 'zero current,' and no such correction was made in previous measurements. The magnitude of the correction is shown in Table IV, and it will obviously account for a discrepancy of this order. It was found that when the current through the coil was 0·12 ampere the 1908 values were reproduced to 1 part in 100,000. It is interesting to note that, owing to the difference in the heating corrections for the two coils, the value for the difference between them varies with the current. The values for this difference, obtained on various occasions, have been given in Table IV, from which we conclude that this difference has remained constant since 1865, and that the measuring current used was of the order of 0·12 ampere. (The low value of 1867 has long been considered as due to an observational error.)

The values obtained for the temperature coefficients are of interest. The following table shows the values obtained on various occasions:

Temperature Coefficients of the Platinum Coils.

B.A. Units per 1° C.

Coil.	1880.	1888.	1908.	1932.
	$\times 10^{-5}$	$\times 10^{-5}$	$\times 10^{-5}$	$\times 10^{-5}$
D	308	308	312	308
E	304	302	314	306

It is evident that the temperature coefficient of the wire is still very near to its original value, although it is far removed from the value for pure platinum (about 400×10^{-5}).

(ii) *The Variations in the Alloy Coils.*

Having satisfied ourselves that the platinum coils had remained unchanged, the changes in the other coils were examined. It was not considered necessary to take so many observations on these coils as on the platinum ones, but in each case a few observations were made at a temperature slightly above 16° C. and a few at a temperature slightly below 16° C. The value at 16·0° C. was deduced from the two sets. In every case the difference between the two sets of values was consistent with the 1908 value of the temperature coefficient, which is reproduced in Table V, together with the resistance values at 16·0° C. and the heating correction.

In the older British Association Reports the values assigned to these coils were usually obtained on the assumption that the mean value of the coils at the temperatures at which they were originally stated to be correct had not altered: in other words, the results were expressed in terms of the mean B.A. unit at the time. Mr. F. E. Smith showed in 1908 that it would almost certainly be more correct to assume that the platinum coils alone had remained unaltered, and our results support this conclusion. Acting on this assumption, and taking the old values for the differences between the coils, Mr. Smith was able to give a table of the values of the coils in terms of the original B.A. unit (1867). Our results enable us to bring this table up to date (Table VI). This table is of great interest as showing the most

TABLE VI.

RESISTANCES AT 16·0° C. IN TERMS OF THE ORIGINAL B.A.U. (1867).

(VALUES OBTAINED THROUGH THE TWO PLATINUM COILS D AND E.)

Coil.	Material.	1867.	1876.	1879–81.	1888.	1908.	1932.	Maximum Difference.
A	Pt–Ir	1·000 00	1·000 77	1·000 56	1·001 47	1·001 22	1·001 40	147×10^{-5}
B	Pt–Ir	1·000 29	1·001 21	1·000 80	1·001 04	1·000 98	1·001 15	92×10^{-5}
C	Au–Ag	1·000 50	1·001 41	1·001 01	1·001 46	1·001 73	1·001 89	139×10^{-5}
D	Pt	1·000 92	1·000 92	1·000 92	1·000 92	1·000 92	1·000 92	0×10^{-5}
E	Pt	1·001 52	1·001 52	1·001 52	1·001 52	1·001 52	1·001 52	0×10^{-5}
F	Pt–Ag	—	—	1·000 16	1·000 72	1·001 60	1·001 78	162×10^{-5}
G	Pt–Ag	1·000 22	1·000 30	0·999 82	1·000 25	1·001 75	1·001 77	195×10^{-5}
H	Pt–Ag	1·000 20	—	—	1·000 42	1·000 44	—	24×10^{-5}
FLAT	Pt–Ag	—	—	1·000 79	1·001 20	1·001 25	1·001 23	44×10^{-5}

probable variations in the values of the coils throughout their whole existence. The values are plotted in Fig. 1. It is apparent from this diagram that the values for 1876 are all comparatively high. At this time the temperature was only observed to 0·1° C., and an error of this amount for the platinum coils would lower all the values to those shown by the dotted lines, which values are regarded as rather more probable than those tabulated.

THE B.A. STANDARD RESISTANCE COILS.

Values in terms of the Original B.A. Unit (1867).

A B — Platinum-Iridium
C — Gold-Silver
D E — Platinum
F G H &
FLAT — Platinum-Silver

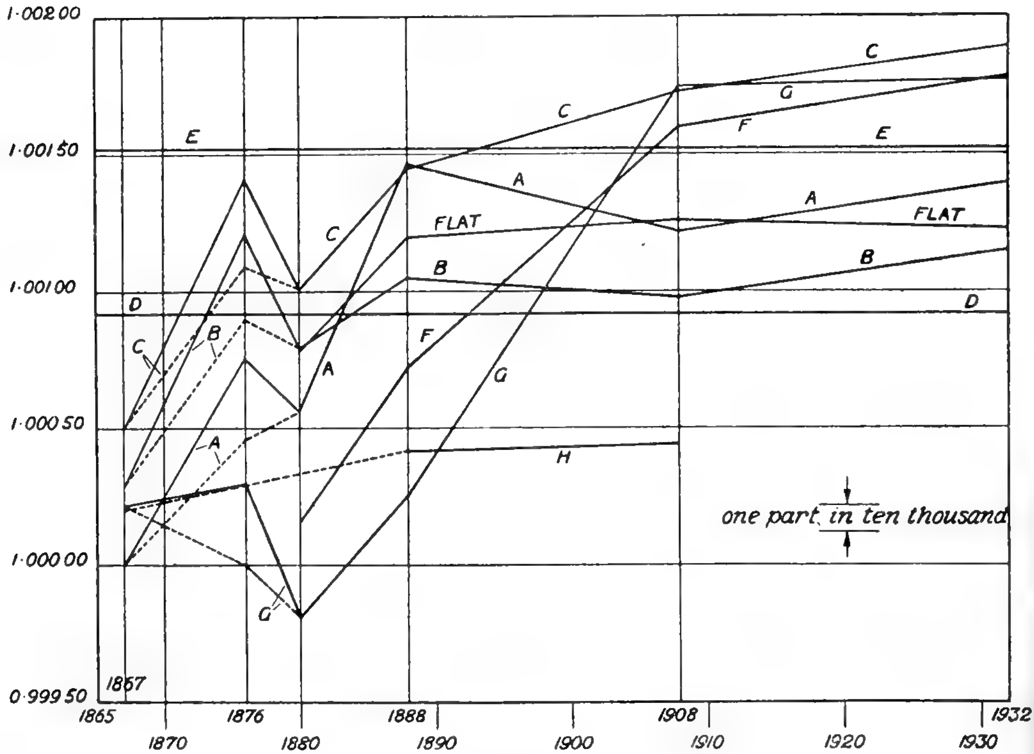

FIG. 1.

The curves show clearly the remarkable constancy of the coils in the last twenty-four years, even in the case of coils F and G, which had changed very considerably before that time. This constancy is probably the result of the storage of the coils at constant temperature throughout the whole period. On one or two occasions between 1879 and 1888 the coils had been tested in melting ice, and it was considered that this was probably the cause of some of the observed changes. Throughout the whole of the recent observations the temperature has not differed from 16·0° by more than 1° C.

Two other interesting tables of values recording the history of these coils were given by Mr. F. E. Smith in 1908, and these have also been brought up to date. Table VII records the values of the coils in terms of the B.A. unit in general use during the period 1891–1903, and Table VIII gives the values obtained on a number of occasions in centimetres of mercury.

TABLE VII.

VALUES OF COILS at 16·0° C. in B.A. Units in 1888, 1908 and 1932, obtained from Comparison with Mercury Tubes, assuming the Resistance of 1 metre of Mercury to be 0·953 52 B.A.U.

Coil.	1888.*	1908.	1932.†
A	1·000 68	1·000 42	1·000 59
B	1·000 25	1·000 18	1·000 34
C	1·000 67	1·000 93	1·001 08
D	1·000 13	1·000 12	1·000 11
E	1·000 73	1·000 72	1·000 71
F	0·999 70	1·000 80	1·000 97
G	0·999 36	1·000 95	1·000 96
H	0·999 63	0·999 64	—
FLAT	1·000 23	1·000 45	1·000 42

* Values subject to a probable error of 4 parts in 100,000, due to the fact that the terminals of the mercury tubes were not exactly at 0° C. No correction has been made for this, since the probable error of the observations was of this order.

† Values for a current of 0·12 ampere (see Table V).

(iii) *The Value of the B.A. Unit.*

When changes in the relative values of the coils were first noted, the B.A. unit was taken, as already stated, to be the mean value of the six coils A, B, C, D, E and G at the temperatures at which they were originally stated to be equal. This has been referred to as the mean B.A. unit for the year in question. The data now available show that the changes in the unit so defined have been approximately as given in Table IX (p. 429).

The value generally used for the ratio of the international ohm to the B.A. unit is—

1 international ohm = 1·013 58 B.A. unit (1892),

this being the value accepted in 1892. However, as the coils were changing in a manner not accurately known, it is evident that the unit in practical use at the Laboratory, normally the mean of all the coils, was a variable quantity. For example, in 1903 Mr. F. E. Smith made an estimation of this ratio, taking the platinum-silver coils as standards of reference (these are the ones

TABLE VIII.

VALUES AT 16·0° C. OF THE B.A. COILS IN CM. OF MERCURY IN 1881, 1888, 1908 AND 1932, OBTAINED FROM COMPARISONS WITH MERCURY STANDARDS.

Coil.	1881. Values deduced from Lord Rayleigh's Determination of the Specific Resistance of Mercury. F and FLAT were used; for relative values of coils see Table III.	1888. Values at time of Dr. Glazebrook's Determination. F, G and FLAT were used; for relative values of coils see Table III.	1908. Values determined directly through N.P.L. Mercury Standards of Resistance, constructed in 1903.	1932.* Values determined directly through N.P.L. Mercury Standards, constructed in 1912, re-calibrated in 1924.	Maximum Difference.
	cm.	cm.	cm.	cm.	cm.
A	104·847	104·946	104·918	104·936	0·099
B	104·872	104·901	104·893	104·910	0·038
C	104·894	104·945	104·972	104·988	0·094
D	104·885	104·888	104·887	104·886	0·003
E	104·948	104·951	104·950	104·949	0·003
F	104·805	104·843	104·959	104·977	0·172
G	104·769	104·807	104·974	104·975	0·206
H	—	104·836	104·837	—	0·001
FLAT	104·871	104·898	104·922	104·919	0·051

* Values for a current of 0·12 ampere in the coil.

which can be measured most accurately), assuming they were accurate in 1888 and estimating from the records the changes which had occurred since that time. The value obtained was—

$$1 \text{ international ohm} = 1{\cdot}013\,67 \text{ B.A. unit (1903)},$$

and this value has been used at the Laboratory for some years. It is to be noted that, in the light of our present knowledge, neither of the above values represents the original B.A. unit. It follows from Table VI that this unit is determined as nearly as can be ascertained by the relation—

$$1 \text{ international ohm} = 1{\cdot}014\,39 \text{ B.A. unit (1867)}.$$

Table IX.

Relative Values of the Mean B.A. Unit.

Year.	Value.	Year.	Value.
1867	1·000 00	1888	1·000 53
1876	1·000 43	1908	1·000 76
1879–81	1·000 18	1932	1·000 85

Of course since 1903 mercury tubes have formed the fundamental standards, and the more recent values have not influenced any actual measurements.

Appendix.

The Manganin Resistance Coils.

In 1895 the British Association obtained from Otto Wolff of Berlin resistance standards of the pattern used at the Physikalisch-Technische Reichsanstalt, and described by Dr. St. Lindeck in the British Association Report for 1892. The wire is of manganin insulated with silk, and after winding the coil was heavily coated with shellac varnish and then baked. In use the coil is completely immersed in oil, and the outer case was perforated so as to allow the oil to come into contact with the wire and thereby control its temperature. Four such standards each of nominal resistance 1 ohm were obtained, and in due course deposited at the National Physical Laboratory. The temperature coefficients of these coils were found to be only 1 to 2 parts in 100,000 per 1° C., and it became a comparatively simple matter to compare them with an accuracy of 1 part in a million. They therefore largely displaced the old B.A. coils for general standardising work.

The history of these coils is shown in the following table and chart. Two of them, Nos. 1690 and 780, have shown remarkable constancy, and even at the present time they are probably the most satisfactory standard coils which the Laboratory possesses. In 1911 each of these two coils was provided with an oil-tight case, which was filled with paraffin oil and hermetically sealed. The improvement in performance which followed this treatment is very striking, and leaves little doubt that most of the changes in resistance previously observed were due to the variations in atmospheric humidity. The coils numbered 381 and 147 were not hermetically sealed. The change in resistance of 381 from 1908 to 1932 is of the same order as that shown by most of the older B.A. coils ; the change in 147 has been very

THE MANGANIN RESISTANCE COILS OF 1895 (P.T.R. TYPE).

Values at 20° C. in International Ohms.

Differences from Nominal Value (1 ohm): Parts in a million.

Coil. No.	1901.	1903.	1907.	1910.	1911.	1914.	1919.	1926.	1928.	1930.	1932.	Maximum Change.
1690	70	71	34	60	41	42	35	31	30	30	26	45
780	−20	−23	−22	+25	−3	−8	−10	−7	−4	−2	+3	48
381	130	156	152	179	180	200	—	—	—	—	277	147
147	−2130	−2030	—	—	—	—	—	—	—	—	−1584	546

much larger. This was found to be a relatively poor coil as early as 1903, and it was not measured in the interval 1903-31, but it is interesting to note

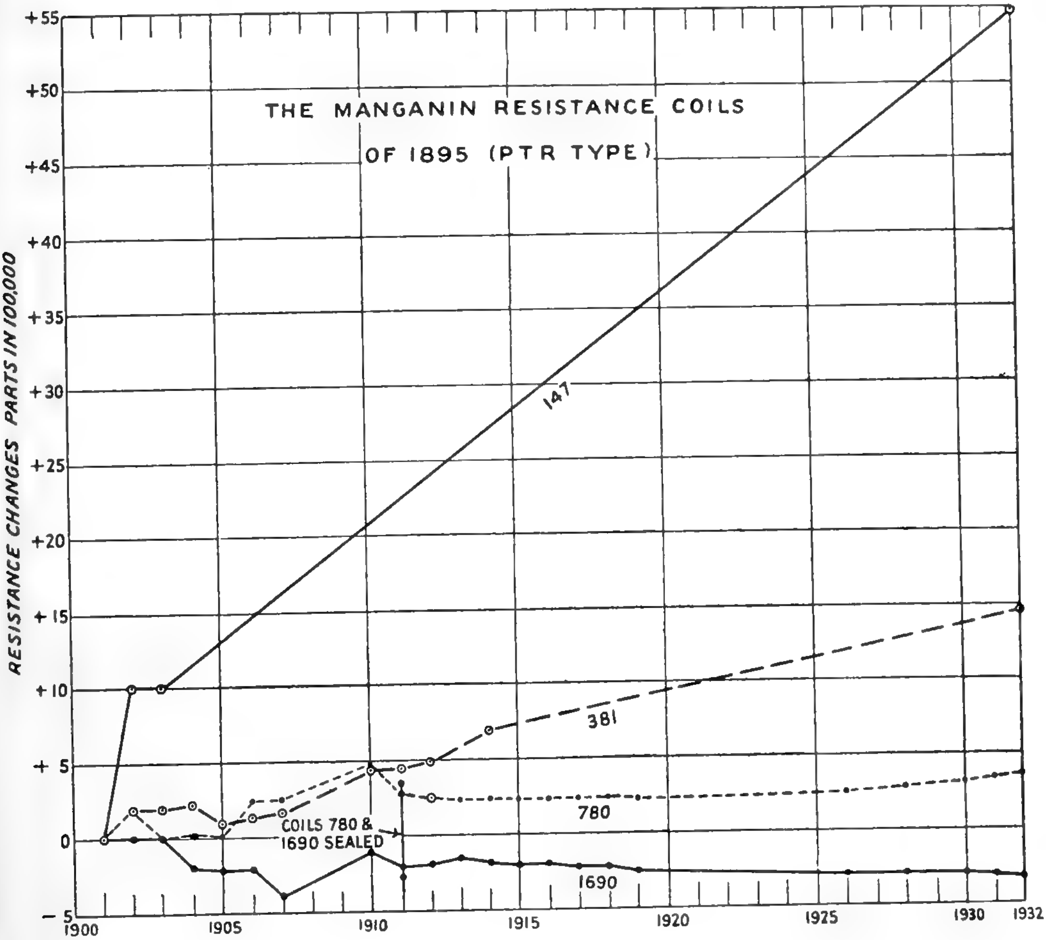

FIG. 2.

that at the present time the value is quite stable from day to day, and that the average rate of change of resistance is smaller than that of many modern coils.

L. H.

EVENING DISCOURSES.

FIRST EVENING DISCOURSE

FRIDAY, SEPTEMBER 2, 1932.

PLANT PRODUCTS OF THE EMPIRE IN RELATION TO HUMAN NEEDS

BY

SIR A. W. HILL, K.C.M.G., F.R.S.

WHEN we come to consider human needs in the light of products derived from plants, it is interesting to notice how ' relative ' they are and how they tend to change in the course of time.

Those plants which yield food, beverages, spices and drugs in particular, as well as those yielding timber for construction and fuel, fibres for clothing and cordage, etc., and fodder for cattle, have always been of primary and universal importance, and may be regarded as among the essential needs of the human race.

There are, however, constant changes and new developments in human needs as regards the vegetable kingdom, which to some extent may be regarded as artificial or induced, since they are concerned with some of the vagaries or artificial needs of our modern civilised conditions.

As a contrast with the primitive conditions of early life in Britain, when our ancestors were content to clothe themselves with skins which they dyed with woad, the modern desire for gramophones may be cited, for some gramophone needles are made from the spines of a Prickly Pear (*Opuntia*) and are sold in packets for the purpose. Opuntias, as is well known, have overrun much of N.E. Australia since they were introduced there from America. Then there is the desire of some youths to appear well dressed by the addition of a stiff white collar, which may be composed of celluloid. For the manufacture of these articles, which do not need the washtub, large quantities of camphor are employed in addition to cellulose derived from vegetable sources.

Another somewhat deplorable human need, at any rate when carried to such excesses as we see it in America, is the present induced human need—or rather craving—for newspapers which is resulting in the destruction of the magnificent forest trees of the Empire in Canada and Newfoundland. Yet another human need of quite recent growth, depending on the vegetable kingdom and so largely supplied by the British Empire, is that of motor tyres, and every sort of rubber article made from the rubber contained in the latex of *Hevea brasiliensis*. This Brazilian plant was first sent out through Kew to the Far East; and to this introduction our propensities for scribbling may perhaps be attributed, since our modern human need for fountain-pens is satisfied from our rubber supplies.

To supply the needs of the traffic of London, until recently the magnificent Jarrah trees (*Eucalyptus marginata*) of Western Australia have been felled to supply wood blocks for paving the streets of the capital of the British Empire, while many other Empire timbers furnish sleepers for our railways.

I may also perhaps—with the permission of our medical friends—be allowed to allude to our present-day habits of cleanliness !—I might almost say our excessive craze for washing, and for the use of soaps with their many and varied perfumes. For all this we are dependent on the vegetable kingdom, since the oils and fats which are the basis of our soaps, as well as the essential oils which furnish the scents, are derived in the main from plants cultivated in one or other of our tropical possessions, and in many cases introduced to our domains from other parts of the world where they are found in the wild state.

Socrates has said, ' I hold that to need nothing is divine, and the less a man needs the nearer does he approach divinity ' ; but in these modern days we have to follow the general trend of events, and the economic botanist seeks to satisfy our human needs, whether natural or artificial, as far as he may be able.

Fortunately for Great Britain, it is possible to meet the growing demand from the vast resources of the Empire ; and this year, meeting at York—close to Hull, one of the great centres of applied botany, the home of one of the largest seed-crushing and oil-extracting centres of the world, not forgetting also the manufacture of cocoa and chocolate in York itself—and with the deliberations at Ottawa fresh in our minds, it seems fitting more seriously to consider some of the contributions which the plant products of our Empire make to satisfy our present-day human needs and cravings.

The subject is so vast that, were I to speak of all the plant products of the Empire which help to minister to our daily wants and enter fully into our domestic economy, little as we think of it, I could easily address you for several hours and thoroughly exhaust your patience. I must, however, confine myself to the more essential products, and first let me draw your attention to some of the food products which are supplied to us from our overseas dominions and colonies.

Among these may be mentioned wheat, which comes to us from Canada and Australia ; rice from the Federated Malay States, Burma, British Guiana and West Africa ; tapioca from the Federated Malay States ; and sugar from the West Indies, British Guiana and Natal.

The home market is largely dependent on fruits coming to us from all parts of the Empire, which include—

Bananas from the West Indies.

Citrus fruits from the West Indies, Australia, South Africa, Palestine and Cyprus.

Apples from Canada, Australia, New Zealand.

Grapes from South Africa and Australia (raisins).

Pineapples from Jamaica, South Africa, Straits Settlements.

Pears and Peaches from South Africa.

Edible Oils are furnished by West Africa (palm oil), Malaya, Ceylon, the West Indies and the Pacific Islands (coconut oil or copra). Ground-nuts we get from India and West Africa, while the *essential oils* include geranium oil from Kenya, patchouli from the Seychelles, and clove oil from Zanzibar.

Foods for animals bulk largely in imports to this country from overseas, including linseed from Canada and India ; cotton, rape and ground-nuts from India ; the last with palm kernels we also get from West Africa ; all of which are the main constituents of various oilcakes.

Important Food Accessories.—Spices and condiments are supplied from India and the colonies, and include pepper, cloves, nutmegs, cinnamon, desiccated coconut, and ginger. Among beverages may be mentioned cocoa, tea, coffee and wines (South Africa and Australia).

Gums, Resins and Drying Oils, of great importance in our manufactures, include linseed from India and Canada, tung oil (experimental in many parts of the Empire), rubber from Malaya, Ceylon and Southern India, gum arabic from West Africa, the Sudan and Somaliland, kauri gum from New Zealand, balata from British Guiana, and turpentine from India, British Honduras and the Bahamas.

Among some important *Drugs, Medicines, etc.*, may be mentioned cinchona from India, chaulmoogra, which has recently been introduced to many of our tropical colonies as a cure for leprosy, and liquorice grown at Pontefract.

Tobacco comes to us from South Africa, Nyasaland, Rhodesia, Jamaica, Mauritius, Cyprus and India.

Clothing includes cotton from India, the Sudan, the West Indies, Nigeria, Uganda, etc.

Tanning materials include wattle barks from South and East Africa, and sumach from Cyprus.

For *transport* we have timber for ships, wharves and lock gates ; fibres for ropes (Mauritius hemp, and sisal from Kenya and Tanganyika) ; kapok for lifebelts.

In the more thickly populated parts of the Empire, the possibility of exporting vegetable products is dependent on the peoples of these countries being able to provide themselves with food. In the humid tropics the main food products consist chiefly of rice and root-crops such as taroes, eddoes, tannias, yautias, yams, tapioca and sweet potatoes, while in the dry tropics they consist of sorghums and various small millets, numerous pulse crops largely replacing the necessity for meat. In certain parts of Africa, also, the plantain and banana are the staple food crops of certain tribes. This is an aspect of Empire production which is liable to be lost sight of, as the resulting products do not appear on the world's markets, and attention is only drawn to their importance in times of famine and crop failure.

There is also an immense amount of vegetable production within the Empire, grown as grazing and fodder for live stock, which comes to this country in the form of dairy produce, wool, meat, etc.

There are, again, vegetable industries which have disappeared or are disappearing on account of the production of synthetic substitutes, or on account of changes in fashion. Of the former, indigo, camphor and vanilla are examples ; of the latter, Sea Island cotton, and most spinning fibres. Jute is decreasing in demand on account of the bulk handling of grain, etc., while cotton and flax have a strong competitor in artificial silk. All these are, or were, important Empire products.

SECOND EVENING DISCOURSE

TUESDAY, SEPTEMBER 6, 1932.

THE USES OF PHOTOELECTRIC CELLS

BY

C. C. PATERSON, O.B.E.

THE photoelectric cell has been known to science for years. It is a device which passes an electric current only when light falls on it, and has been evolved as a consequence of the study by physicists of the connections between light, electricity and matter. The electric currents given by these cells are so minute that until recently only the physicist with his delicate apparatus was able to measure them, but with the advent of the thermionic valve with its power of magnifying currents, the engineer-physicist realised the possibility of applying the photo-cell to numerous everyday uses.

So numerous and varied, indeed, are these applications that I can only describe a few typical ones, chosen to illustrate particular properties of these cells.

The emission of negative electricity from a brightly illuminated zinc plate was demonstrated by Hallwachs after he had received a hint from the work of Hertz. This emission is now called the photoelectric effect. (*Demonstration—The image of an electroscope was thrown on to the screen, and the collapse of the leaves showed the discharge of electricity from an electrically connected zinc plate when this was illuminated with light from an arc lamp.*)

Modern photo-cells employ more highly sensitive surfaces than zinc, and the sensitive surface is enclosed in an evacuated bulb.

This type of cell passes an electric current strictly proportional to the illumination falling on it—a property which enables the cell to be used for a number of quantitative purposes, such as the measurement of area. (*Demonstration—A photo-cell was exposed to the light from a uniformly illuminated opal window. The decrease in electric current consequent upon the reduction of the radiating area by the interposition of an irregularly shaped surface* (e.g. *an animal hide*) *gave a measure of the area of the surface.*)

Certain types of cell respond most strongly to light of one colour, while other types are more affected by other colours. This can be demonstrated by exposing a photo-cell to a spectrum thrown on a screen. (*Demonstration—A cæsium cell and a potassium cell exposed to spectral colours gave their maximum response in the infra-red and in the blue respectively.*)

We now come to consider in more detail the practical application of the photo-cell. As an example of simple ' trigger-action ' we may take the case of the photoelectric street-lighting unit which switches on the lights at the approach of darkness, extinguishing them again in the morning. (*Demonstration.*) This ' trigger-action ' is also used for counting objects as they pass along a moving band. (*A demonstration of a photoelectric counter which counted red balls rolling along a track but allowed blue balls to pass without recording their passage was given.*)

The fundamental properties of photo-cells make it possible to employ them in photometry instead of the human eye. The fact that cells respond differently from the eye in the matter of colour necessitates the use of filters and other devices in photoelectric photometry. It is also possible to measure the temperature of lamp filaments very accurately by means of a ' bridge ' employing red-sensitive and blue-sensitive cells. (*A demonstration of the use of such an apparatus to detect slight changes in light-colour was then given.*)

Since legislation is now making it illegal to allow the emission of black smoke from factory chimneys, it is fortunate that we have in the photo-cell a means of continuously indicating (or recording) the density of the smoke in furnace flues. A beam of light passes across the flue and falls on a photo-cell connected in a valve circuit with an indicator placed in the furnace room. The passage of dense smoke partially obscures the light, and the indicator (perhaps reinforced by an alarm bell) gives warning that the stoking is not being efficiently performed. (*This principle was demonstrated with the aid of a glass-fronted box into which smoke could be blown.*)

Thus far we have considered cases where the cell controls indicators, counters, etc., but, with the assistance of gas-filled relays and contactors, powerful machines may be actuated by light impulses. An electric door-opener operated by the interception of a beam of light by a person approaching the door is an example of this. When the person has both hands occupied, such a device has very real value in saving time and labour. (*Demonstration.*)

Although a great many people are familiar with talking films, comparatively few are aware that without the photo-cell this method of sound reproduction would be impossible. The passage of light and dark strips recorded on the edge of the film, through a beam of light falling on a photo-cell, causes minute variations in the current through the cell. These fluctuations are amplified and passed into a loud-speaker, where they are converted into sound. (*Demonstrations of reproduction and of the special ' recording lamp ' used for recording the sounds on the films were given at this point.*)

By means of photo-cells used in much the same manner as that already described it is possible to produce sound-waves of any desired wave-form, or ' tone-quality.' (*Demonstration.*) Since it is largely the tone-quality which determines the recognisable characteristics of musical instruments, this principle may be of service in the construction of electrical musical instruments.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

THE Conference met in the Exhibition Buildings, York, on September 1 and 6, and in the absence of the President, Sir David Prain, through illness, was presided over by Dr. A. B. Rendle, who read the President's Address (below) after the following resolution had been unanimously passed by the delegates :

'That the warm greetings of the Delegates of Corresponding Societies assembled in conference at York be sent to the President, Sir David Prain, with an expression of their sincere sympathy with him in his illness, and earnest hopes for his complete and speedy recovery.'

The Conference was attended by a large audience, and 53 delegates signed the register, representing 59 societies.

Thursday, September 1.

ADDRESS ON

LOCAL SOCIETIES AND THE CONSERVATION OF WILD LIFE

BY LT.-COL. SIR DAVID PRAIN, C.M.G., C.I.E., F.R.S.,
President of the Conference.

LAST year the Corresponding Societies' Committee recommended the Council of the British Association to instruct the President of this York Conference to direct attention to 'the assistance local societies can render to the preservation of the amenities of their own areas and especially of the flora and the fauna of the countryside.' We know now that the time was ripe. The recommendation was accepted and acted upon by the Council of the Association on November 6, 1931 ; on November 27 the Council for the Preservation of Rural England set up a Wild Plant Conservation Board.

The message of the Association to its corresponding societies is precise. It is not now necessary to explain why local societies *should* help to preserve their local amenities and the flora and the fauna of their areas. Members of all local societies share the views expressed by the President of the Council for the Preservation of Rural England to a local society at Harrogate in 1930, and by the Chairman of the Estates Committee of the National Trust in his Rickman Godlee Lecture at University College, London, in 1931. What delegates to this Conference are asked to do is to beg their respective societies to consider how they *can* assist in preserving the amenities of their own areas and especially the flora and the fauna of their own sections of the countryside.

The message is neither a reasoned appeal to the intelligence of the delegates now present, nor is it an emotional appeal to their sentiments. It is a practical appeal to their collective will—an appeal to which they must respond, if local societies are to do anything to promote objects every one here has at heart. That appeal is made now, on behalf and in the name of our Organising Committee, with a confidence based on the belief that 'where there is the will, there should be a way.' To pretend that the way will be easy, would be idle and foolish; local societies will have to face difficulties so great that often the best they can hope to do is to find a way round them. It may not be amiss to consider some of these difficulties: 'to be forewarned' is sometimes equivalent to being forearmed.

One of the difficulties with which a local society will often have to contend is a lack of sympathy and understanding between its members and those of their neighbours who manage local public affairs. The search after knowledge for its own sake, and the application of knowledge on behalf of the community are equally praiseworthy, and may be equally time-absorbing pursuits; they are, however, intrinsically so unlike that mere lack of leisure may be enough to prevent mutual understanding. But while it requires two to disagree, it is always open to one to encourage sympathy. The objects of a local society as a rule make a more special appeal to its members than the general needs of the local community do: attempts to promote sympathy and establish understanding between local societies and local authorities are, therefore, less likely to be initiated by the latter. This does not make the establishment of mutual sympathy and understanding less desirable: all it indicates is that, as a rule, efforts in this direction must originate with local societies. One of the primary objects of any local society is to promote regional solidarity: one consequence of this fact is that a local society is at least as 'representative' of its local area as any specially elected local authority can possibly be, and at the same time escapes all risk of becoming pledged to the support of particular political principles or devoted to the promotion of particular private interests. The mere existence of a local society should suffice to show a local community that the pursuit of knowledge and the management of public affairs are closely related activities. Nothing but good can accrue to a local area in which those elected to conduct its public business hold friendly intercourse with, and make it their practice to consult, those of their neighbours who may be engaged in adding to knowledge of any kind.

Never is this benefit more likely to be evident than when a local society, anxious to preserve the amenities of its own area, finds it necessary to seek support. As the President of the Council for the Preservation of Rural England remarked at Harrogate, towns 'must expand and the suburb is a straggling compromise between town and country, ill-planned from the urban point of view and equally disregarding the landscape as such.' This applies as truly to the 'town-dormitories' that spring up so rapidly outside most urban boundaries before urban councils can take steps to extend their areas. Until forcible annexation takes place, parish and district councils, though able to insist that the dwellings in these dormitories shall comply with building regulations prescribed by the State, may have but a limited right to declare what type of building should be erected, and may have no power to decide that a particular site is unsuited for building upon. It is not difficult to appreciate why a particular local council may at times feel debarred from taking an active part in the efforts of a local society to preserve the amenities of its own area during the desecration of an estate advertised by a speculative builder as 'ripe for development.' But this affords no reason why a local society should neglect the duty of establishing friendly contact with the local authority concerned : the latter, if sympathetic, may refrain from action that might impede the efforts of an energetic local society.

We are all well enough aware that if every area in England possessed an active and influential local society and if every local society could rely on the support of its own municipal, or county, or district, or parish council, there would still be no assurance that the amenities of a single local area could be preserved : there are difficulties with which neither local authorities nor local societies can cope.

The main cause of these difficulties is a divergence of interest on the part of dwellers in towns and on that of ' those that reside much in the country.' This fact was familiar to classical authors ; in this country it inspired that 'Song of Corydon ' so effectively recited by the President of the Council for the Preservation of Rural England in his address on ' The Personality of English Scenery ' ; we can detect its influence in the letters written by Mr. White of Selborne during the early phases of the Industrial Revolution. For the moment, however, we are more concerned with modern manifestations than with the earlier history of this divergence of interest which, for a brief period, was so completely suppressed that we may be justified in considering its present prevalence as neither a survival nor a recrudescence, but as a new manifestation the origin of which deserves consideration.

The temporary disappearance of the ancient divergence of urban and rural interests which, it is fair to admit, was most warmly expressed by those who lived in the country, was one of the consequences of an appeal to English rural economy made by the captains of industry in manufacturing towns who were directly responsible for that Industrial Revolution which has done so much, since the days of the Rev. Gilbert White, to destroy the amenities and the flora and the fauna of the countryside by creating clouds of smoke that obscure the sun, discharging acrid fumes that vitiate the air, emitting fetid waste that pollutes our streams, and heaping barren mine tailings on what once was fertile soil. If those who cared for the amenities of their own areas at first failed to realise what the effect of these industrial activities must be, they were afforded a prolonged opportunity of appreciating the force of the saying that ' what cannot be cured must be endured.' This endurance had to continue till those who seek knowledge for its own sake brought partial relief by convincing captains of industry that they could reduce their costs if they consumed their smoke and might increase their gains if they turned some of their waste to economic account.

The migration to manufacturing towns of an appreciable proportion of the population of the countryside, which was another consequence of the Industrial Revolution, explains the appeal made by urban interests to rural economy for food to meet the needs of workers in towns no longer able to share in the task of raising food for themselves. The very change in social conditions which induced this urban appeal helps to explain the readiness of the response made to it by rural economy. But compliance with the request involved extension of cultivation ; extension of cultivation involved the issue of legislative injunction for the tillage of manorial waste, and the grant of legislative sanction for the enclosure of common land. Mere extension proving insufficient, English agriculture adopted the intensive methods of cultivation whose continued improvement has characterised its practice, through good report and ill, ever since. This has gone on, not only at home but in our overseas possessions, and not only in raising food for British workers but in supplying much of the raw material that has made British work possible since the Industrial Revolution began. Thanks to this activity, the divergence of interest between rural and urban dwellers, of which the

'Song of Corydon' supplies such clear evidence, gave place to a mutual understanding beneficial to both and advantageous to the commonwealth as a whole. Without the food and the raw material that rural economy was able to place at the disposal of manufacture, the Industrial Revolution might have been arrested. But for this demand on rural economy, English highways might not have received the macadamised surface which enabled those on whose aid industrial enterprise and rural economy alike depended for the distribution of food, raw material and finished goods, to substitute wheeled vehicles for more archaic means of transport.

But this was not the only advantage, nor, from the standpoint of local societies, was it the most outstanding benefit that England owed to the establishment of a rational understanding between rural and urban interests. Compliance with the legislative injunction to make economic use of manorial wastes caused rural economy to give attention to afforestation as well as to agriculture. Lines and belts of trees converted exposed highways into shady avenues and supplied shelter for fields in which crops were grown and herds were tended. Open spaces, neglected since their exploitation and spoliation by an earlier generation, and hitherto deemed unsuitable either for grazing or for tillage, were changed into woodland glades. To these activities many areas in England owe the amenities they now possess and the shelter for the flora and the fauna of the countryside they now provide.

If, twenty years ago, it could be said with some justice that, thanks to her rural economy, England could boast amenities which went far to compensate for the outrages inflicted on the countryside by her industrial system, we can hardly say this now. We have seen the effects of the substitution, in the utilisation of our timber supplies during the war, of the methods of commercial exploitation for those of forest management. We know that much of this damage is reparable, and that a sympathetic Forestry Commission, itself unsympathetically regarded, has the requisite work in hand. But we also know that the damage done during a season of exploitation often takes a century to repair, and there are many local areas where few of us may hope to see again the countryside we once knew. Nor is this all. We have seen, since the war ceased, and still see every day, damage done to our amenities that might easily have been avoided but that never can be repaired. This damage is not wholly due to the unrestrained activity of speculative builders. We observe public authorities taking an active part in the destruction of groves and avenues while engaged in modifying highways to meet the requirements of modern traffic, yet remaining powerless to prevent the conversion of their 'improved routes' into 'ribbon communities.'

This particular result, as most of us know, is one of the indications that urban interests no longer sympathise with or desire to understand rural requirements. We have been familiar, since the days of the statesman who told us, truly enough, that 'we are all socialists now,' with the pious hope of ardent urban reformers that the day may come when the highway from York to London shall have become one long, unbroken street. This urbane policy has already substituted for countless once beautiful examples of rural scenery the bungaloid tentacles of our larger towns. The author of *The Path to Rome* has explained more clearly than its advocates themselves the intellectual attitude which inspires the policy: 'Whenever you see a lot of red roofs nestling, as the phrase goes, in the woods of a hillside in south England, remember that all that is savagery; but when you see a hundred white-washed houses in a row along a dead straight road, lift up your hearts, for you are in civilisation again.'

Our hearts need not be unduly cast down because, for the past half-century, urban and rural aims and interests have been out of tune once more: we can, like our forbears, school ourselves to endure what we cannot cure. But most local societies, anxious to preserve the amenities of their own areas, must be prepared to face the opposition of convinced and earnest members of an influential school of thought, and may find that opposition supported by skilful propagandists influenced less, perhaps, by sympathy with urban ambitions than by prejudice against rural interests, who manifest their real feelings most clearly when they profess urban sympathy with rural wrongs as a means of enlisting rural support for urban policy. They have ready to hand the most powerful of weapons for their purpose—' the lie that is half a truth.'

But members of local societies are able to observe that when urban social reformers make the ' enclosure of commons ' the basis of a charge that English rural economy, a century and a half ago, deprived the rural population of certain hitherto acknowledged rights and privileges, the speakers omit to remind their hearers that this was the result of legislative action taken to enable English agriculture to comply with a request made by English industry. It may be conceded that the agricultural response to this industrial appeal was as free from altruism as the appeal which induced it. But there is no indication that the agricultural response was inspired by selfish motives : on the contrary, the benefits which accrued to rural economy were devoted to the advancement of public interests. That the industrial appeal may have been less unselfish than the agricultural response, is suggested by the fact that, the moment English industry found it possible to obtain supplies of food from other sources, English urban sympathy with English rural interests vanished like a ' morning mist.'

The impatience evinced by the representatives of urban constituencies when the needs of English agriculture are explained or discussed is due to something more than lack of understanding : it is in accordance with a familiar natural law. If it be true that ' gratitude for favours received ' is one of the traits which distinguish instinct from reason, it is equally true that one of the traits which distinguish reason from instinct is the propensity of man as an animal to dislike those he finds it convenient and thinks it safe to treat unjustly. This trait is perhaps more collective than individual, seeing that it is most manifest in social groups that are class-conscious and in members of the community who regard party allegiance as of more consequence than their duty to the State. But all those who serve the State in any capacity are only too familiar with what guides the action of most Government departments. Nor are many of us in our private capacities unaware of the existence of the tendency : we find ourselves, as members of committees, ready to approve lines of action and to adopt courses of policy which, as individuals, we should hardly dream of pursuing.

Nevertheless rural residents have more reasons than one for regarding with some forbearance the attitude towards country interests adopted by denizens of towns. If urban industrial workers enjoy the advantage of devoting their lives to tasks that demand constant attention, they suffer the drawback of having to expend their energies on occupations that soon cease to arouse interest in the labour they involve : the rural labourer enjoys the twofold benefit, thanks to the differences of the seasons, of variety of occupation and corresponding diversity of attention. This reduction of the urban industrial worker to the condition of a machine renders him especially susceptible to corresponding influence from those whose interest is served by misleading him. When the agencies engaged in the distribution of food, raw materials, and manufactured goods borrowed from Industry the idea of harnessing steam, they secured legislative sanctions as inimical to hitherto recognised rights as anything ever granted to rural economy. In the lay-out of their permanent ways and depots these agencies manifested as little regard for rural amenities as had been shown by the producer of minerals or the manufacturer of goods. All that prevented these new 'common carriers' from obtaining control of the destinies of the producers, the manufacturers, and the consumers they exist to serve was their devotion to the doctrine that 'competition is the life of trade.' It is, however, fair to say that these common carriers did nothing overt to impair the harmony of rural and urban interests induced by the Industrial Revolution, until the use of steam was extended to seaborne traffic and supplies of food raised overseas under extensive methods of cultivation could be offered to dwellers in English manufacturing towns at prices with which supplies raised intensively in England could not well compete. The result has been that agriculture, the industry which, so far as the world at large is concerned, is more important than all other industries combined—it supplies the food required by the workers of all other industries as well as of its own—has, so far as this country is concerned, ceased to be an economic occupation. The adoption by English industrial interests of the attitude towards English agricultural interests, that mankind generally adopts towards whatever it has injured, is therefore only natural.

The most outstanding statistical consequence of the Industrial Revolution in this country has been that with us the urban population now out-numbers the rural population. The most important political effect of this statistical fact has been that we now enjoy a franchise which makes it expedient for our legislators so to regulate taxation as to lose fewest votes. To meet this requirement as far as possible, they have adopted the expedient of taxing the dead. This method, like various other human devices, betrays the defects of its merits. What may, when applied to the recompense of industry, be a justifiable confiscation of the earnings of an individual and serve as a salutary discouragement to the unsocial crime of thrift, has, when applied to the resources of rural economy, effects indistinguishable from those of a levy on capital. The practical effect of this legislative discrimination, applied under the pretext of uniformity, in the treatment of rural as contrasted with urban interests, which directly concerns local societies, is the sure and by no means slow elimination of what has, ever since the Industrial Revolution began, been the greatest safeguard of our amenities and especially of the flora and the fauna of the countryside.

The appeal of our Organising Committee to the delegates of the corresponding societies now present in conference is, therefore, in essence, the expression of a hope that henceforth local societies may be prepared to undertake, on behalf of their own areas, a duty that has hitherto been carried out by that type of rural economy which our urban electorate has succeeded in paralysing and is determined to destroy. That the assistance of local societies will be welcomed by what still remains of the expiring agency we are assured. Unfortunately this very fact warns us that the opposition local societies are certain to meet from urban dwellers taught to regard rural amenities as relics of savagery and to consider rows of bungalows as signs of civilisation, will be the more implacable.

There are other difficulties which deserve the attention of local societies. The 'common carriers' authorised to form and maintain roads of their own on which they may use for haulage either coal or current, have now to face the active competition of opponents able to use petrol engines on the old public highways, provided these be supplied with a new and smoother surface at the expense of the community. This favoured agency now enables urban residents, who wish to do this, to visit 'places of historic interest or natural beauty' with an ease and comfort which the lay-out of railway systems and the dictates of railway time-tables denied them. These visits would be more welcomed by country dwellers if the visitors could be induced to take back to town the unsightly litter with which they love to lard the countryside. Local societies who endeavour to modify this urban custom, may find ample scope for the exercise of their powers of persuasion.

Thanks to the energy of the Commons, Open Spaces and Footpaths Preservation Society it is now in the power of rambling clubs, hiking parties and stray wayfarers to plan outings free from the fear of finding that some speculative builder or sporting tenant has meanwhile barred against them some ancient right of way. This advantage carries with it increased risks to the flora and the fauna of the countryside, the prevention of which may call for all the judgment and tact that local societies can command.

The public spirit of many modern teachers has led to the creation of an energetic Nature Study Union which, notwithstanding its many merits, has the disadvantage of endangering the flora and the fauna of the countryside. Local societies, anxious to conserve the wild life of their own areas, must now be at pains to guide the enthusiasm and temper the zeal which are apt to prompt earnest teachers to provide material for study, and to encourage pupils to make competitive collections, on a scale so lavish that little of what is rare in the wild life of a particular locality is likely to be left for 'those that come after.'

The conditions of individual local societies vary so much that any action taken in response to the appeal now made must be left to the unfettered judgment of each. There are, however, a few general considerations to which any local society will do well to attend. The first and most important of these is the maintenance of a sympathetic understanding with the various local authorities in its own area. This is desirable as a matter of general policy, apart altogether from threats of danger to the amenities of that area. Members of local societies may not feel disposed to devote attention to the details of local public affairs, yet may have special knowledge that would be invaluable to local administrators : they should regard it a duty to place their experience at the service of their own local authorities, if or when invited to do so. One of the benefits to an area which has a local society on friendly terms with its various local authorities, is the possibility that such a society may be asked to give disinterested and impartial advice in cases where the interests of independent local authorities threaten to clash. Almost as important is the duty of local societies to remember the truth of Mr. A. P. Herbert's reminder that 'it is far too commonly assumed in the shires that all the really silly things happen in town,' and that the tendency to make use of half-truths is as marked in the case of advocates of rural interests as in that of advocates of urban interests. A season rarely passes without public complaint of the action of some district council in the management of its roadside trees. Less frequent, but just as pungent, are the attacks on officers of the Forestry Commission for their management of the public woodlands entrusted to their charge. It is true that criticisms of the kind rarely receive the sanction of local societies : it is, unfortunately, almost as true that local societies, who should be in a position to enlighten the public of their own areas as to the real facts, rarely take pains to defend their own local authorities when the latter are attacked in this way. It is the duty of a local authority to attend to the comfort and the safety of its own section of the community : it is the duty of the Forestry Commission to further the economic interests of the State. When a local authority lops the trees in an avenue; when a forestry official substitutes soft-wooded for broad-leaved trees, both are carrying out necessary operations. The attacks to which both are subjected are based on half-truths : it is not 'what they do' but 'how they do it' that leads emotional critics to object to their action. The more ground there may at first sight appear to be for complaint, the more manifest is the fact, either that in the area affected there is no local society competent to advise its local authority, or that, if the area possesses a local society, that society has failed to fulfil its primary duty of establishing a sympathetic understanding with its various public authorities.

A local society which has established such a sympathetic understanding will be in a position, when the amenities of its own area are menaced, to seek the aid of its own local authority as well as of some appropriate national organisation. The local appeal should at least defer precipitate local action; the national appeal will ensure sympathetic attention, and may bring helpful advice. Whether the threat be to the general amenities of the area or to some special view-point or beauty spot, a local society can hardly fail to benefit by the experienced advice of the Council for the Preservation of Rural England or that of the Executive Committee of the National Trust. If the damage be due to the modification of an existing thoroughfare or the making of a new one, it is probable that it will be beyond the power of a local authority or a local society to do more than palliate the mischief. In such a case a local society can count upon advice as to means and methods from such organisations as the Road Beautifying Association, the Green Cross Society, or the Men of the Trees.

Experience shows that there is only one safe course possible if the amenities of a local area are to be preserved: the threatened view-point, beauty spot, or piece of landscape must be purchased outright and rendered inalienable. The price demanded will usually exceed what a local society can afford to pay, but this drawback need not deter a courageous local society from securing an option to purchase, and thus preventing the immediate desecration of the threatened amenity. The right to buy having thus been secured, an appeal for funds to complete the transaction can now be made, and in launching that appeal the moral support of the National Trust for Places of Historic Interest or Natural Beauty, and of the Council for the Preservation of Rural England, will be of vital consequence to the local society concerned.

Such a property having been acquired, and the amenities of its local area thereby preserved, the local society responsible must consider the question of ownership. Unless a local society be empowered by charter to that effect, it may not be in a position to declare the property inalienable; even if so fortunately situated, there can be few local societies whose members will venture, during a period like the present, to impose on their successors a burden which modified social and political conditions may conceivably render unbearable. The obvious alternative is to request an organisation like the National Trust, whose existence seems assured so long as England remains true to herself, and whose powers include the right to declare any of its properties inalienable, to accept the property. It is hardly necessary to remind delegates present that acceptance by the Trust of this responsibility will be dependent on two conditions: the local society offering the property must be able to satisfy the Trust that the property offered is in fact 'a place of natural beauty,' and must provide evidence that funds adequate to meet the recurrent expenditure the proper maintenance of the property must entail are in fact available. The existence of the first condition is mentioned in order to remind the delegates of all local societies of the advisability, before asking the Council for the Preservation of Rural England to lend moral support to an appeal for funds, and the practical wisdom—if possible before obtaining an option to purchase—of securing from the National Trust a verdict that the amenity it is wished to safeguard is in fact 'a place of natural beauty.' The existence of the second condition is mentioned for two reasons: one of these will appeal to the delegates of all local societies, since all can appreciate that while there may be room for difference of opinion as to the æsthetic value of a particular property, there can be no doubt as to the cost of its maintenance. The other reason may appeal to delegates of local societies in Yorkshire; they, at least, are aware that their own county is, and has long been, one of the English counties that has been most backward in its support of the National Trust.

The more especial appeal of the Organising Committee that local societies should assist in conserving the wild life of the countryside, raises questions more difficult to resolve than those connected with the safeguarding of local amenities. If a property acquired to safeguard a local amenity be handed over to the National Trust, the Trust, through a managing committee, will endeavour to conserve the wild life in the property: if a local society be compelled to assume ownership, we may anticipate that it will endeavour to do what the Trust would otherwise have done. But absolute protection of wild life in properties acquired to safeguard amenities is not easily provided: properties acquired to safeguard amenities must remain accessible to the public they benefit. If, however, the funds required for the maintenance, as apart from the acquisition, of such properties be adequate, indirect protection of this wild life can in time be made reasonably effective, especially if the local area is so fortunate as to possess a local society on good terms with its local authorities: the society will know what should be done, the public authorities will be in a position to enforce the necessary regulations.

Delegates may think, and indeed may hope, that local societies can count upon the help of their local press in their efforts to safeguard the amenities of their own areas. There is some reason for such hope. The press tries to save us the trouble of forming opinions of our own regarding public affairs and does much to protect our personal liberties against every encroachment save those of D.O.R.A. Even in its gossip columns, which we have high legal authority for hoping to see discontinued, we were surprised to read at Easter praise given, by a writer who has visited the South Coast, to the National Trust and the Council for the Preservation of Rural England, for their support of the local society at Lynton which is endeavouring to preserve Watersmeet from the speculative builder and thus arrest 'the rapid transformation of rural England into a vast chequer-board of bungalow towns, power-stations and petrol-dumps, the blight that has already overtaken the Sussex downs,' and to prevent the further disfigurement 'of that incomparable rural England whose passing we shall some day mourn too late.' Such a paragraph may well encourage local societies to establish a sympathetic understanding with their local press as well as with their local authorities, and to lose no time in doing so lest the influence of local editors be lent in default to the legislators whose sympathies local societies must welcome, but whose understanding of the problem in hand is such as to lead them to imagine that rural amenities can be safeguarded by means of a town-planning bill.

But whatever sympathy the press may express with efforts to safeguard amenities, it is not to be counted upon yet to lend its aid to those anxious to conserve wild life. A writer professing to be the individual who had been on the Sussex Downs at Easter, at Whitsun visited the Chilterns. There the sight of a local policeman preventing the picking of the bluebells of a private citizen led him to reflect that 'an English holiday is not without its humorous occasions,' and to remark some weeks later that, on hearing a 'broadcaster solemnly denounce the people who pull up wild flowers by the roots as a public nuisance that might become a public menace,' he 'could not help feeling that our self-constituted wild-flower protectors are sometimes prone to an almost ludicrous exaggeration.' Fortunately we now possess, thanks to the action of the Council for the Preservation of Rural England, an efficient Wild Plant Conservation Board, which includes representatives of most of the organisations that have the preservation of the flora of the countryside at heart. Though there are various points connected with this general problem as to which diversity of opinion is legitimate, there is reason to think that the practical measures taken by particular local societies may have to be guided by local conditions quite as much as by general principles. But until this new Board has had time to formulate recommendations which the Council for the Preservation of Rural England is in a position to endorse, no useful purpose can be served by the expression of individual views as regards debatable points. What is of immediate consequence is that local societies can now depend on the assistance of a body able and willing to aid them in conserving the flora of the countryside from those dangers that menace it everywhere except on railway embankments and in railway cuttings, whose owners are still permitted to prevent trespass on their property without being held up to ridicule or subjected to censure. What is of almost equal value is that we now possess an organisation capable of reminding wild-flower protectors of the truth of Mr. Herbert's remark as to the fondness for folly which advocates of rural and urban interests share.

In one respect the new Wild Plant Conservation Board has an advantage over any local society: it can treat the preservation of the flora of the countryside as a self-contained activity, whereas our Organising Committee hopes that local societies may be able to assist in conserving the fauna as well as the flora of their own areas. Perhaps the Council for the Preservation of Rural England may one day be able to set up a comparable Conservation Board for our fauna, in spite of the obvious difficulty that whereas the protection of our flora admits of some uniformity of system, in the case of our fauna it is far from certain that measures called for as regards the protection of bird-life would be necessary or might be adequate as regards the protection of insect-life. Anyhow, until such a Conservation Board is set up, local societies can rely, as in the past, on the help of organisations like the Royal Society for the Protection of Birds or the Entomological Society.

The conservation of 'a place of natural beauty,' secured in order to safeguard the amenities of a local area, can never be passive. Passive management of an estate means mismanagement, and is as detrimental to its appearance as it is to the fauna it may shelter and to the flora which adorns it. Those entrusted with its conservation will doubtless keep in mind the sound maxim that 'when it is not necessary to change, it is necessary not to change.' But they will observe, what the casual visitor may be pardoned for failing to notice, that 'change and decay' are as inevitable in wild nature as in human affairs, and that 'leaving things to take their natural course' means the gradual replacement of forms of plant- and animal-life which it is desirable to maintain, by forms whose increase must be carefully watched and may need to be rigidly controlled. If the approval of intelligent visitors is to be merited, those in charge of such a property must excercise an unceasing 'constraint of nature': if the criticism of visitors whose emotions are untempered by knowledge is to be avoided, those in charge of such a property should, in doing what is necessary, strive to use 'the art that conceals art.'

But the conservation of the wild life of a local area may call for something more than the protection of the flora and the fauna present in a property acquired to safeguard local amenities. That local area may include places which the National Trust might not feel justified in regarding as places of natural beauty, yet which the Linnean, the Zoological, or the Entomological Societies might agree with a local society in thinking worthy of protection as being the home of some rare plant; the haunt of some rare bird; the breeding-ground of some rare insect; the place where birds of passage assemble prior to migration or seek repose when they return. Again, the only hope of preserving such a spot may be to purchase it and convert it into a 'sanctuary.'

It is hardly necessary to say to the delegates of local societies that while the acquisition of a sanctuary is indistinguishable from the acquisition of an amenity, the management of the two must differ in principle. While an amenity must remain accessible to the public, a sanctuary must be made as nearly as possible inviolate: the conservation and supervision by competent caretakers of any sanctuary must be more rigid and relatively more expensive than in the case of a property secured to safeguard local amenities. It is even less necessary to remark that it is, if possible, more undesirable that members of a local society should impose on their successors the responsibility of ownership of a sanctuary than that of ownership of an amenity. It may, however, be worth while to point out that this burden is just as unnecessary in the one case as in the other. A sanctuary need not be 'a place of natural beauty'; even if it be, in fact, entitled to be so regarded, the National Trust may be debarred from accepting the burden of ownership because a sanctuary becomes valueless unless access to it be denied. But local societies may approach the Society for the Promotion of Nature Reserves, a body empowered by charter to own sanctuaries of the kind. That Society will require to be satisfied that the property offered to it is, in fact, suitable as a sanctuary, and will be as careful as the National Trust to satisfy itself that the funds provided for its maintenance are adequate. If it be desirable that a property to be acquired in order to safeguard local amenities be declared in advance by the National Trust 'a place of natural beauty,' it will be even more advisable to have it declared in advance by the appropriate authority that a property to be acquired as a sanctuary is in fact suitable as a 'nature reserve.' In connection with a proposed sanctuary it must be remembered that questions of expenditure may arise which do not occur in the case of properties acquired to safeguard amenities. Where a stretch of woodland, subject in the past to a periodic 'coppice-fall,' is acquired so as to ensure the continued existence of some rare plant, it may be essential to maintain the old practice, even if there be no longer any demand for hoops and faggots, lest the species whose preservation is aimed at be choked and disappear. Similarly, where a piece of fenland is acquired because it is the breeding-ground of some rare insect, the invasion of shrubby vegetation must be carefully and constantly checked, while there must be a seasonal cutting of reed and sedge, though there may no longer be a demand for thatch, lest the conditions become unsuitable for the insect-life the 'sanctuary' was acquired to preserve. Necessities of the kind—those quoted are mentioned from actual experience—will enable local societies to satisfy the friends to whom they may appeal for funds that, in the case of a 'sanctuary,' money for maintenance is as essential as money for purchase, and that the endowment of a 'sanctuary' may call for more capital than its acquisition. These necessities enable us to realise, further, that to acquire a 'sanctuary,' and then leave it without adequate protection and careful management, means an unpardonable waste of effort and resources. Since the proper maintenance of a 'sanctuary' may often entail more extensive interference with natural growth than the proper maintenance of 'a place of natural beauty' usually demands, it may often be impossible for those in charge of a 'sanctuary' to carry out their duties so unobtrusively as to escape the attention of those whose æsthetic feelings outweigh their acquaintance with the factors that condition wild life. Local societies will, however, be able to meet criticism by reminding those who bring it that neglect to regulate the factors which condition wild life may mean a sacrifice of that life more to be regretted, because the cruelty involved is more refined and more prolonged, than the destruction caused by those unsympathetic barbarians who find the fact of their rarity a sufficient incentive to the slaughter of rare creatures and the uprooting of rare plants.

Local societies will sometimes find, and as time goes on will do so more often, that the agencies inimical to wild life in their own areas have become so powerful that the establishment of a 'sanctuary' is impracticable, and that the only means of conserving the wild life once characteristic of the neighbourhood is to acquire a suitable site and convert this into an 'asylum' for such plants, insects, and birds known to have at one time been native there, as can be placed in or attracted to the 'asylum.' The question is sometimes asked whether and, if so, how far it is permissible to treat a 'nature reserve' as both a 'sanctuary' and an 'asylum.' The answer must be left to the judgment of individual local societies: the only practical general consideration is the bearing of the decision on ownership. A 'sanctuary' is no longer such when access to it ceases to be strictly limited, whereas an 'asylum for wild life' must be at least as freely open to the public as 'a place of natural beauty.' Its accessibility to the public should prevent the Society for the Promotion of Nature Reserves from accepting ownership of any 'asylum for the conservation of local wild life'; its artificial origin should preclude the National Trust from doing so.

Another question sometimes raised is whether, and how far, a collection of plants representative of a local area may be appropriately included in a 'public garden.' In this case the answer is simple: provided the local authority owning and maintaining the 'public garden' can be persuaded by its local society to permit the collection of local plants to be treated as a distinct section of the establishment, the suggestion, ideal in itself, has the added advantage of solving the otherwise difficult question of ownership, since this would be vested in the appropriate 'local authority.' This suggestion is one which may be appropriately considered at a conference in York because, although it be true that York as a county has been and still is backward in its efforts to assist the National Trust to preserve English amenities, it is also the case that certain Yorkshire towns have been, and are still, singularly public-spirited in the support they have given to the maintenance of their public gardens. It should therefore be an easy task for local societies to persuade their own local authorities to follow what is already a recognised policy and, when establishing public gardens, to devote one section of these gardens to the purposes of 'an asylum for local wild life.' If Yorkshire should lead, other counties would follow.

In connection with the question of establishing, wherever possible, a series of 'asylums for local wild life' it may be possible for local societies to render the cause we have at heart a further service. Since such an asylum must be, on a small scale, a combined zoological and botanical garden, there must of necessity be vivaries and nurseries attached. In these vivaries and nurseries can easily be raised not only all the material required for the maintenance of the collections in the 'asylum,' but also all the material required by the teachers of nature study and their pupils in the local schools. It may well be that on a local society may fall the burden of collecting the funds required, not only for the establishment but also for the maintenance of an 'asylum for wild life.' But this task accomplished, it ought not to prove difficult to obtain the consent of a local council to accept the burden of ownership.

Delegates present will, it is hoped, understand that what has been said must not be regarded as committing in any way the members of the Organising Committee who have suggested the subject now dealt with, or the members of the Council of the British Association who have asked that the subject be considered at this conference. If what has been said be objected to, the fault lies with the speaker. Briefly summarised, his belief is that local societies can best help to safeguard the amenities of their own areas by taking a more active part than many of them have taken in the past in securing possession of ' places of natural beauty ' and handing these over, with adequate endowment funds, to the National Trust. His belief also is that local societies can best help to preserve the flora and the fauna of the countryside by securing, whenever possible, suitable ' sanctuaries for wild life ' and handing these over, with adequate endowment funds, to the Society for the Promotion of Nature Reserves. They can do something to repair the damage already done, and the destruction already caused, by establishing and if possible endowing local gardens and parks, equipped with adequate vivaries and nurseries, and persuading their local authorities to take over these ' asylums for the conservation of wild life.' Local societies should avoid, at all costs, the burden of ownership of any of these safeguards : it is always an unsound principle to possess watch-dogs and bark oneself.

Local societies may anticipate many difficulties and much opposition, some of it due to self-interested motives, but more of it due to misunderstanding. This need not discourage them, provided they are on good terms with and enjoy the sympathy of their own local authorities. With that behind them, local societies can do much : if they neglect to establish cordial and sympathetic relationships with their own local authorities, local societies can hardly hope to render much assistance either in the preservation of the amenities of their own areas or in the conservation of the flora or the fauna of the countryside.

At the conclusion of the President's Address, Dr. Vaughan Cornish dealt with the *Conservation of Wild Life in Relation to the Scheme for National Parks*, urging the importance of taking steps without undue delay to preserve representative regions of wild scenery in England for the recreation of the people. He pointed out that the establishment of protected nature reserves within the wider area of a national park is not incompatible with the free recreation of the people, for which such parks would be established, since, while the breeding ground of rarer animals and birds would be protected, the birds themselves would be free to fly far beyond, and even rare flowers would spread beyond the protected area, which would really add to the enjoyment of the main area in which the people would roam without restriction. Thus there is no insuperable difficulty in the co-operation of sociologists and naturalists in the scheme for national parks, and any conflict of aims is more apparent than real.

A discussion followed in which Prof. F. G. Baily, Mr. H. Burgess, Prof. J. E. Duerden, Mr. H. E. Forrest, and Mr. H. E. Salmon took part.

Tuesday, September 6.

Mr. T. Sheppard in the Chair.

Captain T. Dannreuther, R.N., described a *Scheme for Recording Immigrant Insects*, in which he invited the co-operation of the societies in correspondence with the British Association, especially those in the midland and northern counties of England, where observers could render valuable assistance by keeping watch for and recording the appearance of insects known to be migrants. The collective results of such records would prove of importance and scientific value on a subject where knowledge is lacking for want of systematic observation and available data. The scheme is an adaptation of a card-indexing system devised by Dr. C. B. Williams for tabulating records of insect migration. Captain Dannreuther pointed out that hitherto such records have been fortuitous, and it is hoped that with the aid of local observers such records will continue to be kept systematically, with a view to analysis and subsequent publication.

As to the scientific value of such records, he called attention to the existing lack of knowledge of the habits and true habitats of certain well-known migrants, and instanced several species of the commoner butterflies and moths observed in England during the spring and summer, which it is known cannot survive our winter months, while, unlike migrant birds, there are no apparent return flights to balance the migration. A number of lighthouse- and lightship-keepers from Land's End eastward as far as the north-east coast are acting as observers with the consent of the Trinity Brethren, and he urged that the assistance of the Corresponding Societies would be valued in keeping observation in their own areas, and forwarding the records to him upon the approved cards for tabulation. Such cards, together with further information, can be obtained from Captain T. Dannreuther, R.N., Windycroft, Hastings, Sussex.

Cf. *Report*, Hastings and St. Leonards Nat. Hist. Soc. (1930–31); *Hastings & East Sussex Naturalist*, **4**, 5 (1932); *Bull. S.E. Union Sci. Socs.*, 60, June 1 (1932); *Entomologist*, **65**, 832.

REFERENCES TO PUBLICATION 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. 300–416), 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.

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APPENDIX

A
SCIENTIFIC SURVEY
OF
YORK
AND DISTRICT

PREPARED FOR
THE YORK MEETING
1932

BY VARIOUS AUTHORS

CONTENTS.

A SCIENTIFIC SURVEY OF YORK AND DISTRICT

I.

YORK IN ITS REGIONAL SETTING

BY

A. V. WILLIAMSON, M.A.

NORTH of the line of the Humber, the essential English Lowland protrudes its tongue between the low-swelling eastern flanks of the Pennines and the bold scarps of the Yorkshire Wolds and the North York Moors until its tip is twisted seawards against the East Durham Plateau. The tip is known as the Vale of Tees ; the rest forms the vale which is named, not from the principal river meandering over it, but from the city seated on the river and centrally located within the area.

The Vale of York lies in latitudes roughly midway between the north and south of Britain, and the fact that while structurally united to the Lowland South the area is also intimately related, through its surface deposits and river system, to the Upland North enhances, geographically, the significance of its intermediate location. Its historical associations and its economic adjustments, past and present, also serve to emphasise that intrinsic ' betweenness ' which is the basis of the vale's claim to a regional individuality apart from the recognition it enjoys as a great corridor of through routes.

From the low and indeterminate water-parting between the Tees and the Swale, which marks its entry from the north through the ' Northallerton Gate,' the vale extends south for about 50 miles to the line of the lower Aire and the Humber. Thus north and south it merges into areas of similar plan, although historically the marshlands along the Aire-Humber line were, of course, for long a significant hindrance to movement. Modern industrialism, however, has orientated the Tees lowland to the estuary at its mouth, and the development of the Yorkshire coalfield has so transformed the landscape spreading southwards from about the Aire as to differentiate it clearly from the essentially rural region to the north. A lowland of drift soils, on which arable cultivation co-exists significantly with the raising of livestock, primarily cattle (i.e. mixed farming in the fullest sense), the vale contrasts strongly with the highlands framing it; with the Pennines and North York Moors devoted mainly to sheep, and with the Wolds characterised by a rural economy based on sheep and barley. Probably the 200-foot contour marks, as near as may be, the limits of the essential vale region to east and west. On the east there is a real break of slope at this height and a fairly noticeable change in land utilisation. Westwards, however, the chosen contour only indicates the beginning of a foothill zone, 5 to 10 miles wide, spreading to the Pennines proper. Over this zone, from place to place, farming allied to that of the vale persists, thanks to the red loams derived from the Magnesian Limestone on which the zone is developed.

Along its southern margin the vale is about 30 miles wide, and this width is fairly well maintained as far north as York, i.e. over the southern half of the region. Northwards it tapers and in the latitude of Ripon becomes suddenly constricted to a corridor less than half as wide as in the south.

Within the boundaries given, the Vale of York embraces rather more than 1,000 square miles, the whole of which is less than 200 feet and much of it below 50 feet above sea-level. Developed basically by river action on rocks, mainly sandstones, of the Triassic series, the vale is covered by deposits of glacial and fluviatile origin, varying in depth from 25 to 90 feet, and the underlying rocks only appear as isolated outcrops in one or two places.

In a bird's-eye view the floor of the vale appears monotonously level; in detail it is frequently undulating or hummocky, but the only coherent relief features of real significance are two terminal moraines which extend across it as crescentic ridges some fifty feet above the general level. Of these the more noteworthy one runs from Sand Hutton in the east through Upper Helmsley, Grimston Smithy and Heslington to York, and then loops south-westward through Copmanthorpe, Bilbrough and Healaugh with minor ridges straggling towards Tadcaster and Wetherby. The other, lying a little further south, observes a rough parallelism to the first and stretches from Stamford Bridge through Newton, Sutton-on-Derwent, Wheldrake and Escrick to Stillingfleet, then dies down westwards through Acaster Selby and Bolton Percy. They afford dry going above the marsh and floods, and from time immemorial the most important transverse route in the vale has been identified with the more northerly ridge.

The vale is watered, rather than drained, by the Ouse and its tributaries. The Ouse collects the drainage of an area four times as large as the vale, and all its tributaries save one flow from the Pennines to its right bank. The exception is the Derwent, which joins the Ouse after that river has received all its Pennine affluents except the Aire, i.e. not far above the head of the Humber estuary. All the rivers of the vale are prone to overflow in certain reaches, but the Derwent is notorious in this connection. The extent and peculiar shape of its catchment area—this covers some 800 square miles and includes most of the North York Moors and the Vale of Pickering—causes the Derwent to swell very rapidly after rain (its volume may be quadrupled within 24 hours), and this, combined with the shallowness and irregularity of its bed, frequently infested with reeds which operate to accentuate the sluggish flow of its waters, makes it an exceptionally ill-famed river. Flooding is most frequent and widespread at Stamford Bridge, and along the tidal reach of the river, i.e. below Sutton, especially in the Bubwith neighbourhood. The rise of the tide up the Ouse tends to pond back the Derwent, and also to silt up its lower course with warp (tidal sediment). The river is especially shallow near its junction with the Ouse ; in places it is only 3 feet deep, whereas it should be 12 feet at low tide. The Derwent enters the Ouse in an upstream direction at an angle of about 30 degrees. At one time it joined the Ouse 4½ miles further down. Bubwith, seated on a hairpin bend of the Derwent midway between the confluence of this river with the Ouse and the entry of the Pocklington Canal, is as it were caught between two fires ; and perhaps the presence of a raised road and bridge adds to its troubles. Extensive areas of swamp and marsh have been reclaimed, but the problem of drainage remains acute in the southern part of the vale, particularly the south-central, where the high sub-surface water-table is a reflection of it.

The vale is characterised by a medley of soils varying within narrow limits, so that a summary account is of little value. South of the York moraine, however, sandy loams—light, easily-worked soils—are predominant, while alluvium occurs immediately along the rivers, and there is also warp. The latter embraces ' natural ' warp, which spreads along the Derwent extending south-eastwards from Sutton-on-Derwent, and ' artificial ' warp, which displaces the foregoing south of the Selby-Hull railway and reaches to the Humber. The alluvium, heavy and frequently liable to flood, is generally under grass ; so also the natural warp, which is an infertile stratified lacustrine deposit of glacial parentage. By contrast, the artificial warp is of high fertility and carries a variety of crops. North of York natural warp spreads north-west for some 10 miles up the centre of the vale. This is girdled by sandy loams, which are again broken by alluvium along the rivers, while towards the marginal uplands they give place to boulder clay. Finally, the latter predominates across the extreme north of the vale, where it passes into the ' Northallerton Gate.' The strength of the clay here in the north has long caused it to be esteemed as wheat land, but the greater part is under grass. Regarded as a whole, the soils of the vale support good crops, particularly when adequately sweetened with lime, which is to hand in the margins of the vale. In the eastern part of the area beneficial results have accrued in the past from marling, a practice hardly surviving now. Many of the lighter soils are also improved by running sheep on them. The agriculture of the vale is one important manifestation of the ' betweenness ' of the region (see, further, Chap. XIV).

Climatically the vale enjoys conditions approximating to those which support the arable lands *par excellence* of England, and with a mean July temperature of 60° F. the region just has a sufficiency of summer warmth to ripen wheat, which, north of the vale, will ripen only in exceptionally favoured spots. Rainfall, which is liable to occur practically every other day, decreases from an annual total of just under 30 inches near the marginal uplands to barely 25 inches in the centre of the region. The wettest month is October, and the late summer receives a noteworthy share of rain, but September is comparatively dry. The fact that July and August are credited with few rainy days in relation to the amount of rain which they receive, so that rain is most intense at this time, is due to a high frequency of thunderstorms. September favours the harvest, but the heavy falls of late summer frequently deplete the yield of various crops. (Climatic details for York will be found in Chap. III.)

The city of York stands where the Ouse, changing direction from south-east to south, breaks through the more northerly of the two morainic ridges already noted, and at a point where the river is joined by a left-bank tributary, the Foss. The latter, meandering south, enters the Ouse at a sharp angle just within, i.e. north of, the ridge. The moraine, on reaching the Ouse from the east, loses its identity as a ridge and widens north and south along both banks of the river into a complicated series of elongated mounds. Thus boulder clay is heaped upstream as far as the bend at Clifton ; sands and gravels sprawl downstream to Bishopthorpe and Fulford, and, indeed, struggle as far as the southern moraine at Escrick. A little west of the Ouse the moraine regains individuality, but rather as a series of minor ridges than as a single major feature. As a result of these complications the land rises most steeply from, and achieves its maximum elevation along, the banks of the Ouse immediately above the point where the Foss enters it ; it is flanked there by boulder clay. This applies especially to the left bank or north side, as it may be called just here. It was on this side, on the low eminence in the angle of the confluence, overlooking the Ouse and the marshy terrain spreading along and beyond the Foss, with forest and more marsh on the third side, that the Roman fortress was built ; and this area has persisted as the core of the city from its genesis. Placed at once both in the geographical centre of the vale and at the crossways of its arterial natural routes, the north-south route by the river and east-west route *viâ* the moraine, the settlement also clearly enjoyed a good command over the surrounding low-lying lands and a large measure of natural security.

Despite the march of time, the salient features of the lay-out of Roman York can still be recognised. Stonegate adheres fairly faithfully to the line of the Via Principalis, High and Low Petergate to that of the Via Prætoria, while Blossom Street, Bootham, Monkgate and Walmgate represent the original approach roads to the gates of the castra. The suburban, i.e. extra-mural, development which marked later Roman times was identified mainly with the high ground on the south side of the Ouse and chiefly the neighbourhood where the railway station now stands. Subsequent expansion followed very much in the Roman wake and resulted in further walls being erected. Those built under the Normans were closely related to the walls which followed later in the mediæval age, and are preserved to-day. On the north-east and north-west the latter conform almost exactly in alignment to the Roman walls, while to the south-west they enclose roughly the area of Roman suburban settlement. On the south-east there is an extension from Feasegate to Paragon Street. The absence of walls in the vicinity of the Foss is sufficient evidence of the significance, historically, of its marshes. After a lapse of centuries, Drake's map of 1736 shows very little settlement outside the mediæval walls; only a few dwellings in their immediate shadow in Bootham, Monkgate and Marygate. Life and property were not yet altogether secure, and economically the city was languishing. Significant extra-mural expansion was delayed yet another hundred years. With the arrival of the railway, fresh life was breathed into the city, following three centuries of decline due, in large measure, to the decay of the Ouse as an artery of traffic. The railway reached York in 1839 (eight years after the birth of the British Association in the city), and in response houses, primarily of the working-class type, began to spring up beyond the walls mainly to the south and the north-east. The influence of the gravel ridges in connection with these and later developments is discernible, revealing itself in the arms of dwelling-houses extending in the directions of Escrick and Bishopthorpe, along the Mount, and to the village of Acomb.[1] More recently, expansion has been particularly marked to the north of the city and on its east side; this continues. Noteworthy in this connection are the Cocoa Works Model Village at Earswick and the Corporation Housing Scheme at Tang Hall. The limitations placed upon the expansion of population north-west and south-east along the banks of the Ouse remain as ever. Within about a mile and a half of Ouse Bridge, in both directions, the river is liable to flood. Such land, however, provides open space and in places is suitable for industrial purposes. The present centre of industry is in the neighbourhood of Foss Island. It is not possible here to enlarge upon the town-planning proposals for York and its rural neighbours to the north, east, and south. It must suffice to say that the demarcation of zones within the area incorporated under the scheme, and the ring and other arterial roads now being developed, will, it is hoped, ensure the healthy expansion of population and industry, and meet the acute need for relieving the traffic congestion in the heart of the city while also preserving its ancient and historic monuments in an appropriate setting.

Economically, York retains its age-old place as a route centre and the principal market town of a rich agricultural region. Before 1757, when the lock was built at Naburn, about 5 miles below the city, the Ouse was tidal up to York, and the golden age in her economic history depended upon the sea-going boats that tied up to her quays. Early in the sixteenth century the silting of the Ouse was already beginning to agitate certain minds, and, with the progressive increase in the size of sea-going boats in later days, the tonnage reaching the city dwindled until in the eighteenth century it ceased. The Ouse is still serving the city, however, and about 140,000 tons per annum are at present carried to and from York by the waterway. The boats most commonly employed carry from 80 to 110 tons, chiefly coal, gravel and cement. A larger type, able to accommodate a cargo of about 230 tons, is favoured for the transport of grain and seeds for crushing.

[1] It is realised that it is natural for a town to expand along its approach roads, and as these gravel ridges carry such roads they have attracted houses to them. Yet it is fair to claim a direct influence as above.

Some reference has already been made to the part played by the railway in relation to modern York, and its importance cannot be overestimated. In the decade 1841–51, immediately following the introduction of the railway, the city's population increased by over a quarter as against 10 per cent. during the previous ten years. The formation of the North Eastern Railway in 1854, with headquarters at York, was a further stimulus, while the opening of the Carriage and Wagon Works in 1884, and its expansion in following years, were reflected in further substantial growth of population.

Since it became the headquarters of the North Eastern Area of the London and North Eastern Railway Company, the importance of York as a junction has been enhanced from a regional standpoint, while it is worth recording that the whole of the main-line traffic between Doncaster and Newcastle is controlled from here.

As some indication of the part played by York as a collecting and distributing area it may be noted that roughly 1,900,000 goods wagons, nearly three-quarters of them laden, pass through the railway marshalling yards in a year. The city itself receives 490,000 tons of rail-borne goods per annum, of which the largest item is coal, and sends out 145,000 tons of goods a year, the details of which afford a clue to its industries. The main item is refined sugar from the local factory, and second to this is confectionery, which represents York's principal industry apart from the railway itself; oil-cake is another important item. The first two commodities travel far afield, while the third feeds the agricultural area round about. Some 6,300 wagons of livestock are also despatched each year—a reflection of the fact that as a market York handles more cattle than any other centre in England and Wales.

I wish to acknowledge my debt to F. H. Graveson, Esq. (Assistant to the Divisional General Manager, N.E. Area, L.N.E. Railway); to F. J. Spalding, Esq., B.A., LL.B. (Town Clerk of York); and to F. Spurr, Esq. (City Engineer and Surveyor of York). The work of my own students has also been helpful.

II.

GEOLOGY

BY

C. E. N. BROMEHEAD, B.A.

The immediate neighbourhood of York is not of great interest to the general geologist, since no rocks older than the glacial deposits are exposed. Even to the glaciologist it has become of less interest since the last visit of the British Association ; at that time (1906) several large brick pits at Dringhouses afforded sections of a thick deposit of laminated clays, but these are now either filled in or flooded.

Were the superficial deposits to be removed the position of York would be seen to lie in the centre of a plain occupied by Triassic rocks. This plain, the Vale of York, is bounded on the west by the uprise of older rocks less easily eroded than the sandstones and marls composing the Trias, on the east by newer rocks overlying it. To the north-north-west the plain narrows towards the Tees valley, and is known as the Vale of Mowbray, southwards it widens to the Humber and is continued in the Vale of Trent. The western margin is everywhere formed by Permian rocks, of which the dominant member is the Magnesian Limestone, but at the base of these is a great unconformity. In the south they are underlain by the Coal Measures, forming the great Yorkshire coalfield. During the meeting of the Association a visit will be paid to the Conisborough area, where beds near the top of the Middle Coal Measure will be seen immediately beneath the Permian, but not far from Tadcaster the whole of the Coal Measures is cut out and the Permian rests on Millstone Grits. A geological excursion to Tadcaster and Bramham will demonstrate this point. The northern boundary of the ' concealed coalfield ' beneath the Permian and Trias is not known, but the balance of evidence is in favour of a west to east line. It may safely be assumed that no Coal Measures are present beneath York.

The eastern margin of the Triassic plain is formed, from north to south, by the high ground of the Hambleton Hills, the Howardian Hills, and the Wolds. The two former consist of Jurassic rocks, the last of chalk. It is impossible in this short account to give a detailed description of the beds or to discuss the many interesting problems which their characters and distribution suggest, but sufficient may be said to indicate the main points which will arise on the various excursions. In the Hambleton Hills the escarpment shows a complete succession from Lower Lias to the Calcareous Grit. In the Howardian Hills the highest ground is occupied by beds belonging to the Lower Oolites. These two blocks are separated by a trough due to faulting, known as the Gilling Gap, in which most of the ground is occupied by Kimeridge Clay. The gap forms a connection between the low-lying ground of the Vales of Mowbray or York on the west and the Vale of Pickering on the east.

Due east from York and at a distance of about 12 miles is the escarpment of the Chalk Wolds. It is recorded that when William Smith first visited York he climbed to the top of the Minster tower and saw the Wolds in the distance. From the form of the ground he recognised that the rock was chalk, thus confirming his ideas of stratigraphy. Prof. Kendall has suggested that that day was the birthday of stratigraphical geology. A word of warning may be inserted here. From the same or any other elevated viewpoint, the visitor to York will see in the distance a white horse cut on the scarp of the hills ; if he comes from the South of England he may assume that he is looking at the chalk, but he would be wrong. This white horse is cut in Corallian rock on the flank of the Hambleton Hills, almost due north from York.

If our visitor now asks why the hills rising above the Triassic plain should be of Jurassic rocks to the north and of Cretaceous rocks to the east, he has hit upon one of the most interesting phenomena in Yorkshire geology. Near the town of Market Weighton the Upper Cretaceous strata rest on Lower Lias. As this neighbourhood is approached from north or south the Jurassic beds of North Yorkshire and of Lincolnshire successively thin out and disappear. Moreover, several of them, which show evidence of having been deposited, when well developed, in comparatively deep water, change their character ; instead of deep sea mollusca they contain beds of oysters, clearly indicating the proximity of a shore-line or, at least, of shallow water. The known area of non-deposition centres round Market Weighton, and the disturbance is usually spoken of as that of the Market Weighton Axis, but the direction taken by the axis is a matter for speculation. Opportunity to study the variations of several members of the Jurassic sequence and their successive overlaps will be afforded on the excursion to Wharram, etc.

Such, in brief outline, is the ' solid ' geology of the York neighbourhood. In glacial times the Vale of York was invaded by a glacier which came over Stainmore and descended Teesdale. The north-west corner of the Cleveland Hills divided this stream into two branches ; one descended the Vales of Mowbray and York, the other continued towards the sea and then turned south along the coast, being driven inland by ice from Scandinavia, which filled the North Sea. The Vale of York glacier brought with it boulders of such rocks as Shap Granite, Brockram from the Vale of Eden, and carboniferous rocks from the Pennines ; a fine example of the first-named may be seen at the southern end of the up platform of the excursion station. It was joined in its southward course by tributary glaciers from the dales of West Yorkshire, Swaledale, Wensleydale, Nidderdale, Wharfedale and Airedale, but no glaciers originated in the hills to the east. There a number of glacial lakes was formed, as the natural drainage was obstructed by the ice in the Vale of York and along the coast. These lakes and the many channels by which they discharged have been described by Prof. Kendall in a classic paper. The largest lake occupied the Vale of Pickering and overflowed along what is now the Derwent Gorge, from Malton to Kirkham Abbey. These will be seen on the excursions, as will a fine series of overflow channels near Kilburn. On the long excursion to Robin Hood's Bay those members who prefer exploring the moors to studying Lias zones and boulder clay cliffs on the coast will find many glacial features to interest them.

Detailed interpretation of the glacial phenomena around York will be a subject of discussion during the meeting and many of them will be seen on the excursions. We do not wish to anticipate what will be said then, but mention must be made here of the two great crescentic ridges, composed in part of gravel but more largely of boulder clay, which cross the Vale, as indicated in the previous chapter. The outer, or more southerly, of these merges to the west in the marginal deposits. The inner ridge, known as the ' York Moraine,' after curving round through York, passes westward into a complex of ridges and mounds. From York narrow ridges of gravel also extend southwards and south-westwards towards the ' Escrick Moraine.'

Apart from these elongated mounds the boulder clays and gravels are mostly buried beneath late glacial and post-glacial clays and muds. York owes its position to the morainic mounds which provided a feasible route across the swampy vale at the tidal limit of the river Ouse. One swamp, indeed, survives to the present day. Askham Bog, on the left of the road and railway as one approaches the city from the Leeds direction, lies in a hollow amongst the glacial ridges, from which there is no natural drainage outlet. It is, in fact, the remnant of an inter-morainic lake.[1] The flat tract of Knavesmire, now the racecourse, occupies a somewhat similar position ; in the early summer of 1932 it partially resumed the lake-like condition.

Since the immediate neighbourhood of York affords little opportunity for studying the local geology in the field, it may be well to draw the attention of visiting geologists to the chief features of interest in the geological department of the museum and to certain points in what may be called the ' human geology ' of the city. The museum and grounds of the Yorkshire Philosophical Society will be open without charge to all members of the British Association for the period of the meeting. In the latter may be seen a few of the larger glacial boulders discovered in the district and brought here for preservation. In the main building of the museum the geological collections have been vastly improved under the care of the present honorary curator, Mr. S. Melmore. One of the chief treasures is the collection of mammalian remains from Kirkdale Cave, rendered world-famous by Dr. Buckland. The specimens have recently been cleaned and re-labelled, and are so arranged that all can be readily inspected. The cave is, or rather was, situated about a mile and a half west of Kirkby Moorside, but has been so largely removed by quarrying as to be hardly worth a visit from the geological point of view. The remains in the museum are probably the finest example of the contents of an early Pleistocene hyena den in the world. In the same room will be found an important collection of fossil bones from the pre-glacial beach deposits of Sewerby, near Bridlington, and many mammalian fossils from the drifts in various parts of the county.

One room is devoted almost entirely to Saurian remains from the Yorkshire Lias ; these include what is thought to be the largest nearly complete Saurian known, a specimen of *Ichthyosaurus crassimanus*. In the main geological gallery the attention of palæontologists will naturally be drawn to the large number of type specimens, mostly Phillips's, which have been brought together and well displayed by Mr. Melmore. Other groups specially worthy of notice are the shells from the glacial beds of Bridlington, etc., the specimens from the famous sponge-bed in the chalk of Sewerby and Flamborough cliffs, and the plants from the Middle Estuarine and Corallian rocks of North-East Yorkshire.

In other departments of the museum are many exhibits which throw interesting lights on the history of economic geology. In the Hospitium, which houses most of the Roman antiquities, the lead coffins and water-pipes show the lavish use of that metal by the Romans. There is no

[1] Reference to the botany of this bog will be found in Chap. IV, and to its zoology in Chap. V.

inscribed pig of lead, but a cast is shown of one from near Pateley Bridge, belonging to the reign of Domitian. The Romans were, therefore, mining the lead of the West Yorkshire dales at an early date ; it has been suggested that one of the main objects of the Roman conquest of Britain was the exploitation of her mineral wealth. In this connection we may mention a unique Roman lead-pouring ladle from Walsingham Moor in the Ethnographic Room. Gowland long ago pointed out that Roman pigs of lead showed a kind of stratification, indicating that the mould was filled in a number of successive stages. Here we have the ladle actually used for pouring in the molten metal ; it is of bronze, and holds about two and a half pints.

The Romans also appreciated the jet from the Upper Lias of the Whitby region. Some of the ornaments made of this material, particularly the carved portrait heads, surpass anything that has been done in more recent times. The jet was brought to the important city of York and carved there, as shown by the undressed lumps and partially carved ornaments on the railway station site.

An important question in local economic geology is that of building materials. York is situated in a clay plain and nearly all the houses are of brick. A considerable number of ancient oak-framed buildings survive and add greatly to the attractions of the picturesque streets. The clay plain north of the city was formerly occupied by the Forest of Galtres, a name probably meaning gall or oak trees. About nine miles away, in the Tadcaster district, the Magnesian Limestone affords excellent building stone, and the principal buildings, the Minster, the city walls, and the churches are of this material. The Romans were quick to realise its value ; the multangular tower in the museum grounds is a fine example of their work. The blocks are well hewn, though comparatively small. The wisdom, or shall we say the honesty, of the Roman quarrymen in selecting sound stone is noticeable if we contrast the weathering of their work with that of Magnesian Limestone in any of the mediæval buildings. They also used it to some extent for inscribed monumental tablets and statuary, but for this class of work usually preferred gritstone from further west. In the Saxon period the use of Magnesian Limestone died out. Prof. Kendall has remarked that throughout Yorkshire pre-Conquest work in churches is always executed in gritstone, even when this had to be brought from a distance and the limestone was available on the spot. In York the tower of St. Mary's, Bishop Hill Junior, dates from before the Conquest ; the lower part is largely of limestone, but it is obvious that the blocks used have been taken ready-made from the Roman wall. When this source was exhausted, the gritstone was used. The point is borne out by the fine series of Anglian crosses in one of the rooms of the architectural department of the museum (in the basement). The date of the magnificent, though mutilated, figure of Our Lady and Child in the Chapter House of the Minster has been a matter of dispute amongst antiquaries. The fact that it is of Tadcaster stone is strong evidence for a post-Conquest date, say first half of the twelfth century. Another good instance of the use of this stone for sculpture is the figure in the museum known as Our Lady of York, and for delicacy of carving the extensive remains of the shrine of St. William, also now in the museum, are unsurpassed. No more ornamental stone is available anywhere near York. Purbeck 'marble' has been much used in the Minster; the effigy of Archbishop de Gray (*c.* 1255) in the south transept is one of the finest examples of the use of this material in the country. More accessible was the alabaster of the Chellaston district of Derbyshire. Apparently some of the mineral was brought by water down the Trent and up the Ouse, and a York school of alabaster carving arose in the fifteenth century. Water-carriage was probably used by the Romans to bring stone from Tadcaster, but the writer has learnt that the trip down the Wharfe can to-day be somewhat arduous, even for a small boat. No particular source can be assigned for the gritstone used before the Norman Conquest, but in more recent times Rough Rock from the Scotgate quarries near Huddersfield has been used in the Castle.

Some of the above notes are as much archæological as geological. Perhaps we may close with an appeal to archæologists. Between Boston Spa and Newton Kyme the Wharfe is crossed by a Roman road; the exact site of the ford can be located with some precision, but even when the river is low the water there is something like 20 feet deep, while an easy fording can be made on a bed of gravel 200 yards up-stream. In other words, the river Wharfe has cut back this shallow about 200 yards in, say, 1,700 years. It would be of interest to geologists and to geographers if archæologists would collect similar figures in as many localities as possible.

III.

THE CLIMATE OF YORK

BY

E. G. BILHAM, B.Sc., D.I.C.

THE following account of the climate of York is based on observations made by the Yorkshire Philosophical Society at a station among the ruins of St. Mary's Abbey, in the grounds of the Yorkshire Museum, 56 ft. above mean sea-level. The Society acquired the site in 1827, and the meteorological observations date back to 1832. In 1871 the station became a 'telegraphic reporting station' of the Meteorological Office, and the records preserved in the Office go back to that date. In 1899 the station reverted to the status of a 'normal climatological station'—that is to say, a complete set of readings was taken twice daily, at 9 h. and 21 h. G.M.T. It has maintained that status to the present day.

In 1881 a sunshine recorder of the new Campbell-Stokes type was set up on the roof of Bootham School, no suitable site being available in the Philosophical Society's grounds. Records with the same instrument were made continuously until 1930, when the old recorder was replaced by a new instrument. We thus have available a record of sunshine dating back to the original introduction of the Campbell-Stokes instrument. The chimneys of buildings westward of the site cut off a little sunshine near the time of sunset, but the loss from this cause is not serious. There is also a slight cut-off by the Minster towers, to the south-east, from November to February.

The observing station in the Philosophical Society's grounds may be regarded as thoroughly representative of the City of York, but it is rather too much shut in for satisfactory observations of wind. It is proposed, therefore, to restrict this article to the discussion of the climatological elements other than wind.

In Fig. 1 curves are given showing the annual variation of the more important elements. Following the standard practice of the Meteorological Office, the averages of temperature (daily maximum, minimum and mean), rainfall and sunshine refer to the period 1881 to 1915. A relatively short period is sufficient to give satisfactory averages of humidity, and those given in this article refer to the ten years 1921–30. Extremes of temperature refer to the sixty years 1871 to 1930.

Rainfall.

Referring to Table I, we see that October, with 68 mm., is normally the wettest month, and February, with 38 mm., the driest. The summer holiday months, July and August, are only slightly less wet than October. There is a very pronounced dip in the annual rainfall curve at September, a feature found in the annual curves at most British stations. The number of days of rain is highest (18) in October, November and December, and lowest (13) in June and September. The wettest month of any name was October 1903 with 177 mm., but September 1918 gave the highest fall reckoned as a percentage of the monthly normal. It is of interest to mention that no rain actually fell in the calendar month of February 1891. The 2 mm. credited to that month fell in a shower at about 6 A.M. on March 1. This amount, however, was entered to February 28 in accordance with the convention whereby the 'rainfall day' terminates at 9 A.M. on the day of reading.

To judge from the statistics given in the last column but one, York is relatively free from heavy individual falls of rain. The highest recorded fall is 58 mm., on July 25, 1886—a relatively low figure when it is remembered that we are dealing with a period of nearly sixty years.[1] In five of the twelve months the highest daily fall has only slightly exceeded an inch (25·4 mm.).

With an annual fall of 618 mm. York is one of the driest spots in Yorkshire. Its rainfall is, in fact, almost exactly the same as that of London (Camden Square, 622 mm.). The wettest year, 1912, yielded 138 per cent., and the driest year, 1921, 66 per cent. of the average for

[1] This record was surpassed on May 21, 1932, when a fall of 70 mm. occurred.

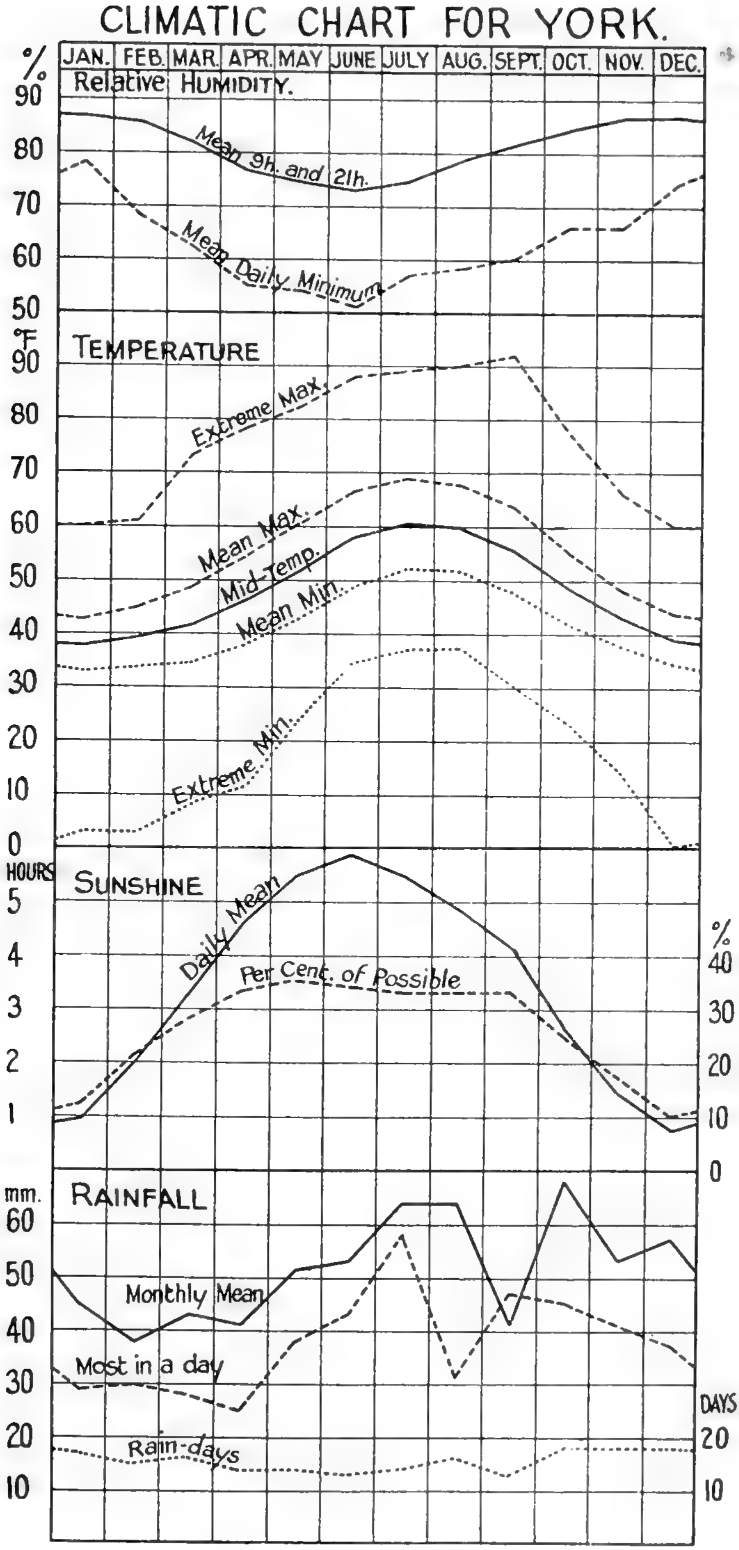
CLIMATIC CHART FOR YORK.
JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC.
Relative Humidity.
Mean 9h. and 21h.
Mean Daily Minimum
%
90
80
70
60
50
°F
Temperature
Extreme Max.
Mean Max.
Mid-Temp.
Mean Min.
Extreme Min.
90
80
70
60
50
40
30
20
10
0
HOURS
Sunshine
Daily Mean
Per Cent. of Possible
5
4
3
2
1
%
40
30
20
10
0
mm.
Rainfall
Monthly Mean
Most in a day
Rain-days
60
50
40
30
20
10
DAYS
20
10

Fig. 1.

TABLE I.—RAINFALL.

	Average Fall, 1881–1915.		Days of Rain (0·2 mm. or more).	Highest in Period 1873–1931.			Lowest in Period 1873–1931.			Greatest Fall in 24 hours to 9 h.	
	Amount.	Percent. of Annual Total.		Amount.	Percent. of Normal.	Year.	Amount.	Percent. of Normal.	Year.	Amount.	Year.
	mm.			mm.			mm.			mm.	
Jan. .	45	7·3	17	124	275	1928	7·4	16	1880	29	1913
Feb. .	38	6·1	15	99	261	1900	2·0	5	1891	30	1884
March	43	7·0	16	85	198	1909	5·1	12	1929	28	1889
April .	41	6·6	14	106	258	1882	1·5	4	1912	25	1898
May .	51	8·2	14	102 *	200 *	1903 *	11·4	22	1895	38 †	1889 †
June .	53	8·6	13	154	290	1912	0·5	1	1925	43	1892
July .	64	10·4	14	156	244	1888	11·2	17	1913	58	1886
Aug. .	64	10·4	16	137	214	1878	21·6	34	1913	31	{ 1900 1928
Sept..	41	6·6	13	148	361	1918	5·8	14	1910	47	1931
Oct. .	68	11·0	18	177	260	1903	15·2	22	1879	45	1892
Nov. .	53	8·6	18	104	196	1878	11·9	22	1909	41	1901
Dec. .	57	9·2	18	154	270	1876	6·3	11	1905	37	1882
Year .	618	100·0	186	850	138	1912	406	66	1921	58 †	July 25,† 1886

* May, 1932, yielded 144 mm. (282 per cent.). † 70 mm. on May 21, 1932.

the period 1881–1915. From a map given by Dr. J. Glasspoole in *British Rainfall*, 1925, p. 266, we may estimate the 'standard deviation' of annual rainfall as 17 per cent. of the normal yearly fall. The driest three consecutive years—1904, 1905 and 1906—yielded a mean rainfall equal to 88 per cent. of the normal—a figure which may be compared with the standard value of 80 per cent. ordinarily adopted by water engineers. Of the last ten years, four (1924, 1925, 1926 and 1929) have given an annual fall appreciably below normal. This is a point of some interest in view of the fact that in the same period the rainfall over England and Wales as a whole has been excessive in every year except 1929.

Temperature.

Table II gives monthly and yearly averages of daily maximum, daily minimum and 'mid-temperature' (mean of maximum and minimum) referred to the standard period 1881–1915, along with particulars of the highest and lowest readings in each month from 1871 to 1930. The means for the year may be compared with similar data for other low-lying inland towns :

	Height.	Mean Max.	Mean Min.	Mean Daily Range.
	ft.	° F.	° F.	° F.
York . .	56	55·4	41·2	14·2
Lincoln . .	58	55·6	41·4	14·2
Norwich . .	93	55·4	41·9	13·5
Cambridge .	41	57·3	40·6	16·7
Nottingham .	82	55·6	41·1	14·5
London (Westminster).	27	57·0	44·0	13·0
Bath . .	66	57·0	41·9	15·1

The mean monthly data call for no special comment. In regard to the extremes it is interesting to note that 60° has been reached in every month of the year, and that readings below freezing point have occurred in every month except June, July and August. The highest summer temperatures are a trifle low for an inland station. The situation of the station renders it rather liable to low minima, and we see that a reading of zero Fahrenheit occurred in 1879. A further point of interest is that in most months the extreme minimum occurred during the thirty years preceding 1900, and the extreme maximum in the thirty years subsequent to 1900. The same year, 1921, yielded both the highest and lowest readings in July.

The long series of observations at York provides an opportunity of investigating the vexed question of changes of temperature within the period covered by living memory. I give below the mean values derived from the observations during the two periods of thirty years—1871–1900 and 1901–1930—for January, July, and the year.

Period.	January.			July.			Year.		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
1871–1900	42·6	32·3	37·5	68·9	52·0	60·5	55·1	40·8	47·9
1901–1930	43·9	34·9	39·4	68·9	52·7	60·8	55·4	42·1	48·7

It will be seen that for January there has been a substantial rise both in the mean maximum and mean minimum, resulting in a rise of about two degrees in the mid-temperature. July shows little change, but in the whole year there is a rise of about a degree in the mid-temperature, the main proportion of which is contributed by a rise in the minimum. It is impossible to be certain that the whole of these differences are real; they may be due in part to the growth of trees or other changes in the environment of the observing station. Also a slight rise in the mean minimum may be expected from the fact that from 1871 to 1899 the

TABLE II.—TEMPERATURE.

	Mean Max.	Highest Daily Max.		Mean Min.	Lowest Daily Min.		Mid-Temperature.*
	° F.	° F.		° F.	° F.		° F.
Jan. .	42·9	60	6th, 1916	32·9	3	15th, 1881	37·9
Feb. .	44·7	61	16th, 1927	33·5	3	8th, 1895	39·1
March	48·5	73	28th, 1929	34·5	8	10th, 1883	41·5
April .	54·2	78	24th, 1893	37·7	11	2nd, 1917	46·0
May .	60·4	82	{ 30th, 1895 / 31st, 1922 }	42·9	24	18th, 1891	51·7
June .	66·5	88	27th, 1878	48·7	34	1st, 1898	57·6
July .	68·9	89	{ 22nd, 1873 / 10th, 1921 / 7th, 1923 }	52·1	37	5th, 1921	60·5
Aug. .	67·9	90	9th, 1911	51·4	37	14th, 1887	59·7
Sept. .	63·7	92	1st, 1906	47·4	30	26th, 1885	55·6
Oct. .	55·3	78	1st, 1908	41·8	23	24th, 1926	48·6
Nov. .	48·4	66	2nd, 1927	37·6	14	19th, 1871	43·0
Dec. .	43·8	60	5th, 1898	34·1	0	7th, 8th, 1879	39·0
Year .	55·4	92	Sept. 1, 1906	41·2	0	Dec. 7, 8, 1879	48·3

* $\frac{1}{2}$ (max. + min.).

readings referred to the 24 hours ended 8 h., while during the last 30 years they referred to the 24 hours ended 21 h. As they stand, however, the figures accord with the general belief that our winter climate has become milder—a conclusion which is supported by other statistical evidence.

Humidity.

The data of Table III are based on daily observations of dry and wet bulb thermometers in a Stevenson screen at 9 h. and 21 h. during the ten years 1921–30. On the basis of the results obtained at our observatories it may be assumed that the average of the readings at 9 h. and 21 h. agrees within about 2 per cent. with the average for the whole day, in all months.

Table III.—Humidity.

	Vapour Pressure.		Relative Humidity.			
	9 h.	21 h.	9 h.	21 h.	Mean of 9h. and 21h.	Mean Minimum.
	mb.	mb.	%	%	%	%
Jan.	7·0	7·3	87	86	87	78
Feb.	6·7	6·9	86	86	86	68
March	7·2	7·2	80	83	81	62
April	7·8	7·8	74	79	77	55
May	9·5	9·7	72	77	75	54
June	11·3	11·4	70	76	73	51
July	13·7	13·7	73	76	75	57
Aug.	13·4	13·6	77	80	79	58
Sept.	12·0	12·2	80	83	81	60
Oct.	9·8	9·9	83	86	84	66
Nov.	7·5	7·7	86	87	87	66
Dec.	7·1	7·2	87	87	87	74
Year	9·4	9·5	80	82	81	63

The yearly means are almost identical with those for Kew Observatory, Richmond, Surrey, and the annual variation is very similar. It may be said, in fact, that in regard to relative humidity the York figures are typical of those usually obtained at low-lying inland stations.

Relative humidity is an element subject to a large diurnal variation, and we cannot, therefore, regard mean values for the day, or at fixed hours in the morning and evening, as giving a complete statement in regard to this important climatic factor. It is possible, however, to arrive at an approximation to the mean diurnal minimum of relative humidity by taking advantage of two well-known facts: (*a*) that the minimum relative humidity occurs, on the average, at the same time as the maximum temperature; (*b*) that the diurnal range of absolute humidity (vapour pressure) is very small. Inspection of observatory statistics shows that the vapour pressure at 21 h. is, on the average, within about 0·2 mb. of the vapour pressure at 14 h. or 15 h., the normal time of occurrence of the maximum temperature. We may, therefore, calculate approximate mean minimum values of relative humidity from the relationship:

$$\text{Minimum relative humidity} = \frac{\text{Vapour pressure at 21 h.}}{\text{Saturation pressure corresponding to maximum temperature}} \times 100.$$

The data given in the last column of Table III and plotted in Fig. 1 have been calculated in this way. Data for other stations are not available for comparison, but it has been thought desirable to give the figures for York, partly because of their intrinsic interest and partly to illustrate the fact that more information can be obtained from humidity data based on readings at morning and evening hours than is sometimes supposed.

Sunshine.

The normal daily duration of bright sunshine is given in the second column of figures in Table IV. The third column gives the percentage of the astronomically possible sunshine, the figures being obtained by

Table IV.—Sunshine and Miscellaneous Phenomena.

	Sunshine.			Mean Number of Days of:			
	Length of Day.	Bright Sunshine.	Per cent.	Snow.	Snow lying at 9 h.	Hail.	Thunder-storm.
	Hrs.	Hrs.					
Jan.	7·95	0·97	12	3·2	3·2	0·1	0·1
Feb.	9·67	1·99	21	2·8	2·1	0·3	0·1
March	11·77	3·26	28	2·6	1·4	0·7	0·1
April	13·96	4·60	33	0·8	0	1·0	1·0
May	15·89	5·48	35	0·1	0	0·8	2·3
June	16·96	5·83	34	0	0	0·4	1·3
July	16·48	5·48	33	0	0	0·1	2·8
Aug.	14·79	4·87	33	0	0	0·1	2·9
Sept.	12·69	4·17	33	0	0	0·2	0·7
Oct.	10·52	2·65	25	0·1	0·1	0·4	0·4
Nov.	8·53	1·43	17	1·3	0·5	0·1	0·2
Dec.	7·40	0·77	10	3·5	2·7	0·2	0·3
Year	12·23	3·46	28	14·4	10·0	4·4	12·2

expressing the mean recorded sunshine in each month as a percentage of the mean length of the day. Situated as the recorder is among the chimneys of York, there is no doubt that the record is greatly affected by local smoke obscuration. In December and January the mean duration of sunshine bright enough to affect the Campbell-Stokes instrument is under one hour per day—a value comparable with that found in large manufacturing cities. During the summer months, however, sunshine is relatively abundant, the mean values for June and July approximating to those for Scarborough. The mean value for the year is distinctly low, as will be seen from the following comparative data :

	Yearly Mean Duration.	Percent. of Possible.
York	3·46 hours	28
Durham	3·60 ,,	29
Nottingham	3·70 ,,	30
Cambridge	4·29 ,,	35
Coventry	3·75 ,,	31
London (Westminster)	3·30 ,,	27
Birmingham	3·50 ,,	28

Miscellaneous Phenomena.

The last four columns of Table IV show the mean number of days of occurrence of snow, snow lying at 9 h. over more than half the surrounding country, hail, and thunderstorms. These means are based on the ten years 1921–30. Snow occurs on about fourteen days a year, and thunder on twelve—figures which indicate about the usual frequency of these phenomena at low-lying inland stations in the North of England. Thunderstorms are most frequent in July and August, when they occur on about one day in ten, and rare in the winter months. Unfortunately, statistics are not available from which to give similar tables for ground frost and fog.

I am indebted to the Director of the Meteorological Office for providing facilities for the extraction of the data in this article from the official records preserved in the Office.

IV.

YORKSHIRE PLANT ECOLOGY

BY

T. W. WOODHEAD, Ph.D.

NEARLY a century ago, John Phillips, one of the founders of the British Association,[1] gave an outline of the geology and vegetation of Yorkshire which has greatly influenced the writings of subsequent workers. He pointed out that the county provides an ideal area for the study of vegetation in that it contains within its boundaries an almost unequalled range of habitat conditions, and strata ranging from the Silurian slates of Sedbergh, the calcareous and siliceous series of the carboniferous system, through a succession of beds to deposits of pleistocene times. This area has attracted many workers, and the flora of the three Ridings has been admirably described by John Gilbert Baker for the North Riding, F. Arnold Lees, the West Riding, and J. F. Robinson, the East Riding. The vegetation of the Pennines has been mapped and described by W. G. Smith, W. M. Rankin, C. E. Moss, and F. J. Lewis. F. Elgee has described the Clevelands, and the vegetation of that area has been mapped by W. G. Smith, but the maps remain unpublished. On these works the following account is mainly based, and to them readers are referred for fuller details ; I am also indebted to Prof. Goode for an account of the East Riding.

The Pennine uplands form the western border of the county. In the extreme north-west is Upper Teesdale followed by the north-western calcareous dales, the rest consisting of the gritstone and coal-measure country of the middle and southern Pennines. Upper Teesdale is part of the Cross Fell massif, and Mickle Fell, 2,591 ft., is the highest part of the county and is of interest in that it formed part of an extensive nunatak area during the glacial maximum, hence provides many interesting problems for the botanist, and is noted for its arctic alpine rarities and species of closely restricted range, some of which may be relics of a preglacial flora. Species of special interest are *Thalictrum alpinum*, *Draba incana*, *Potentilla alpestris*, *Dryas octopetala*, *Primula farinosa*, *Bartsia alpina*, *Pyrola secunda*, *Polygonum viviparum*, *Tofieldia palustris*, and *Equisetum pratense*.

Especially interesting on account of their limited distribution in Britain are *Helianthemum canum*, *Potentilla fruticosa*, *Saxifraga Hirculus* and *Gentiana verna* ; the wonderful blue of the last on these Fells suggests a Swiss *Alpen-weisen* in summer.

The Tees, which forms the northern limit of the county, enters at

[1] See Chap. XV.

Cauldron Snout and passes over an irregular series of basaltic cliffs, bordered by a ridge of Scar Limestone. These cliffs provide a contrast and variety both in scenery and vegetation, and the limestone, at the point of contact with the intrusive rock, has been changed into a coarsely granular 'sugar' limestone, on which many of the rare plants are found. On the basalt is an extensive development of Juniper.

Proceeding southwards, extensive moorlands are developed on the non-calcareous Yoredale grits and shales. *Sphagnum* bogs cover a large area and *Sphagnum* is the chief peat-former ; at the base of the peat are remains of trees, especially birch. Across Stainmore is a broad pass between the Vales of Eden and Tees and the Vale of York, covered with boulder clay.

The north-western calcareous dales again offer a striking contrast, and include the sources of the Swale, Ure, Nidd, Wharfe and Aire. This is a deeply dissected area with only peaks of limited extent rising above 2,000 ft., e.g. Whernside, Ingleborough and Penyghent. This district almost rivals Teesdale in the interest of its flora, occurring chiefly on the great limestone scars and pavements, as at Kettlewell, Arncliffe, Malham, Gordale, Settle and Ingleborough. The higher ground, capped with Millstone Grit, is covered with cottongrass moss, ling and grass-heath predominating on the higher slopes and extending some distance over the leached limestones below. A striking feature in the landscape is the white limestone walls dividing pastures which provide excellent grazing for sheep.

The scar woods of the Mountain Limestone bear a rich flora ; ash is the dominant tree, oak is rare in the dales except on the alluvial plains of the rivers. There is much hazel as an undershrub, also *Prunus spinosa*, *P. padus*, Holly, *Cornus sanguinea*, *Viburnum Lantana*, and *Rubus saxatilis*. The more interesting plants of the ground flora are *Aquilegia vulgaris*, *Actæa spicata*, *Viola odorata*, *Spiræa Filipendula*, *Geranium sylvaticum*, *Saxifraga umbrosa*, *Galium boreale*, *Polemonium cœruleum*, *Melampyrum sylvaticum*, *Lathræa squamaria*, *Orchis apifera*, *Convallaria majalis* and *Melica uniflora*. In the scar woods of Upper Wharfedale occurs the rare lady's slipper (*Cypripedium Calceolus*). In the neighbourhood of Settle, Malham, and Gordale occur *Actæa spicata*, *Potentilla alpestris*, *Saxifraga stellaris*, *Ribes petræum*, *Galium boreale*, *Hieracium crocatum*, *Bartsia alpina*, *Primula farinosa*, *Polygonum viviparum*, *Aspidium Lonchitis* and *Nephrodium rigidum*. On Ingleborough occur *Saxifraga oppositifolia*, *S. aizoides*, *Sedum villosum*, *Epilobium alsinifolium*, *Salix herbacea*, *Carex rigida*, *Poa alpina* and *P. rigida*.

A small area in the neighbourhood of Sedbergh is on the Silurian slates, and on Howgill Fells and Cautley Crags occur *Alchemilla alpina*, *Saxifraga stellaris*, *Circæa alpina*, *Epilobium alsinifolium*, *Meum Athamanticum*, *Pyrola secunda*, *Hymenophyllum unilaterale* and *Lycopodium alpinum*.

While the moors above 1,250 ft. are generally dominated by cottongrass, which forms peat five feet or more in depth, the moors west of the Swale, from Masham Moor to Pately Moor, and further south, Burnsall Moor, Blubberhouse Moor and Rombalds Moor have a shallower peat and are dominated by *Calluna*, cottongrass being subordinate. It is significant that this moorland area has a lower rainfall than that either to the north or south.

South of the Aire gap the cottongrass moss is again dominant, and from here to the southern limit of the county the district is composed entirely of rock of the Millstone Grit series and the Coal Measures. In this gritstone area few species occur excepting those of wide distribution, one of the most interesting being *Trientalis europæa* on Soil Hill on the moors between Halifax and Keighley, its most southern station in Britain. Others of interest are the cloudberry (*Rubus Chamæmorus*), forming grey-green patches on the dark cottongrass moss, and the rarer bearberry (*Arctostaphylos Uva-ursi*).

Sphagnum bogs are infrequent and of small extent and often bear a network of the slender stems of cranberry (*Vaccinum Oxycoccus*). On the summit plateau of the Pennines is probably the greatest development known of cottongrass moss. Buried trees are common at the base of the peat, birch, oak, hazel and occasionally pine, which are the remains of the Pennine forest submerged by peat during Atlantic time. Over considerable areas retrogression is going on, the peat being completely removed, revealing patches of bare stony ground slowly becoming reinvaded by hair-grass and mat-grass. The better drained slopes are covered by bilberry, crowberry, and grass-heath, with an extensive development of bracken up to the higher springs on the clough sides. Relics of the Birch-Oak-Heath Forest occupy the rock terraces and slopes too steep or stony for cultivation. This type degenerates into the *Calluna* moor and grass-heath.

On the Coal Measures at lower levels moist oak woods prevail on the deeper soils over the shales and have a richer ground flora, but the oak-heath type is frequent on the Coal Measure sandstones. Oak is the dominant tree in these woods, but is often replaced by plantations of sycamore, and to a less extent by beech, elm, and pine. In the river valleys are relics of the Alder-Willow thicket. Fringing the moorland is upland pasture, where the dark sandstone walls contrast strongly with the white walls of the calcareous dales. In the Coal Measure area hedgerows are more frequent, especially over the shales, but they usually have a poor flora. Arable land is rare on the foothills and in the dales of the Pennines, the land being largely given up to pasture.

Cutting off the carboniferous rocks to the east is the Permian ridge or Magnesian Limestone tract which runs through the county from north to south and forms a boundary between the western uplands and the great central Vale of York; this ridge is cut through by the rivers flowing from the Pennines and in part is covered by drift carried down by former glaciers of the dales.

This tract provides several contrasts to the dark soils and pastures of the Coal Measures. The rainfall is low and the fertile soil favours a rich and varied vegetation. The reddish soil of the ploughed fields in the spring contrasts with the vivid green of the pastures, and the rich hedgerows have a varied flora both in shrubs and herbaceous species. Little uncultivated land exists in the tract, yet it is one of considerable interest to the botanist. Trees are usually abundant and of fine growth;

the dominant tree is ash, but beech is abundant and grows well and to a large size. If beech is native in the county (and that is doubtful) the Permian tract, also the slopes of the Chalk Wolds, provide good conditions for its development. Natural woodlands do not occur, but there are extensive parklands and plantations with fine trees in great variety, and Studley Park, near Ripon, contains most of the woodland trees grown in Britain.

The few uncultivated lands are either hazel copse or grassy common, as Hook Moor, near Aberford. Typical examples of Permian vegetation may be seen at Thorpe Arch, Boston Spa, Jackdaw Crag and the neighbourhood of Knaresborough ; the more interesting shrubs in the hedgerows are barberry, holly, maple, spindle tree, purging buckthorn, and blackthorn, and of herbaceous species found on this tract are *Anemone Pulsatilla*, *Helleborus viridis*, *Actæa spicata*, *Reseda lutea*, *Helianthemum vulgare*, *Cerastium aquaticum*, *Arenaria tenuifolia*, *Linum perenne*, *Geranium sanguineum*, *Sison Amomum*, *Pastinaca sativa*, *Asperula cynanchica*, *Dipsacus pilosus*, *Arctium intermedium*, *Inula Conyza*, *Carduus eriophorus*, *C. acaulis*, *Campanula patula*, *Chlora perfoliata*, *Atropa Belladonna*, *Linaria Elatine*, *Calamintha Nepeta*, *Hottonia palustris*, *Daphne Laureola*, *D. Mezereum*, *Orchis pyramidalis*, *Ophrys apifera*, *Spiranthes autumnalis*, *Carex divulsa*, *C. digitata*, *C. ornithopoda*, *C. strigosa*, and *Brachypodium pinnatum*.

Most of the above species are of special interest when we consider their distribution in Britain, and when indicated on a map the Permian ridge is seen to be a great line of postglacial migration or persistence of southern species which reach their northern limit in Yorkshire. Excluding critical genera and species, about sixty-five species reach their northern limit in Yorkshire and twenty more species reach their limit across the Tees in Durham, and their distribution can be traced along the ridge, then eastwards to the calcareous Hambleton and Howardian Hills and chalk Wolds, and westwards to the mountain limestones of Upper Wharfedale and Upper Teesdale. Along the great tract of Grits and Coal Measures these species are almost absent. On the other hand northern species reaching their southern limit in Yorkshire find their chief centres on the limestones of Upper Teesdale and the north-western dales, to a less extent on the calcareous eastern dales and to only a slight extent on the Permian, Millstone Grits and Coal Measures.

The north-eastern or Oolitic hills include the Hambleton and Howardian Hills bordering the Vale of York and the North York Moors and Cleveland Hills. The glacial geology of this area has been admirably described by P. F. Kendall and the natural history and vegetation by F. Elgee.

The North York Moors rise to over 1,400 ft. and the subsoil is formed from the sandstones and shales of the Lower Oolite. Running in a synclinal depression of the Oolite is the Esk. Its principal tributaries join it from the south and form a succession of dales cut down into the Lias ; the main ones are Basedale, Westerdale, Fryupdale, and Glaisdale, and near the coast, Iburndale. The Cleveland Moors are the finest heather moors in Yorkshire ; ling is the dominant plant, but in the moister hollows and slacks bell-heather and cottongrass predominate, the last occurring on deep peat. Changes seen in the vegetation are closely related to the glacial history of the area ; in parts formerly occupied by the glacier lakes bracken is conspicuous, also on the moorland slopes of the valleys. The moist overflow channels are occupied by peat, with an abundance of cottongrass, rushes and sedges, and make a marked contrast with the surrounding heather moor. Plantations of conifers form a zone along the lower margin of the moorland, but afforestation of the heather moor, as at Allerston Moor, is seriously hindered by the presence of moor pan.

Draining these moors to the south are the tributaries of the Derwent which form a series of well-wooded and picturesque dales, including Forge Valley, Newtondale, Rosedale, Farndale, Bransdale, and Bilsdale, each with an interesting flora. In Forge Valley and in the neighbourhood of Hackness occur *Helleborus viridis*, *Aquilegia vulgaris*, *Actæa spicata*, *Cornus suecica*, *Atropa Belladonna*, *Myrica Gale*, *Spiranthes autumnalis*, *Epipactis ensifolia*, *Maianthemum bifolium*, *Osmunda regalis* and *Equisetum hyemale*. At the head of Newtondale is a small branch glen, the Hole of Horcum, noted as a station for *Cornus suecica*, one of the few montane plants found in the east but absent from the western calcareous dales. Other plants of interest in Newtondale, in addition to some above-mentioned, are *Trollius europæus*, *Astragalus hypoglottis*, *Carduus eriophorus*, *Inula Helenium*, *Salvia verbenaca*, *Neottia nidus-avis*, *Habenaria albida*, *Ophrys mucifera*, *Gagea lutea* and *Convallaria majalis*.

In Ryedale and the neighbourhood of Helmsley a similar flora occurs, and there is one of the stations of the lady's slipper orchid. The Vale of Pickering is a flat low-lying tract, extending from the coast inland for thirty miles. It is intersected by streams from the dales and contains many carrs and marsh lands.

The Howardian Hills comprise two narrow parallel terraces which extend from the calcareous hills eastwards to the Derwent and are situated on the south-west of the Vale of Pickering and separate it from the Vale of York. The northern terrace is composed of calcareous beds of the Lower Oolite ; the southern one of Lower Oolite based on Lias. This tract furnishes a great variety of surface and vegetation—moorland, woodland, parkland (including Castle Howard), also Terrington Carr, a well-known heathery swamp, and though there are no montane species, there are as many of the rarer species to be found within an equal area as anywhere in Yorkshire excepting Upper Teesdale.

The Hambleton Hills form a calcareous range with an elevation of 1,100 ft. At Boltby Scar, Whitestone Cliff and Roulston Scar are three fine precipices formed of calcareous grit. Whitestone Cliff is a perpendicular cliff 100 ft. deep, the base of which is covered with fallen debris from the summit. At the foot of this cliff is Lake Gormire, the largest tarn of the East Yorkshire Hills. These grits rest upon Oxford Clay, rendering them unstable, and a landslip thus produced closed one end of what was probably a glacial lake overflow channel and obstructed the drainage. Except for the drainage from the hill bank no streams flow into it, and its waters are mainly supplied by rain and diminished by evaporation. The following plants occur here and along the hillside to Roulston Scar: *Trollius europæus*, *Draba inflata*, *Viola lutea*, *Stellaria nemorum*, *Geranium sanguineum*, *Lathræa squamaria*, *Primula farinosa*, *Trientalis europæa*, *Gagea lutea*, *Acorus calamus*, *Lycopodium selaginoides* and *Pilularia globulifera*.

The Vale of York is a low-lying, richly cultivated tract extending from the Tees to the Trent and covered by thick beds of alluvial muds, silts, and glacial deposits of gravels, sands and clay. Formerly a wet, marshy area, drainage and enclosure have taken place from 1670 onwards, and now the greater part of it is highly cultivated. Small areas, however, still retain a primitive vegetation. Strensall is the site of a military camp, for which it has been greatly modified, with the loss of many interesting plants. Askham Bog, two miles from York, is perhaps the most primitive area, and preserves the conditions which formerly prevailed over a wide area of the Vale of York. Here the drainage is held up by two minor loops of the York moraine and has never established a proper drainage system. The bog and adjoining brick ponds have a rich marsh and aquatic flora, which was described by the Rev. W. C. Hey as consisting of 'pools bordered by flags, sedges, bulrushes and marsh ferns, jungles of Osmunda, with birch, willow and blackthorn. The Bog is a tangled mass of flags and sweet gale and various low-growing trees.' Since then some of the ferns have been almost exterminated.

The Chalk Wolds form a crescentic ridge of hills rising to 800 ft., running north from the Humber to Grimston, then turning east to the coast at Flamborough Head. The chalk is hard, similar in character to a normal limestone, very porous, and strongly calcareous, except where it is covered with boulder clay. Along the northern edge a bold escarpment overlooks the Vale of Pickering, and another along the western edge commands a view of the Vale of York, the strata dipping towards the Plain of Holderness. On both slopes, dales are cut deeply into the chalk. Many of these are dry and often covered with chalk and flint gravel. The Wolds are highly cultivated, woodlands are few, and there is very little natural vegetation. Areas of natural chalk grassland are few; the largest is Millington Pastures in the Londesborough district. The escarpments and dales provide a suitable habitat for the beech, which is a commonly planted tree, and Robinson, who refers to it as 'the tree of the Wolds,' regards it as native. Owing to the extreme porosity of the chalk, bogs and marshes are absent, and only around the base do springs occur which afford habitats for aquatic and marsh plants.

East and south-east of the Wolds lies the Plain of Holderness, covered entirely with glacial and alluvial deposits. A long tongue of land extends to the south-east, ending in the hook of Spurn. Much of Holderness is only a few feet above sea-level, its highest point being about 100 ft. The soil is a stiff clay except for certain gravelly morainic ridges and the alluvial valleys of the streams. The soil conditions favour agriculture and market gardening and also afford good pasturage; as a result practically the whole area has been changed by extensive drainage and cultivation, and little native vegetation persists. In strong contrast to the previous divisions of the county heaths are absent. The species most worthy of note are *Vicia lathyroides*, *Lathyrus palustris*, *Rosa pimpinellifolia*, *Bupleurum rotundifolium*, *Cicuta virosa*, *Sium latifolium*, *Cnicus eriophorus*, *Lactuca virosa*, *Atropa Belladonna*, *Pinguicula vulgaris*, *Polygonum Bistorta*, *Epipactis palustris*, *Habenaria viridis*, *Acorus Calamus*, *Lemna gibba*, *Damasonium stellatum*, *Lastrea Thelypteris* and *Botrychium Lunaria*. The cowslip is very abundant in the damp meadows, adders-tongue fern is common, so also are *Geum rivale* and *Hottonia palustris*. Holderness is the home of the hawthorn, and nowhere is it more beautiful and luxuriant.

The coast line is very varied, the most striking part being the magnificent chalk cliffs of Flamborough and Bempton. South of Flamborough, the coast consists of low cliffs of glacial deposits undergoing constant erosion, which renders plant colonisation impossible. These clay cliffs pass into the long sand and shingle spit of Spurn Point, which takes the form of a slightly curved and greatly elongated sandhill, partially protecting the Humber from the open sea. Spurn is the most interesting botanising ground in the district, and the following plants may be found: *Claytonia perfoliata*, *Erodium moschatum*, *Trifolium scabrum*, *Blackstonia perfoliata*, *Erigeron acre*, *Suæda maritima*, and *Hippophae rhamnoides*. *Convolvulus Soldanella* also is plentiful, and Spurn is particularly attractive when this plant and *Ononis* are in full flower.

The fourth part of the coast is that of the south, bordering the estuary of the Humber between Spurn and the Wolds. Here the plant habitats are formed by the banks of mud and sand which are constantly being deposited and eroded by the river and the tides. These banks afford a most interesting series of successional vegetation states. *Glyceria maritima*, *Scirpus maritimus*, *Armeria maritima*, *Cochlearia* spp., *Glaux maritima*, *Triglochin maritimum* and *Aster Tripolium* are conspicuous, and the last-named often grows to great size.

V.

ZOOLOGY

BY

A. J. A. WOODCOCK.

THE area to which this account refers is contained within a circle of twenty miles radius, with its centre at York. A brief description of the area will be given first, and then some of the more interesting districts within easy distance of York will be mentioned. The western edge of the area includes the junction of the north Pennine Dales with the Plain of York. Through these dales the following rivers enter the district: the Swale

(16 m.[1]), the Ure (8 m.), the Nidd (24 m.), the Wharfe (26 m.) and the Aire (30 m.). These all flow into the Ouse (45 m.). The lower parts of the tributaries and the whole of the Ouse are wide, deep and slow-flowing, and form the drainage system of the long, flat plain which crosses the district from north-west to south-east, and comprises most of our area. The Foss (18 m.) drains the northern part of the plain and joins the Ouse at York. On the north lie the North York Moors, and from these the Rye (16 m.) flows into the Derwent (38 m.), which proceeds southwards to join the Ouse below Selby. Beyond the Derwent Valley we extend to the Wolds, which form our eastern boundary, and in this area the only waterway of any importance is the Pocklington Canal.

We include, therefore, elevated heathlands to the west and north, country of the ' down ' type to the east, while the central portion and that to the south are flat alluvial lands, of which the major part is cultivated very intensively, leaving but a small fraction in a wild or primitive state. That which is still untouched, however, comprises, as would be expected, several most interesting districts, which will well repay a visit. Of those which are readily accessible from York, Askham Bog is perhaps the most noteworthy. This is a genuine piece of unspoilt fenland, situated three miles from York on the road to Tadcaster, and is probably the sole remaining representative of a distinct type of country, once prevalent in the Plain of York. Its surface is virgin peat, which reaches to a depth of 8 feet, and rests upon clay. Though dwelling-houses have extended very near to it, especially within recent years, and it is perhaps no longer so rich a hunting-ground as formerly, it is still a very famous place, and the records of its fauna extend back for a period of just over a hundred years.

Flat, sandy commons are a feature of the plain. They are characterised by hummocky surfaces of coarse grass, heather-covered spaces, and in the wetter parts rushes and cotton-grass, frequent marshy hollows, and woods of pine and birch and sallow. Left as these commons have been in an uncultivated state, they have a rich and varied fauna. The nearest is a stretch which begins with Strensall Common, about five miles to the north-east of York, and extends to the districts known as Sandburn and Stockton Commons. At Sandburn the wooded area is much increased. Of the part actually at Strensall that nearest to York has been occupied by the War Office as a military camp for many years, and rendered useless from the point of view of the naturalist, but the rest is good.

Skipwith Common is smaller in extent, about nine miles south from York ; the area of ponds and marsh is greater than at Strensall.

Allerthorpe Common is a region of about a square mile in area, about fourteen miles east of York. It has all the characteristics already described, and, though surrounded by well-cultivated country, is itself untouched, and abounds in many good things.

Of wooded areas there are the districts around Castle Howard and Kirkham Abbey, fifteen miles to the north-east, and the thickly wooded region of Aldby Park and Buttercrambe, about seven miles east. There is woodland at Stillington, and still further to the north we adjoin the richly wooded district of Byland.

[1] The distances indicate the length of the rivers contained by our area.

We possess most types of fresh water, with the exception of large lakes and mountain tarns. The following are quite close to the city. Hob Moor (2 m.) contains old brick workings, giving both deep and shallow clay-bottomed ponds. The Ings begin beyond the city, and extend along the banks of the Ouse. They are water meadows of alluvial deposit with ditches and hollows periodically flooded. Bootham Stray (2 m.) is a flat stretch with ponds and ditches, typical of the grass-lands of the district. Stockton Common, already mentioned, contains private fish-ponds, old 'stews,' and marl-pits typical of the arable lands. The Foss is a silted-up, overgrown, disused water-way, extremely rich in its varieties of aquatic life. The above description is intended to give a rapid survey of the regions which the York naturalists have found most productive, in order that members of the British Association may readily select places to visit with the greatest advantage.

The various forms of life to be found in these regions are now to be discussed. In the account of them which will be given such species as would be almost certain to be present will not be mentioned.

Birds and Mammals.

The Derwent Valley is a nesting place for large numbers of snipe, redshank, and green plover, but during the past three years the heavy floods during the season of incubation have destroyed large numbers of nests. During the winter these flooded areas are the resort of many thousands of mallard and widgeon. There are also large numbers of teal, pochard, tufted and golden-eyed duck.

Skipwith Common has also been adversely affected by floods. A colony of about 500 pairs of black-headed gulls has been established here for many years. About ten pairs of shoveller have nested here, as also do the pochard, mallard and teal. There are also always several pairs of nightjars during the summer months. The green plover is becoming scarce in this area, because its nests are raided by the black-headed gulls, and when situated on arable land, much of which has been reclaimed from the common, many eggs are destroyed by farmers' rollers.

The thickets of birch and sallow in Askham Bog are the summer haunts of sedge warbler, reed bunting and the garden and blackcap warblers. The rarer reed warbler has nested here in recent years, and so has the grasshopper warbler. The sparrow-hawk, kestrel and jay occur, and also the coot, little grebe and snipe. Askham Bog was once the haunt of the bittern.

At Strensall Common was once a colony of black-headed gulls, but they were driven away by the soldiers from the camp, who constantly raided their nests. Numbers of duck, which nested on the marshy parts, also suffered from the same cause. A few pairs of mallard and tufted duck still occur. Curlews may often be seen and heard, and in recent years several pairs have nested on the common. The long-eared owl and tawny owl nest in the fir thickets, and so also does the great spotted woodpecker. The jay and carrion crow, the sparrow-hawk and the kestrel also occur in good numbers. Ringdoves nest here in large numbers, and the rarer stockdove occurs.

The adjoining woods of Sandburn are famous fox coverts, and both otters and badgers occur. The red squirrel, once common, has given way to the grey.

In the thickly wooded region of Castle Howard and Kirkham are to be found all the common species of birds and mammals. The lesser spotted woodpecker nests near the Castle, and every year a few pairs of pied flycatchers are observed. The large lake is a famous bird haunt. Usually there are three pairs of great crested grebe nesting there, and about six pairs of reed warblers. Mallard and tufted duck, coots, moorhens, and little grebes nest abundantly. Turtle doves are summer visitors to all these woods, and at Kirkham Abbey is a famous colony of badgers, which has an ancient history. Otters are also often seen in the vicinity of the pretty falls in the river Derwent at Kirkham Abbey. Sandpipers, dippers and kingfishers occur at this point, but they are considerably more numerous a little higher up the river and along the course of the river Rye.

Aldby Park and Buttercrambe Woods have very extensive bird populations, and in 1931 a pair of nuthatches reared their brood successfully at Aldby Park. They thus set up a new record. Turtle doves are very numerous here during the summer months.

The landrail has decreased most markedly during recent years in the whole of the York district. Since its tendency to decrease was first noticed it has been the subject of special observation, and only six were noted in 1930, and four in 1931. A few years ago this bird was very abundant on Clifton Ings, and could be heard constantly during a summer evening walk along the river bank for two or three miles. Now it is very unusual to hear one.

Before the war there was a large heronry at Stillingfleet, and as many as fifty-six nests were counted at one time in the heron wood. This wood, however, was cut down and the herons displaced, with the result that very small parties are scattered over that area, the largest being in the Shireoak Wood at Healaugh, a region of 400 acres. Here from six to ten nests are protected annually by Sir Edward Brooksbank.

Fresh-water Fauna.

In the extremely flat district within ten miles of York the sluggish rivers are inhabited by ' coarse ' fish. These are plentiful, and all species on the British list have been taken with the exception of the spinous loach. The sturgeon occasionally ascends the Ouse as far as Naburn Lock, but has not been recorded lately. On the other hand, the burbot eel has appeared in the river Derwent this year, two having been caught during May, at Elvington. The burbot was once common in our rivers, but has become exceedingly scarce. Lampreys ascend the main stream and its tributaries, and have been reported recently in the Isle Beck at Thirkleby, and in the Skirpenbeck, near Stamford Bridge. The flounder is also plentiful in suitable waters ; specimens of both the flounder and the lamprey were taken from the York Waterworks settling beds during netting operations, the flounder in 1929, the lamprey in 1931.

The streams from the lower slopes of the Moors and Pennines in the northern and western parts are, of course, swifter, and here any many good trout and grayling streams, mostly preserved waters, which are periodically restocked. The Yorkshire Fishery Board has a committee for netting and restocking. The Board's coarse fish rearing ponds are from five to seven miles to the north-east of York, and here fish, mostly perch and roach, are bred to replenish the various waters. This year (1932) the Board has established a trout hatchery at Keld Head, near Pickering.

The Ouse with its tributaries is an important salmon river, the salmon ascending the Ouse as far as Aysgarth, and they enter the Derwent during flood periods. Salmon parr have recently been caught in its tributary, the Rye. The Report of the Yorkshire Fishery Board for 1931 shows that 823 salmon were caught in the Ouse during that year, the average weight being 10 lbs. 3¼ ozs.

It is noteworthy that in the two runs of the salmon up the Ouse, the one in the spring and the other in the autumn, the fish take the left-hand fork of the river at the junction of the Swale with the Ouse, thus passing into the Ure. Though both rivers are free from pollution, the Ure is a salmon river, the Swale is not. Mr. S. H. Smith, F.Z.S., of the Yorkshire Fishery Board, is at present engaged in researches with a view to the restoration of the Swale as a salmon river. A very full account of the present position of this research may be found in the *Naturalist*, April 1932, and there is a further reference in the Report of the Yorkshire Fishery Board for 1931. Briefly the argument is as follows. There is an obstruction at Topcliffe Weir. After the building of the weir Swale ' homing ' salmon would be unable to return, and so in time the Swale has ceased to be a salmon river. If, then, salmon were to be reared in the Swale now, and then found after a period of years to be returning to try the Swale, the construction of a fish pass at Topcliffe would be justifiable. The results of Mr. Smith's investigations will be awaited with great interest.

In connection with the restocking of the waters by the Board, Mr. Smith is carrying out interesting experiments with selected fish, which are measured and marked before being released. The results of these, up to date, are to be found in the Board's reports for 1929, 1930, and 1931.

On the occasion of the last visit of the British Association to York in 1906, the Handbook, in dealing with the fish fauna of the district, said : ' Without doubt the greatest curse our fish fauna has to face is the constantly increasing pollution of our streams.' It is satisfactory to find that since that date the Yorkshire Fishery Board has got this matter in hand, and considerable progress has been made in the prevention of pollution.

The common frog and toad, the crested newt and the smooth newt are plentiful, but there is no recent record of the palmated newt.

The flatness of the district results in much stagnant water and sluggish streams, conditions suitable for ensuring an abundance of the smaller Crustaceans, but not for the fresh-water crayfish, which is only sparingly distributed. Two very recent accounts of the prevalence of the crayfish in Yorkshire are contained in the *Naturalist* for 1930 and 1931.

The Mollusca are very richly represented. About forty-four fresh-water species occur in the area, most of them abundantly. Nine of these have been added to the list since the visit of the British Association in 1906. The Foss, once a navigable river, has been allowed to silt up, and being unscoured by any fast-flowing current, has become a most profitable centre of study for all kinds of fresh-water biology, but its Mollusca are particularly important, some thirty-four species having been recorded from that river alone, practically within the confines of the city itself.

Insects.

The areas previously described are all noteworthy hunting-grounds. The Lepidoptera have been studied very carefully and continuously, so that our records are very full. The reproach in the Handbook of 1906 about the neglect of the so-called Microlepidoptera no longer holds. Of butterflies, the Peacock, the Comma, and the Wall are rare, and the Wood Argus does not occur. About thirty-three species are recorded as having occurred, but this number includes, of course, the very occasional wanderers, such as the Clouded Yellow and the Camberwell Beauty. It is interesting to note that, as a rule, the annual arrival of our Painted Lady butterflies is about five to seven days after the record of the insect's appearance upon the South Coast, that is, usually, during the first week in June. The White-Letter Hairstreak, after being unnoticed for many years, has again been found in the north of our district. The Duke of Burgundy occurs in Newton Dale, just out of our area, and the Brown Argus on the Wolds at Millington.

Of moths, the following have been given to me as the 'best things' to be obtained in the localities mentioned. At Askham Bog: *Acronycta leporina*, *Leucania impudens*, *Cœnocalpa lignata*, *Collix sparsata* and *Scotosia vetulata*. At Strensall and Sandburn: *Palimpsestis or*, *Cybosia mesomella*, *Agrotis agathina*, *Eurois occulta*, *Xanthia paleacea*, *Acidalia straminata*, *Triphosa dubitata*, *Eucosmia undulata*, *Epione vespertaria* (*parallelaria*). This common has the distinction of being the one locality in England for *Epione vespertaria*, although odd specimens have been taken once or twice in other places. At Sledmere: *Abraxas ulmata*, *Asthena blomeri*. At Pickering: *Trichiura cratægi*, *Ortholitha bipunctaria*. At Millington: *Parasemia plantaginis*, *Ino geryon*. At Cropton: *Aplecta nebulosa*, *Lithomoia solidaginis*, *Xanthorhoe tristata*. At Hovingham and Garrowby: *Eupithecia pusillata*. At Wass: *Plusia interrogationis*. At Gilling: *Venusia cambrica*.

The Coleoptera of York have been investigated for many years, and the records extend back for more than a century. Amongst the pioneers was Archdeacon Hey, who began in 1840, and whose records include much that is of the greatest interest, particularly with respect to the water beetles of Askham Bog. But the pools of Askham are not all what they were at the time of the visit of the British Association in 1906. They have not been drained, as have so many pieces of fenland which the naturalists of a former generation knew, but have silted up with the accumulated dead leaves of the trees growing round them, and these in the pools themselves have formed a thick, souring mass very destructive to insect life, and some of the greatest rarities seem, from the more recent records, to have become quite extinct.

Of the Carabidae, *Carabus monilis* is common, and *C. nitens* occurs in its own type of locality. *Blethisa multipunctata* is still at Askham Bog, and *Miscodera arctica* is found at Allerthorpe Common and Stillington Common. Of the Longicornia, *Rhagium bifasciatum* is very abundant at Strensall, and *Strangalia armata* is to be found at Askham Bog. *Clytus arietis* is common at Kirkham. The York plain is very rich in Chrysomelid beetles. *Chrysomela graminis* is still abundant annually on Clifton Ings, and again at Skipwith Common, while *Melasoma populi* is to be found in numbers both at Allerthorpe and Strensall. *Gastroidea viridula* appeared in enormous numbers on the Ings last year.

It is not surprising that the dragonflies are well represented, when we consider how well supplied with ponds the district is. The Agrionids are abundant about most waters. Both *Calopteryx virgo* and *C. splendens* are found. Clifton Ings is their nearest habitat, and there are records for Buttercrambe and Castle Howard. *Æschna grandis* has been taken on Clifton Ings, and of the other Æschnas, *juncea* is the most frequently found. *Libellula quadrimaculata* is in some years exceedingly common on the larger ponds both at Strensall and Skipwith.

In the *Naturalist* for years back are very good lists of the insect fauna of Yorkshire, and the reader who consults its pages will be able to appreciate the great amount of systematic entomology which is being carried out in Yorkshire by the members of the Yorkshire Naturalists' Union.

No account of the natural history of the district would be complete without a reference to the special charms of York itself. Though not at all a small city, its associations are essentially rural. Its older parts have generous gardens, even in the centre of the city, and the extent to which these are frequented by birds is quite unusual. The dawn chorus in the spring and early summer causes comment from the visitor from another town, when he hears it for the first time.

For several years a pair of kestrels has nested in the main tower of York Minster, a pair of barn owls in the turrets of the Theatre Royal, and another pair in Bootham Bar. A pair of tawny owls frequents Bootham Park, and another pair the Museum Gardens. The kingfisher, which is found along the banks of the Ouse, may be regularly seen on the river within the city boundaries. A few minutes' walk from the houses in Clifton will enable one to put up a snipe, and curlews may often be heard calling when we walk through the streets during the quiet of night.

A pair of otters has for some years reared young on the river Ouse, and usually they may be seen during the night watches in the vicinity of the old Guildhall and Common Hall Lane—in other words, in the very heart of the city. Otters are often found along the course of the river Foss, and at several other points on the outskirts of the city. The grey squirrel frequently comes into the gardens of the houses in Clifton.

The Yorkshire Philosophical Society, intimately associated with the foundation of the British Association, has rich natural history collections in its Museum. These include general collections of a very complete nature, and in addition the following special collections of local importance: the Hey Collection and the North Collection of Land and Fresh Water Mollusca, the Allis Collection of Lepidoptera, and the Hey Collection of Coleoptera. In view of what has been said already about the work which Archdeacon Hey began in 1840, and carried on till his death in 1882, the value of the last-mentioned of these collections will be easily understood.

Much of the valuable work of the Yorkshire Philosophical Society is carried out by its York and District Field Naturalists' Section. This is an association with a very long history, which was reconstituted in 1874. At the present time it is considering the question of the compilation of a totally new Flora and Fauna of the area to which this account has reference, and it is hoped to make a beginning with the publication of this during the course of the coming year. The Field Naturalists' Section is preparing an exhibition in connection with the forthcoming visit of the British Association, and in this it is hoped to gather together much that will be representative of the biology of the district, and be an illustration and amplification of the substance of this account. Its members will also be very pleased to give any information on the subjects of which they have special local knowledge.

The Annual Report of the Yorkshire Naturalists' Union, published in the *Naturalist*, surveys yearly the fauna of the district, and the same journal gives records of newly discovered species and the occurrence of rare and occasional visitors. There are also available the very complete local records kept for many years back by the York Naturalists' Sectional Recorders. These are kept in the library of the Yorkshire Philosophical Society. As pertaining particularly to birds, we have also 'The Birds of Yorkshire,' by T. H. Nelson and W. E. Clarke, and 'The Art of an Old Wildfowler,' by S. H. Smith, which applies in particular to the birds of the Derwent Valley.

In conclusion, I have to express my very great indebtedness to Mr. S. H. Smith, who supplied me with his invaluable notes on the birds and mammals; to Mr. A. Smith, who gave me all his records of local Lepidoptera; and to Mr. C. Allen, for his information on the fresh waters and their fauna.

VI.

HISTORICAL GEOGRAPHY

BY

PROF. HAMILTON THOMPSON, D.Litt., F.B.A., F.S.A.

At the point at which York first comes definitely into history, during the Roman occupation, its importance seems to have been inferior to that of the city of Isurium, on the site of Aldborough, close to the junction of the Ure and Swale. The advantages, however, which its central position gave it as the military headquarters of the district, led to its connection with the Roman roads which skirted the edges of the plain. The present road which runs east to the Wolds at Garrowby Hill united it to the road from Brough on the Humber to the Roman station on the Derwent at Malton; while the normal approach from the south is represented by the road which leaves York by Micklegate Bar, and, running south-south-west to Tadcaster, joins the road from Doncaster and Castleford to Isurium on Bramham Moor. A road also led from York north-west to Isurium, approximately on the line of the modern road to Aldborough and Boroughbridge. Protected on the north by the forest land on the left bank of the Ouse, the roads which joined York to the rest of the country ran east and west; and the Roman Eburacum, midway between two lines of road which ran from south to north, held the communications and commanded both at once.

The Romans, then, made Eburacum, a name in which the Celtic appellation of the place was latinised, a strategic centre which became the capital of the northern province of Britain, and, at any rate in the later days of the Empire and in face of the danger with which Picts and Scots threatened the north, the headquarters of their power in the whole country. Of its history during the earliest period of Teutonic invasion nothing can be said. Ida, the founder of the Northumbrian kingdom, made his home far to the north on the basaltic rock of Bamburgh; and, south of the Tees, another Anglian chieftain, Ælle, made himself master of Yorkshire and founded the kingdom known as Deira. His famous son, Eadwine, who united both the northern kingdoms and, ruling from the Firth of Forth to the Trent, pushed his conquests beyond the Pennines and to the borders of Wales, certainly recognised the importance of York. It would be, perhaps, incorrect to speak of York as his capital, for he made his residence in various parts of his realm, and, where the king was, there was the capital for the time being. But, with the conversion of Eadwine and his court to Christianity, it was within the walls of the Roman city that the king received baptism and the metropolitan church of the north was founded. Although after the death of Eadwine in battle at Hatfield, east of Doncaster, in 633, the Northumbrian kingdom was again divided, and York itself played only an incidental part in its subsequent reunion under Oswiu, the city was the natural metropolis, civil and ecclesiastical, of Deira. In the middle of the eighth century, during the decline of the kingdom, the bishop of York first took the title of archbishop, and the school established in connection with the cathedral church became, under its famous master Alcuin, for the time being one of the most celebrated centres of education in Europe.

By virtue of its position on a tidal river at the head of a great estuary, York offered itself as an objective to invaders who came from the lands across the North Sea. In 867 the Danish host, after wintering in East Anglia, came up the Humber and, taking advantage of civil war between two rival kings, conquered York. From this period began that epoch of Danish colonisation which has left its indelible mark upon the place-names of the East and North Ridings, and decided the eventual form of the name York itself. To the Danish conquest we probably owe the civil division of Yorkshire into the three Ridings, with York, the seat of the Danish jarl, at the point where they meet. It is interesting to notice, however—a point which has been generally overlooked—that until within the last hundred years the wapentake of Ouse and Derwent in the East Riding, which lies south of York between the two rivers, was included for ecclesiastical purposes with the parishes of the North Riding archdeaconry of Cleveland. Although there is no evidence for the division of the diocese of York into archdeaconries before the Norman Conquest, yet the archdeaconries, when they came, followed the civil limits of the Ridings pretty closely; and this exception seems to point to an early arrangement by which the North Riding originally extended further south.

In the events of the Norman Conquest York played a conspicuous part. While the Conqueror was preparing for his invasion of England, Harold's brother, Tostig, who had been dispossessed of his earldom of Northumbria, joined with the Norwegian king Harold Hardrada in an attack upon York from the Humber. The brother earls Edwin and Morcar were defeated by the invaders at Fulford on the outskirts of the city, and the imminent danger of York compelled Harold to abandon his preparations for defence in the south and march in haste northward. He entered York from the west and won a victory over the Northmen at Stamford Bridge, on the Derwent, where Harold Hardrada fell. But this swift campaign enabled William to land in England unopposed, and, a fortnight after Stamford Bridge, Harold, unable to recover lost ground with a tired and straggling army, was defeated and slain at Hastings.

During the three years that followed, York was the danger point of the North of England to the foreign conqueror. The Anglo-Danish population of the city, so recently saved from one invader, now prepared to resist another and uphold the claims of the English prince, Edgar the Ætheling, to the throne. In 1068 William came from the siege of Exeter to York and quelled the revolt temporarily. But the garrisons of the castles which he founded on either bank of the Ouse were unable to hold them in his absence against the rebels, who allied themselves with a band of Danish marauders. York was set on fire by the Norman soldiers, and for the slaughter which ensued William took condign vengeance by laying waste the whole country from York to the Tees and Tyne. It was long before Yorkshire recovered from this visitation, and the extent of William's punitive operations is seen in the record of wasted land which, sixteen years later, appeared in Domesday Book.

The foundation of castles at York was part of the strategic plan by which the Conqueror imposed his dominion upon his English subjects. The castle, the symbol of feudal lordship, was imported into England from Normandy, and was intended at once to protect and to overawe the town in its vicinity. Castles of earthwork with timber defences rose in the neighbourhood of towns, especially at the crossings of rivers, which had come into importance during the Danish wars. At York, William's first castle, the mound of which remains close to Skeldergate Bridge, was founded on the right bank of the river; but shortly afterwards was superseded by one upon the opposite bank in the strong position formed by the meeting of the Ouse and the Foss.

The extent of mediæval York is still clearly visible in the walls by which the city is encircled. The original settlement and the Roman city had been upon the left bank of the Ouse, but by the time of the Norman Conquest the city had already spread across the river, and the present walls, following the Roman lines of defence in their north-east portion, surround this wider area and gradually took the place of the wooden stockade, which was its first defence. Communication between the two parts of the city was furnished by Ouse Bridge at the east end of Micklegate. The four gateways or bars of the city gave access to main roads. Through Micklegate Bar passed the western road to Tadcaster, from which branched the north-western road to Boroughbridge and Catterick. Bootham Bar, the north gate, led to the roads through the forest of Galtres to Easingwold and Helmsley. On the east side, the road to Malton and Scarborough passed through Monk Bar, and through Walmgate Bar, on the south, the road to Market Weighton and Beverley. Standing at the junction of these main thoroughfares, York was the centre of communication for all parts of the county and permanently maintained the importance which it had acquired in Roman times.

Throughout the Middle Ages, York formed the main barrier against the constant inroads of the Scots east of the Pennines and was the base of the English offensive for the Scottish campaigns of the fourteenth century. Not only was it upon the direct way from London to the Scottish border at Berwick; it also was on the route to Carlisle and the Solway by the road which, branching westward from the road to the north beyond Catterick, crosses Stainmore to the valley of the Eden. Modern roads and railways have made light of the mountainous regions of north-western England, which the mediæval traveller avoided and through whose passes Scottish forays into Craven and the dales of Yorkshire met with little or no opposition; and, in our changed conditions, the former importance of York as the key to the whole line of the border may easily be overlooked. Scottish warfare was of a desultory kind, and the raids which were its habitual method were conducted upon no strategic plan. The vales of York and Mowbray were from time to time the scene of battles, of which the most famous was the battle of the Standard, fought in 1138 some miles north of Northallerton, on the rising ground between the vale of Mowbray and the basin of the Tees. None of the later battles fought on the soil of Yorkshire against the Scots were more than skirmishes, such as the rout suffered at Myton-on-Swale in 1319 by the levies hastily armed by Archbishop Melton, and the affair near Byland Abbey in 1322, in which Edward II narrowly escaped capture. Although in the first of these the English defeat was severe and attended by considerable slaughter, it was not followed up by an attack on York, which lay in safety behind the fighting-line, screened by its outer belt of forest-land. If the open country-side suffered from the depredations of the Scots, it was equally exposed to plunder from the defenders, who retaliated upon them from the base at York; and the English army, which won the battle of Neville's Cross, near Durham, in 1346, and was billeted in the North Riding, especially upon monasteries, wrought havoc which reduced their entertainers to poverty.

During this period York was from time to time the royal headquarters, the scene of parliaments summoned for the defence of the realm, and, in the imminence of danger from France in the Hundred Years' War, the place to which the royal exchequer and the offices of government could be temporarily transferred. In the later days of feudal warfare it became an object of contention between rival parties. Thomas of Lancaster, the rebellious cousin of Edward II, occupied a strong position in Yorkshire, commanding the valleys of the Aire and Calder from his great castle of Pontefract; and his hold upon the approaches to the city was broken only by his defeat and capture at Boroughbridge upon the Ure in 1322. The neighbourhood of Pontefract to York and the support which the house of Lancaster could command from its tenants in the county secured the unopposed march of Henry IV from his landing-place at the mouth of the Humber in 1399, a success repeated by Edward IV in 1461, when the position of the Lancastrian cause in Yorkshire was precarious. In the interval between these two events the strife between the houses of Lancaster and York had arisen. The central battles of the Wars of the Roses were fought upon the main approach to York from the south. In 1460 the battle of Wakefield, fought at Sandal, south of the Calder, was followed by the triumphant entry of Margaret of Anjou and her royal husband into York; but the success of that year was reversed in the next, when the Yorkists forced the passage of the Aire at Ferrybridge and won a complete victory at Towton, in the country between the Aire and Wharfe.

In all these military operations the rivers of Yorkshire have played a large part, and it is within the area watered by the western tributaries of the Ouse that the strife of rival parties for supremacy in the north has been contested. The rally points of the rebels in the Pilgrimage of Grace, after York had been seized, were Pontefract and Doncaster. It is noticeable that, while warfare throughout the Middle Ages again and again came near the gates of York, it stopped short of the city. From the time when the Conqueror quelled the Anglo-Danish rebellion in 1070 to the era of the Civil Wars in the seventeenth century, York suffered no siege, and the nearest approach to a battle close to its walls was the abortive muster of an ill-disciplined crowd on Shipton Moor, north of the city, in 1405, to meet a royal army, which was followed by the summary execution of Archbishop Scrope. But in 1642 York was besieged by a Parliamentary army under Fairfax. The siege was relieved by the Earl of Newcastle, whose defeat of Fairfax at Tadcaster gave Pontefract to the Royalists and isolated the Parliamentary base at Hull. Early in 1644 York was again besieged. Prince Rupert, coming from Lancashire at the end of June, relieved the city; but his attack upon the besiegers, who were about to retreat along the line of the Wharfe, ended in the battle of Marston Moor, to the west of York, on July 2, and the surrender of York to the Parliament.

If York was thus important as a military base in a disturbed age, its communications by road and water gave it a commercial pre-eminence as the chief market of Yorkshire, and the centre of northern trade. Its citizens received from Henry II, soon after the beginning of his reign, the grant of a gild merchant, which was confirmed by John. Subsequently it enjoyed the full activity of vigorous civic life, controlled, as in other large towns, by the gilds of the various crafts, but possessing its strong organisation of merchant traders with a monopoly of foreign trade. It is probable that in prehistoric days it was a trading settlement in which the flint-workers of the Wolds found their market, and that its commercial advantages were thus recognised before it became a great political and ecclesiastical centre. So long as merchant ships could come up the Ouse to the wharves of this inland port, it retained a position in trade independent of its significance from other points of view in national history. With increase in the tonnage of ships, it lost the eminence which it held in this department, and its commerce shifted to more convenient ports. Similarly, the industrial revolution, which converted the villages of the West Riding into great towns, left York on one side and created new emporia for trade which far surpassed it in size. York, however, secure in its long prestige and rich in the possession of historic monuments of unsurpassed interest, the centre of a wide agricultural district untouched by modern developments of industry, survived the decline of its former commercial prosperity. Its accessibility from all parts of the county by an admirable system of roads and its position midway between the manufacturing region of the Pennine valleys and the great expanse of rural country which stretches to the coast still made it the natural centre of the public life of Yorkshire. With the coming of railways, as already indicated in Chap. I, York, on a main line from London to Scotland, developed new activity and became the nucleus of a system which sent out branches following with little variation the historic routes which had carried traffic for centuries. With railway communication, the way was open for new manufactures; and to-day, with the revival of road traffic on a scale undreamed of by the promoters of railways within the last century, the geographical situation of York is a permanent asset to her prosperity which no passing changes can alter.

VII.

PREHISTORIC ARCHÆOLOGY IN YORKSHIRE 1906–1931

BY

FRANK ELGEE.

DURING the quarter of a century since the British Association last met in York, our knowledge of prehistoric Yorkshire has been considerably extended. The year 1905 had seen the publication of J. R. Mortimer's

Forty Years' Researches in East Yorkshire—the greatest contribution to Yorkshire prehistory that had appeared since Greenwell's *British Barrows* in 1877, from which it differs in being exclusively a Yorkshire book by a true-born Yorkshireman. It marked the close, as it were, of the barrow-digging phase, which had dominated prehistoric archæology in Yorkshire throughout the Victorian Age. In the last twenty-five years this method of research has been much less pursued. The distinctive features of the period have been the establishment of an earlier human occupation than had previously been realised ; the exploration of West Yorkshire, the prehistory of which had hitherto been little studied ; a study of the distribution, succession, and origins of prehistoric cultures ; the discovery of numerous settlement sites unknown or very imperfectly understood by nineteenth-century archæologists ; and the beginnings of a critical survey of earlier records and researches in order to winnow the chaff from the grain. Moreover, collections of prehistoric antiquities in museums continued to develop, notably at York, where the Yorkshire Museum has been enriched by the Mitchelson, Boynton, and Harland collections ; and at Hull, where the Mortimer Museum of Prehistoric Archæology, formerly at Driffield, was opened in 1929. Smaller instructive collections have also been established in the museums of Bridlington, Hornsea, Huddersfield, Middlesbrough, Skipton, and other towns.

The first general survey of the prehistory of Yorkshire appeared in the *Victoria County History* in 1907 (13), a useful summary of our knowledge at that time. The possibility of a Palæolithic period is hinted at ; the importance of the Neolithic Age is over-stressed on unsatisfactory evidence ; and there is no consciousness of a widespread Mesolithic culture. Origins and distributions are not discussed. A topographical list of antiquities is still the only one for the whole county that has been published. Even at the time it was admittedly far from complete, and now, of course, it is much more so. Nevertheless it is the indispensable skeleton for that exhaustive list which we hope will be prepared in the future.

It will be most convenient to adopt a chronological order in this survey, beginning with the Palæolithic Age. Figure references in brackets are to the bibliography at the end of this section.

Palæolithic Age.

The occurrence of a Lower Palæolithic hand-axe near Bridlington,[1] and an abundant Pleistocene fauna in caves and the drift, had shown that there was no reason why remains of Palæolithic man should not occur. So efforts have been made to discover Palæolithic implements in the drift and other superficial deposits, with the following results.

In 1922 and again in 1931, E. R. Collins described and figured a series of implements, made of local chert, from Upper Nidderdale (14–15). He arranges them in four series, according to what he considers to be the age of the deposits in which they occur.

(1) Implements from a deposit probably due to the final melting of the

[1] Evans, *Ancient Stone Implements* (1897), 580, 582.

ice, and lying below the peat (6 in.–15 ft.) which covers the tops of the moors. They include triangular points made from tabular blocks of chert, cores and flakes; a massive scraper; and a flake with bulb of percussion. As there is nothing in their form or technique which is comparable to well-known Palæolithic types, Collins finds it impossible to date them; though, as they are an advance on implements from lateral moraines, he thinks they might be Upper Palæolithic.

(2) Implements from terraces and river gravels, consisting of material apparently washed out of the lateral moraines of the Nidderdale glacier at the end of the Ice Age. He records four rolled implements from these beds.

(3) Implements from lateral moraines at Scar (980–1100 ft.), and at Byer Beck (950–1050 ft.). They are mostly sharp, but a high percentage are slightly rolled. They include lozenge-shaped points and 'beaks'; a heart-shaped tool with a cutting-edge on one side, the other being in its natural state; a massive triangular implement ($1\frac{3}{4}$ lb.); and a steep-sided scraper with boldly trimmed edge and flat base.

(4) Implements from river-bed gravels between Goyden Pot Hole and Manchester Hole. These are massive, much rolled, and with few exceptions patinated a light chestnut colour. The smallest number of blows has been used in making them. They include types that resemble early Chellean hand-axes. They occur at the very bottom of the dale, where they were deposited by the glaciers which swept them off an old land surface.

J. P. T. Burchell has recently described a tortoise-core industry of flint points, scrapers, and gravers from Danes' Dyke, Flamborough. They occurred on an old land surface below a weathered deposit, which, on being cut back, proved to possess all the features of a boulder-clay, containing chalk fragments and an abundance of Cheviot and Scottish erratics. At Beacon Hill this deposit was more earthy though containing the same kind of erratics. At its base, and resting on the surface of the Upper Purple Boulder-clay, or, where that is absent, on gravels, sands, and loams, he found a similar industry. He assigns both to the Upper Mousterian culture (10).

Burchell regards the Danes' Dyke clay as the result of direct glacial action. On the other hand, the Geological Survey regard the Beacon Hill bed as a land-wash, comparable to the Coombe deposits of the south of England, and not a true boulder-clay. If Burchell's views are right, then the industries ante-date the last glaciation of Yorkshire; if the Geological Survey are right, then they must be post-glacial.

A deposit similar to that at Beacon Hill caps the well-known glacial sections at Kelsey Hill and Burstwick, ten miles east of Hull. It contains similar erratics, and in it Burchell found scattered flakes and cores, and, at its base, signs of an occupation level.

Below this bed is a rather stoneless clay which he calls the 'Hessle' boulder-clay of inland sections, and which, because of its colour, he equates with the Upper Purple clay of Danes' Dyke and Flamborough. If this correlation is correct, then the deposit cannot be the Hessle clay—a term reserved for the foxy-red clay with Cheviot and Scottish erratics—for the

Upper Purple clay of the coast does not contain these erratics, being a deposit of the western ice.

However this may be, the clay at Kelsey overlies sands and gravels usually considered to be the moraine of the western ice. They have yielded bones and teeth of mammoth, rhinoceros, reindeer, bison and walrus. In them Burchell found several flint implements, of which he figures a Levallois flake and an ovate hand-axe, and which he refers to the Early Mousterian culture. These appear to be the first Yorkshire implements from a deposit containing Pleistocene fauna.

In 1922 R. A. Smith figured a flint implement found at a depth of 4 ft. in undisturbed boulder-clay in Lower Eskdale, N.R. He compared it to Mousterian points (43).

As the writer has not yet been able to examine the sections or the implements recorded by Collins and Burchell, he is not in a position to criticise their conclusions, which, it must be admitted, have not met with general acceptance (37). That their researches are serious attempts to throw light on the Palæolithic Age in Yorkshire cannot, however, be gainsaid, whatever the ultimate verdict may be.

Mesolithic Age.

The researches of Woodhead (46) into the history of vegetation on the southern Pennines have shown that post-glacial times can be subdivided into an Arctic Period, *c.* 10000–7000 B.C.; a warm Boreal Period, 7000–5000 B.C.; and a wet Atlantic Period, 5000–3000 B.C. It is possible that the Arctic Period was contemporaneous with the deposition of the Hessle clay in East Yorkshire. In the Boreal Period the more genial and drier climate enabled scrub and woodland, interspersed with dry sandy heaths, to spread over the southern Pennines, now treeless and thickly clothed with peat formed in the wetter climates of the Atlantic and later periods.

On the original sandy surface below the peat thousands of pygmy-flint implements and other tools of the post-Palæolithic or Mesolithic Age have been discovered at altitudes above 1,000 ft. on the Huddersfield Pennines by Buckley (7–9), Petch (31), Woodhead (46), and others. They are recorded by Armstrong from the Sheffield Moors (4). They occur on the northern Pennines, and also on the Eastern Moorlands, where Elgee (18) has observed sites below shallow peat at 800–1,300 ft.

These implements were the work of tribes of food-gatherers and hunters, who wandered over and camped on the high, drier sandy grounds during the genial Boreal Period. They avoided the swamps of the valleys and lowlands, though there seems no reason why they should not have camped on the many sandy tracts in those areas.

The Pennine pygmy-flints have been divided into a broad blade industry resembling the early Tardenoisian culture of Belgium, and a narrow blade industry almost certainly originating from the Aurignacian culture of Upper Palæolithic times, and so well developed at Cresswell in Derbyshire. Aurignacian chert flakes and tools have been found on Windy Hill (1,000 ft.), on the Pennines west of Huddersfield, below a densely packed early Tardenoisian floor containing over 5,000 flints, including 100 broad blade pygmies. The two industries have each been subdivided into an earlier series, characterised by angle and true gravers, and a later, often patinated, series distinguished by the typical Tardenoisian micro-graver. Important sites have been located on Warcock Hill, Marsden, where the stratigraphy has been ascertained; White Hill and Lominot with broad blade pygmies; March Hill (1,340 ft.), which has yielded more than 6,000 flints and 500 tools of a narrow blade industry; Cupwith Hill, with 100 micro-gravers; and Dean Clough, with typical small pear-shaped points. The Eastern Moorland sites have furnished Châtelperron points, angle-gravers, and other implements with Aurignacian affinities.

The more or less contemporaneous Baltic Maglemose culture is represented by two bone harpoons and typical flint hand-axes from Hornsea and Skipsea in Holderness. Armstrong described these at the Hull meeting of the British Association in 1922, when their authenticity was challenged by Sheppard (3, 36). Their genuineness is now generally accepted. A perforated reindeer antler and boar tooth implement found in 1889 in the Elland Cave on Malham Moor, W.R., must also belong to the same culture,[2] such tools being frequent in the Baltic region.

A bone harpoon found many years ago in the Victoria Cave, Settle, and regarded as Neolithic by Boyd Dawkins, is now known to belong to the Mesolithic Azilian culture.[3]

Neolithic Age.

The period between the end of the Mesolithic Age and the beginning of the Bronze Age is obscure, despite the statement that 'Yorkshire possesses a vast amount of evidence upon which the story of man during this important period can be constructed' (13). The truth is exactly the reverse; there is little or no evidence of a lengthy period of pastoral and agricultural life without a knowledge of copper or bronze. This so-called Neolithic Age is based chiefly on the doubtful evidence of flint and stone implements, many of which we now know to have been made and used in the Bronze Age, such as tanged flint arrow-heads, perforated stone battle-axes, and even ground and polished axes, usually regarded as typical Neolithic implements.

Some axes may be earlier, notably the type with conical butt, rounded section, and slightly incurved sides, so abundant near Bridlington, where there was an extensive axe-manufacturing industry (38). Made of basalt or greenstone from the local drift, they are often much weatherworn, a condition bespeaking a considerable antiquity—an inference supported by their resemblance to axes from the upper levels of the Danish shell-mounds. From Bridlington they were conveyed to other parts; examples are known from Aldborough, Sheffield, Cleveland, Durham, the Cambridge region, and elsewhere.

As a class the Yorkshire axes await systematic study to throw light on their ages and origins. Many further examples have been found and recorded since 1906. Elgee has discussed the distribution of those in

[2] Now lost, but represented by a cast in Manchester Museum.
[3] In Giggleswick School Museum.

North-East Yorkshire, where they are most frequent on the coast, Limestone Hills, and in the Vale of Pickering. Their almost complete absence from the Eastern Moorlands is significant in view of the intensive and widespread Mid Bronze Age culture of that region (18).

Again, the unchambered long-barrow culture of East Yorkshire, also regarded as typically Neolithic, overlaps the Early Bronze Age. The long barrows excavated by Greenwell (19) and Mortimer (27) have been reviewed by Elgee (18), who considers them a degenerate and late expression of the chambered long-barrow culture of the south-west. Raistrick (33) has described a stony long barrow at Bradley, near Skipton, the first and only known example in West Yorkshire. Its primary interment lay in a cist, not a chamber, a circumstance indicative of Early Bronze Age influences, when cist-burial was frequently practised.

The Yorkshire long barrows give no support to the theory that their builders were prospecting for metal, for they are concentrated on the Wolds, Howardian and Limestone Hills, non-metalliferous areas, then scrub and grassland, suitable for pasturage.

The Bronze Age.

The excavation of hundreds of round barrows in East Yorkshire between the Tees and the Humber by Bateman (6), Atkinson (5), Greenwell (19, 20), and Mortimer (27) laid the foundations of our knowledge of the Yorkshire Bronze Age. The most important barrow excavations in the period under review were those carried out by W. Hornsby and his colleagues on the Cleveland coast (23–25). Raistrick (32–33) has described the contents of some West Riding barrows, our knowledge of which falls far below those of East Yorkshire.

The relative chronology of the pottery from the barrows was fully established by the late Lord Abercromby in his monumental work on British and Irish Bronze Age pottery (1). He proved that the oldest barrow pottery was the beaker or drinking-cup, 150 having been found in Yorkshire. This ware was introduced by invaders from the Rhinelands, who almost invariably interred their dead in deep graves under round barrows, and used simple bronze knives, awls, and flat axes of Early Bronze Age type.

These invaders were chiefly brachycephalic and of rather stocky stature. Amongst them, however, were members of a tall dolichocephalic race, to which Elgee has recently directed attention, and which he assigns to the stone battle-axe folk of Central Germany and Denmark, who possessed similar physical characters (18). Seven skeletons of this type have been recorded.[4]

More or less contemporaneous with beakers was the food-vessel ware, a totally different kind of pottery, which, as R. A. Smith has shown, was

[4] From Duggleby Howe, C.I. 68·8, S. 6 ft. 3 in. (27, pp. 31, 39); Aldro (with beaker), C.I. 70, S. 5 ft. 11·3 in.; Garton (with food-vessel), C.I. 72, S. 6 ft. ·03 in.; Garton (with beaker), C.I. 72, S. 5 ft. 10·3 in.; Mortimer (*J. A. Inst.*, vi, 330–4), Borrow Nook (Mid-Wolds), three (one C.I. 70·51), nearly 6 ft. high (29, p. 492). See also (30).

derived from the highly decorated Neolithic bowls (41). Food-vessels are essentially a north-country pottery with its chief centre in Yorkshire, whence come 340 examples. Their provenance reveals the mingling of the Early Bronze Age invaders with the long-barrow people, a mingling that led to the extinction of the beaker ware, the spread of cremation at the expense of inhumation, and ultimately to the homogeneous insular culture of the Mid Bronze Age. For cremation led to the custom of depositing the ashes of the dead in urns which at first only differed from food-vessels in being larger. The transition is well displayed by several Yorkshire urns, notably one from Hinderwell Beacon, N.R., which not only resembles a food-vessel in shape, but was also associated with a small food-vessel (25). In time the urn developed into large and small vessels with overhanging rims, the most abundant and most widespread species of prehistoric pottery in Yorkshire, 400 to 500 being known with the certainty that many more await discovery. The contemporary incense cups, of which 170 have been found, can also be traced back to the food-vessel. Elgee suggests that they held offerings to the cremated dead (18).

Elgee has dealt in detail with the distribution of these wares in East Yorkshire (18). Beakers are most abundant on the Wolds (130 examples); with isolated examples from near Thirsk, Pickering, and Whitby in North-East Yorkshire; and a few from the West Riding. Food-vessels show a wider distribution. They are most numerous on the Wolds (254 examples), on the limestone hills between Pickering and Scarborough, and thence sparingly northwards along the coast. Fewer than a dozen are recorded from the West Riding.

Both wares are practically absent from the moors and dales of North-East Yorkshire, where, however, urns are very numerous, more so than on the Wolds, on which they are comparatively rare. They have occurred on the Howardian Hills, in the Vale of York north of Boroughbridge, and in Airedale, Calderdale, the Don Valley, and elsewhere in West Yorkshire. The increase of population during the Bronze Age is convincingly revealed by these figures and distributions.

Elgee ascribes many settlement sites on the Eastern Moorlands to what he terms the urn culture. They are marked by large urn barrows on the ridges and by cemeteries, often containing hundreds of cairns probably covering inhumations, standing stones, flint implements (scrapers, three-tanged arrow-heads and ruder tools), irregular cultivation plots, sometimes forming low terraces or lynchets on slopes, and hut-pits. Many settlements are now the site of farms of which they were the forerunners, and the position of which is often just below the moor edge or well down the sides of the dales. Others survive on spurs between valleys, the best preserved occurring on Glaisdale, Danby, and Crown End Riggs in Eskdale. These spurs were defended by single, double, or even quadruple cross-ridge ditches and ramparts, strengthened by parapets of rude upright stones such as can be well seen on Crown End and Guisborough Moor (18). A further account of these sites will be given in a paper on the human geography of the Eastern Moorlands (Section E).

A semicircular camp on Eston Nab (800 ft.) in the extreme north-east of the county has been partially excavated and will be described in a paper to Section H. Potsherds from hearths within it are identical with those associated with Late Bronze Age implements in the Heathery Burn Cave, Co. Durham, an association not observed at Eston Nab.

The Bronze Age of West Yorkshire has been studied by Raistrick, who gives plans of stone circles ; also of two disc barrows (near Askrigg in Wensleydale), the first that appear to have been noted in the county (32). These structures all seem to date from the Mid Bronze Age. Urns have been found within stone circles (Danby, N.R.),[5] and earthen circles (Todmorden, W.R.).[6] The impressive Thornborough and Hutton Moor circles near Ripon were assigned to a late phase of the Early Bronze Age by Crawford (17) on the evidence of a single food-vessel from a barrow situated between two of the Thornborough circles. A Mid Bronze Age date is equally probable, because cremations and urns have more frequently been found in the neighbourhood.

Even Yorkshire's greatest megaliths—the Devil's Arrows near Boroughbridge in the same region—may be no earlier than the Mid Bronze Age. There is no evidence of a large Neolithic or Early Bronze Age settlement there, for only a large community would have erected such colossal stones. The megaliths of the Eastern Moorlands also occur in a region rich in Mid Bronze Age remains. In this region they take the form of monoliths on or near barrows, circles (with urns), rows, and groups of three stones adjoining urn barrows (18). There is no evidence that the Yorkshire megaliths were erected by metal or jet traders, nor that there was any far-flung trade in Whitby jet (18). The excursion on September 3 will give members the opportunity of seeing many prehistoric remains on the Eastern Moorlands.

Raistrick has dealt with the dispersion of bronze implements and has shown how they were carried from the Wold area across the morainic ridges at York and Escrick into West Yorkshire (32). Kitson Clark first called attention to this route by which flint was conveyed from East to West Yorkshire, where in its natural state it is unknown (11). The main route led through the Aire Gap, and evidence is accumulating to show that it formed a cross-country trade-route between Ireland and Denmark in the Bronze Age.

Elgee has also studied the distribution of bronze implements, especially the socketed axe and leaf-shaped sword of the Late Bronze Age. It shows that the chief settlement areas of this age were Holderness, the northern margin of the Vale of Pickering—both lowland areas—and, to a less extent, Calderdale, Airedale, and round Ripon. As these implements have never been found with urns, or on the surface of the Eastern Moorlands where the urn culture was dominant, he follows Crawford and Peake in ascribing their introduction to invaders. He also suggests that the pressure of these and later invaders drove the urn people into the Moorland country where they may have survived into the Iron Age or even later (18).

Further discoveries of bronze implements, chiefly late, have from time to time been made. Many have been recorded by Sheppard, who has

[5] Atkinson, *Gent. Mag.*, xiv, 440–4, 1863.

[6] *Proc. Yorks. Geol. Soc.*, xiii, 447.

also described those in the Hull, Whitby, Scarborough, and Doncaster Museums (39).

A Late Bronze Age spear-head and socketed axe were found in the lake-dwellings at Ulrome and Barmston in Holderness. Though discovered fifty years ago, these dwellings were not critically described until 1911 (42). At Ulrome there was evidence of a much older structure associated with numerous perforated ox-bone adzes, implements which suggest Maglemose affinities. Pottery from the later dwellings proved habitation in Iron Age and Roman times.

Recent excavations in the Pickering lake-dwellings, discovered in 1895, show that they were more or less contemporaneous with those of Holderness (12).

Early Iron Age.

The most important addition to our knowledge of this age is the Hallstatt site on the Castle Hill, Scarborough, the first of its kind to be found in the north of England. It consisted of more than thirty rubbish pits, which were revealed during F. G. Simpson's excavations of a Roman coast-guard fort, below which they lay. In the pits and on the surface in which they were sunk were scattered numerous potsherds of Hallstatt type, associated with Late Bronze Age implements and a fragment of an iron pin. The overlap of the Late Bronze Age and Hallstatt cultures is here very clearly displayed. The pottery indicates that the Castle Hill settlers probably came directly across the North Sea from the Rhinelands (44–45).

Otherwise we have no evidence of a widespread Hallstatt culture in Yorkshire. Bronze must therefore have remained in use until superseded by iron in La Tène times.

As is well known, East Yorkshire is unusually prolific in La Tène chariot-burials, which were fully described by Greenwell and Garson (21). Since 1906 one has been discovered at Hunmanby (40), and another at Pexton, near Pickering (26).

The associated skeletons were chiefly those of a moderately dolichocephalic and mesatacephalic race from 5 ft. 2 in. to 5 ft. 10 in. high in the men; and from 4 ft. 11 in. to 5 ft. 7 in. in the women. Thus the charioteers were quite different from the Early Bronze Age folk, and they must have been new-comers to East Yorkshire. That they came from Gaul is proved by the resemblance of their interments to the chariot-burials of the Marne, the neighbourhood of Paris, etc. Historically they were a branch of the Parisii, who gave their name to Paris and, according to Ptolemy, inhabited East Yorkshire *c.* A.D. 160 (18).

The chief centre of La Tène culture was the Wold area, especially at Arras, between Market Weighton and Beverley, and at the Danes' Graves near Driffield. Here large cemeteries of small round barrows containing chariot-burials are indicative of permanent settlements. At Atwick, twelve to sixteen miles south-east of the Danes' Graves, numerous pit-dwellings were discovered by W. Morfitt, and described by Greenwell and Gatty (22). At the time they were supposed to be Neolithic, but pottery found in them is certainly Iron Age. Usually the pits were about 5 ft. deep, of elongated form, a few even being 40 ft. long by 9–10 ft. wide. They were all excavated in boulder-clay, and were filled with a hardened blackish mud overlain by soil. Rough stone hearths occurred in them, round which lay potsherds; broken bones of ox, horse, sheep or goat, pig, red deer, and in one instance the complete skeleton of a dog; heavy stone pounders; and rude flint knives and flakes.

La Tène culture is sparingly represented on the limestone hills near Pickering. Elsewhere in North-East Yorkshire it is practically unknown.

Recent research is revealing that Iron Age sites are numerous and widespread in West Yorkshire. On the plateau of the Great Scar Limestone in Wharfedale, Raistrick finds saucer-shaped barrows, often encircled by a trench, up to 30 yards in diameter. They have yielded iron knives, coarse pottery, bronze and iron ornaments, and multiple burials. Adjoining the barrows are extensive lynchets and cultivation plots of Celtic type. Twelve lynchet groups occur in Upper Wharfedale, one of the best preserved in the High Close Pasture north of Grassington (16). The cultivators lived in huts, the circular foundations of which can be seen in Grass Wood and elsewhere. In them iron knives with deer-horn hafts, like those from the barrows, have been found; also spindle-whorls of stone, pottery and lead (one of Roman type), saddleback querns, pounders and charred barley, the most ancient evidence of this cereal in Yorkshire (35).

In Littondale, Celtic fields are associated with regular enclosures of rough masonry 5 ft. wide at the base, and in places still 3 ft. high—the ruins of circular and rectangular dwellings or chambers, ranged round a rectangular space with two entrances (35).

The folk who lived on these sites must have been the Brigantes who dominated West Yorkshire in Roman times. Their origins are obscure. Most probably they were descended from the urn folk of Yorkshire who had been subjugated by the Late Bronze Age invaders and amongst whom La Tène culture spread after the invasion of the Parisii.

In the 1912 volume of the *Victoria County History* there is an admirable survey and list of earthworks, with many plans (2). This account stripped our earthworks of much error and pedantic lumber that had gathered round them. They are chiefly classified under types, for the age of many was, and still is, unknown. The survey clearly demonstrated the mediæval age of such works as Skipsea Brough, E.R., long regarded as prehistoric on little or no satisfactory evidence.

Other works are shown to have been mediæval boundary banks or park enclosures. To the latter class the great earthworks at Forcett and Stanwick Parks, N.R., almost certainly belong, though they are still often supposed to be Brigantian strongholds of the first century. This ascription was based solely on the statement that Early Iron Age antiquities [7] were discovered within them, whereas they actually occurred at Langdale, a mile to the south outside them (2). Nothing has been found within the works to prove their Brigantian origin.

In all probability the Brigantes constructed hill-top camps like the

[7] In the British Museum.

oval work at Wincobank near Sheffield (Roman potsherds at bottom of the fosse); the Castle Hill, Almondbury, the original features of which, an oval rampart and ditch, have been disturbed by a Norman motte and bailey castle, and whence Brigantian coins have been recorded (31); and the village on Ingleborough mountain, comprising numerous circular hut-foundations which have yielded Roman potsherds,[8] and enclosed by a massive drystone wall built on the precipitous edge of the level summit. These and similar works in West Yorkshire were no doubt constructed to oppose the Roman invaders.

We have yet no evidence of pre-Roman La Tène camps. Whether they will be found on the Wolds, the centre of the earliest La Tène culture, future research must decide. For at the present juncture it is not possible to form any definite conclusions about the plexus of earthworks in that region. In the first place, since the Wolds have been enclosed and cultivated, the earthworks have been greatly interfered with. Mortimer envisaged them as well as it was possible, and his account is full of detailed interest (27). In the second place, their complexity is the outcome of a long period of occupation by varied peoples from long-barrow times onward, and this in itself makes research work still more difficult. It has been too readily assumed that they are all prehistoric—many no doubt are, but the possibility of others being Anglian or mediæval should be borne in mind. A similar warning holds good for the Scamridge Dykes and other earthworks in North-East Yorkshire, concerning which nothing further can be related here, but a sketch of them has been given by Wheeler (45), and they will be dealt with in the forthcoming *Archæology of Yorkshire* in Methuen's County Archæology Series.

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VIII.

ROMAN EXCAVATIONS AT YORK

BY

THE REV. A. RAINE,

HON. SECRETARY, YORK ROMAN EXCAVATIONS COMMITTEE.

THE object of this article is to outline the story of the York Roman excavations, 1925–8, and to give a summary of their results. In 1922 the idea of carrying out some scientific excavation at York was mentioned to Sir C. R. Peers by the writer. In 1923 H.M. Office of Works granted permission for work to be begun at the north-east angle of the Roman fortress, where it was hoped to find some remains of a corner tower.

In order that the work might be co-ordinated with other Roman excavations in Yorkshire it was decided that it should be carried on under the ægis of the Roman Antiquities Committee of the Yorkshire Archæological Society. On May 2, 1925, a meeting was held at the Mansion House, York, and a General Committee was chosen, of which the Archbishop of York (Dr. Lang) consented to be President, the Lord Mayor Chairman, and Edwin Gray, J.P., the Hon. Treasurer. Mr. S. N. Miller, Lecturer in Roman Antiquities at Glasgow University, was asked to undertake the direction and supervision of the work. Mr. Miller was in charge through the four seasons of excavation, and published two reports on the work in the *Journal of Roman Studies*. From first to last the York City Corporation rendered every possible help, not only giving generous financial assistance, but also allowing us to employ their experienced workmen and to use their tools and materials.

The object of the excavations was to gain some definite information about the history of the legionary fortress, about which little was known. Certain obvious limits to the work were plain from the beginning. The area within the line of the fortress wall is almost completely covered with buildings, so the excavation had to be limited to the defences which lie beneath the existing mediæval walls and rampart. It was felt, however, that work on the defences would in all probability give us the historical data we needed ; and, further, there was a possibility that at the north-east corner we might find some structural remains which could be left open, and give to York another monument of its greatness in Roman days.

For a detailed account of the excavations the reader is referred to the *Journal of Roman Studies*, 1926 and 1928.

The work lasted for four seasons :

1925, September—October. Excavations were begun at the north-east corner, and unexpectedly fine remains of the tower were brought to light. A trench was also cut at the one available unoccupied spot along the eastern defence line.

1926, July—October. The work at the north-east corner was completed and an examination was made of the south-west corner tower, better known as the Multangular Tower, in the grounds of the Yorkshire Philosophical Society.

1927, September—October. The fortress wall was laid bare in three places, one on the west, two on the north side.

1928, September—October. A search for an outer defence line on the west was conducted in the gardens of the Territorial Association and of the School for the Blind.

Historical Results of the Excavations.

First Period.—The fortress was founded in the governorship of Quintus Petilius Cerealis, A.D. 71–74—probably in 71. The area of this first fortress has not yet been determined, the line of the north and east defences alone having been discovered. It is hardly likely that it was intended to house two legions. The probability is that it enclosed an area of 60 to 70 acres. The defences consisted of a double ditch and an earthen rampart surmounted by a strong wooden fence. The internal buildings were probably of wood. It is quite possible that the first fortress may have been intended to be temporary, and that Cerealis and his successors planned to erect a permanent fortress elsewhere, but in any case the choice was good, as the site commanded the tribal crossing of the Ouse and had good water communications. The earthen rampart, with postholes, was found in six of our trenches. Remains of wooden structures of the first fortress period were discovered when erecting the new York Public Library, near the south-western corner tower.

Second Period.—An imperial inscription, dated A.D. 108–109, found in 1854 on the site of the eastern gateway, recording some work accomplished by the ninth Legion, which then garrisoned the fortress, is generally taken as dating the first stone fortress wall. A fragment of this wall was found by us in 1925, and part of a barrack block of the same date was discovered in 1927. York had now become a stone fortress.

About A.D. 115 occurs the mysterious disappearance of the ninth Legion; the presumption is that somewhere it was trapped and annihilated. If this was the case it would be expected that some traces of the disaster would be found in the fortress. Dateable objects found in relationship with the walls of the north-east corner tower favour a date for its construction early in the second century A.D. The fortress wall at this point dates from late in the second or early in the third century. The tower walls may, therefore, belong to the first stone fortress of A.D. 108–109, or they may be a reconstruction *c.* A.D. 120. It is possible that the tower was damaged after the annihilation of the garrison. Further, a few fragments survive of what must have been an important inscription, found outside the western gateway of the fortress. This inscription, containing the titles of the Emperor Hadrian, who visited Britain A.D. 120, quite possibly recorded work done on the western gateway and defences. If this was the case, then they may have received damage when York was without a legion. Further, a leg of a gilded bronze statue of an emperor was found in 1820 at Milsington, in Roxburghshire. This dates before A.D. 120 and must, says Sir George Macdonald, have been taken from a fortress. There does exist some evidence, then, that York received damage after the destruction of the ninth Legion.

Third Period.—Our excavations at the north-east corner revealed that the fortress had received great injury towards the close of the second century A.D., and that the fortress wall had been so seriously damaged that it had to be entirely rebuilt. This reconstruction took place in the reign of Commodus or Septimius Severus, 'following upon a serious disaster, which is no doubt to be connected with the troubles that broke out at the accession of Commodus and led to the abandonment of Scotland *c.* A.D. 182.' This reconstructed wall is still standing at the north-east corner to a height of sixteen feet, and is a most impressive relic of the Roman occupation. From the north-east corner the wall has been exposed to rampart level for a considerable distance, and part of an interval tower has been laid bare. The complete excavation of the interval tower cannot be undertaken for another three years, part of it being in a yard leased by the Corporation. Structurally it appears to be of the same character as the corner tower. Its excavation should supply important evidence bearing on the conclusions arrived at respecting the corner tower.

In the second season of the excavations, 1926, not only was the work at the north-east corner completed, but also an examination was made of the south-west corner. The work here is different in character from that of the north-east corner, the tower projecting outside the fortress wall. It was found that the tower and stretch of wall adjoining belonged to the reign of Constantius at the beginning of the fourth century. The ditches were of the same date and part of the same defence system. We found here no trace of the earlier defences we had discovered at the north-east corner.

The work, therefore, to be carried out during the third season of digging (1927) was obvious. It was to attempt to define the extent of the earlier and later defence systems. It was already known that the Constantian wall ran from the south-west corner as far as the western gateway of the fortress. We now cut a trench in the Canon's garden half-way between the western gateway and the north-west corner, and once again found the Constantian wall. It plainly continued to the north-west corner. Two trenches were cut in the north line of defence between Monk Bar and the north-west corner, at a wide interval, and in each case remains of the earlier defence system were found. The junction point of the earlier and later defences plainly lies at the north-west corner. Excavation here, unfortunately, is impossible.

We had now arrived at this—the defences on the north and east sides of the fortress had been found to date from *c.* A.D. 71 to *c.* A.D. 200; the defences on the south and west sides of the fortress dated from the beginning of the fourth century; the junctions of the earlier and later systems are almost certainly at the north-west and south-east corners. The further question now demanded an answer—Whereabouts on the west and south lay the line of the early defences? No trace of them was discovered in the course of our excavations of the fourth-century defences on these sides.

A clue to the answering of this question was found during the excavation, referred to above, in the Canon's garden. Underneath the rampart belonging to the Constantian fortress wall were found remains of several apartments of a barrack block: under the floors were discovered potsherds that dated the structure to the early part of the second century. The discovery of this barrack block here presumed an earlier defence line outside the fourth-century defences. In 1928, our last season of excavation, in the garden of the Territorial Association and also in one of the gardens belonging to the School for the Blind, lying outside the fourth-century wall, we attempted to find some trace of the earlier defences. Although in this we were not successful, it must be remembered that during this last season scarcity of funds forced us to limit our operations very strictly. It was impossible to make the extensive examination that may be necessary. One significant discovery, however, was made—namely, that of a very heavy Roman road pointing from the fortress towards the old ford of the Ouse at Clifton. This road was not coming from the fourth-century gate but from a point in the fourth-century wall some sixty yards south of the gateway. The presumption is that this road led to the gateway of the earlier defences on the western side. It is possible that the earlier defences on the southern side were discovered in 1883, when a massive Roman wall was found under the General Post Office in Lendal running parallel with the later defences.

It would seem to follow, then, that Constantius, at the beginning of the fourth century, reduced the size of the fortress. At the same time reconstruction took place within the fortress itself. In the summer of 1928, in preparing for the construction of an underground lavatory near to the south-east corner, it was found that barrack buildings had been levelled and a building of different character had been erected, probably, so far as the evidence went, at the beginning of the fourth century. This finding has been confirmed, and the evidence for a Constantian reconstruction on a large scale has been greatly strengthened by the discovery in 1930, in digging cellaring for the Mail Coach Inn in St. Sampson's Square, of extensive remains of a large bath-house. Owing to the public-spirited generosity of the owners, the Tadcaster Brewery, these remains have been preserved. This bath-house stands on a site that in the earlier fortress would normally be covered by barracks. The structure with its bonding courses and similarity to the work at the south-west corner dates itself to the beginning of the fourth century. As Mr. S. N. Miller suggests (*Roman York: Excavations of 1926–7*, p. 98), the probable inference will be that the Roman garrison no longer lived in the fortress in permanent quarters, and that this will lend support to the view 'that the military authority in Britain followed the practice, originally authorized by Severus, of allowing the legionaries to live a family life in the settlements and cities outside the walls of their strongholds.'

York almost certainly suffered damage during the troubles of A.D. 367, when the sixth Legion must for a time have abandoned the fortress.

It is perhaps to this period that we must assign the filling in of the north-eastern corner tower. In the excavations we found that within the Roman period the basement of the tower had received a very compact filling consisting largely of burnt matter, and this had been strengthened by a row of massive blocks of limestone in two courses extending from the fortress wall to the back wall of the tower. The south-west corner tower in the grounds of the Yorkshire Philosophical Society seems to have been solidified and strengthened in a similar way. The filling in this latter case was removed in 1831.

Such, very briefly, are the results of the work carried out by Mr. S. N. Miller for the York Roman Excavations Committee, 1925–8. This work has given us for the first time definite data for the history of the Roman fortress of York. It has, of course, supplied us with a number of new problems that await solution, but these problems in no way affect the main conclusions.

IX.

ROMAN MALTON AND DISTRICT

BY

PHILIP CORDER, M.A., F.S.A.

Malton.[1]

Antiquaries have long been aware of the existence of a large Roman fort or camp at Malton, but nothing was known of its history before excavation was undertaken by Dr. J. L. Kirk, F.S.A., in 1927. Malton is situated rather less than half-way between the legionary headquarters at York and the Yorkshire coast, on a tongue of land, the eastward extremity of the Howardian Hills, dominating the Vale of Pickering to the north, and having the river Derwent on the south and east. To the south-east lay the ford over the river, discovered in 1862, from which roads led to the coast and southwards along the western edge of the Wolds to Brough-on-Humber, and so south to Lincoln. This road not only provided the natural line of advance for the troops who first occupied the site in the first century, but may well have been the normal route from Lincoln to York, as it avoids marshy land and awkward river crossings.

The earliest occupation of the Malton site was probably during the campaign of Petilius Cerialis against the Brigantes, about A.D. 71. It consisted of a large camp of at least 22 acres and probably much more,

[1] *The Defences of the Roman Fort at Malton.* By Philip Corder, 1930. (Yorks. Arch. Soc.)

with roads and wooden buildings. An early ditch, part of the northern defences of this camp, was traced in the autumn of 1931, and is remarkable in turning twice through an obtuse angle in a length of 350 ft. Not long after this, perhaps under Agricola, a permanent fort of $8\frac{1}{2}$ acres was established on the site, with a rampart of sandy clay river silt, 30 ft. wide, and internal buildings of wood. Early in the second century the rampart was raised and widened and a massive revetment of stone, 10 ft. wide at its base, added to it. The headquarters building, of which only slight traces remain, was similar in construction to this wall, and was probably contemporary.

The north-east gate of this period was a single gate flanked by unusually massive towers, and here was found evidence to suggest that a partial rebuilding of the defences in stone had been begun at an earlier period. To provide a stable foundation for the stone wall, the innermost early ditch had been filled up and, on at least two sides of the fort, two great ditches about 23 and 35 ft. wide were dug. On the south-east side, facing the river, however, there was only one ditch.

The consolidation of the northern frontier in the reign of Hadrian led to the withdrawal of the garrison from Malton, and although there is evidence of continued occupation of the civil settlement south of the river at Norton during the second century, the fort seems to have lain empty until it was reconditioned, probably under Severus, early in the third century. The internal buildings may have served as a quarry for the inhabitants of Norton, for at first the new buildings were again of wood. The rebuilding of the north-east gate, and perhaps of the fort wall, testifies to the reoccupation of the fort, and the abundance of coins and pottery suggests a peaceful occupation lasting until late in the century. The fort was then abandoned, for, spread along the back of the north-east rampart and underlying later roads and buildings, was found a thick deposit of charred wheat, in some places more than a foot thick. This can only be explained as a deliberate destruction of the contents of the granaries, undertaken before a withdrawal. It cannot be precisely dated. Probably early in the fourth century it was followed by a complete rebuilding of the north-east gate, a single arch 11 ft. in span being flanked by guard-rooms 6 ft. wide. Coins of Carausius, however, are relatively plentiful, and it is at least possible that the rebuilding of the fort may belong to a rather earlier period.

Throughout the whole of the fourth century Malton was in full occupation. The internal buildings were of stone : in the north corner—the only internal area excavated—these were rectangular hutments with narrow spaces between. In the floors of these houses, and even in one of the guard-rooms of the contemporary north-east gate, were found as many as thirty-one skeletons of newly-born infants, sometimes buried in lime, but more often merely laid in the floor. This suggests a much laxer discipline than in the earlier Empire.

That the fort was destroyed in the disturbances of A.D. 369 seems probable. Its reconstruction by Theodosius provided one very interesting feature. On the north-east side the fort wall must have been so ruined that no attempt was made to reconstruct it. Instead, a new ditch was dug, cutting through the surviving core and removing, throughout most of its length, even its footings of blue clay and stone. The north-east gate, which had suffered severely, was again patched up. Among other buildings of this period was an apsidal-ended structure on the north-east rampart near to the north corner. This was built over the ruins of an earlier square building. Adjoining it was an open paved yard, containing a large semicircular hearth, which itself overlay a blacksmith's forge.

Pottery similar to that found in the coastal signal stations was found in great abundance at this level, and it seems safe to conclude that the fort served as base to the signal stations at Filey and Scarborough, with which it was directly connected by road.

The final period of the occupation has left no recognisable building, but is characterised by roughly metalled or cobbled areas. Such a road surface, rutted by wheeled traffic, and sealing beneath it quantities of calcite-gritted ware, was found overlying the remains of the north-east gate. The most striking feature of this last phase of the defences is two rectangular trenches, 6 ft. wide, cut across the causeway leading into the north-east gate.

The Langton Villa.[2]

In March 1926 the late Rev. C. V. Collier, F.S.A., partially excavated two hypocaust chambers on the East Farm, Langton, about four miles south-east of Malton. His untimely death led to the intermission of the work, which was completed by Dr. J. L. Kirk, F.S.A., and the present writer in 1929–30. The ground on which the settlement is situated has a slight southward slope; it is sheltered on the north by Langton Wold, which separates it from the Malton fort. The excavations covered an area of about 3 acres, and revealed an unexpected military occupation in the first century, succeeded by a civil occupation which probably began late in the second century or early in the third century. This continued throughout the fourth century, and the abundance of coins and pottery contemporary with the coastal signal stations indicates a flourishing civil occupation in the last thirty years of the century.

The earliest occupation was a small fortlet of 0·31 acre, defended by a well-cut V-shaped ditch and having a single entrance near its south corner. Its southern defences were supplemented by a second, smaller ditch. No traces of rampart or internal buildings were found, but this is not surprising, as the site was covered by successive later occupations. In the filling of this early ditch was an interesting collection of sherds, the bulk of which were hand-made calcite-gritted ware similar to that found recently on the Iron Age sites on the Costa and at Thornton-le-dale.[3] With it, however, was a small group of Flavian sherds, among which rustic ware predominated.

The evidence of coins and pottery for a civil occupation of the site before the latter part of the third century is very slight. Built inside the eastern end of an earlier stone building was a complete small bath-

[2] *A Roman Villa at Langton, near Malton, E. Yorkshire.* By Philip Corder and John L. Kirk, 1932. (Yorks. Arch. Soc.)

[3] *Y.A.J.*, vol. cxviii, 1930.

house, consisting of a single hypocaust chamber into which led a tile-built flue, 9 ft. long, which heated a warm bath or cauldron, built in a small rectangular recess. Opening out of the hypocaust were a cold bath and a tiny cement-lined semicircular recess, retaining its lead outflow pipe. Pottery found in the flue and stoke-hole showed that the whole structure had gone out of use before the beginning of the fourth century.

Some 55 yards to the west, and north of the early fortlet, was a small corridor house, originally 52 ft. long and 19 ft. 6 in. wide, probably erected in the first half of the fourth century. It partly overlay an earlier rectangular building that may have been an earlier dwelling-house. This corridor house originally consisted of two hypocaust chambers with separate furnaces, joined by a corridor. One of these rooms had opening from it a small cement-floored rectangular chamber that had the appearance of a bath. Subsequently the house was enlarged by the addition of a veranda on the southern side and two additional hypocaust chambers at the front and back of the house, but at opposite ends. Two of the hypocaust chambers were certainly provided with tesselated pavements, having a design in red, white, yellow and black, while the walls of all four were covered with coloured plaster.

Probably contemporary with the house were two long rectangular buildings to the south-west, overlying the site of the early fortlet. The easternmost of these showed two distinct periods of occupation. In its southern end lay a single hypocaust chamber, 8 ft. long by 6 ft. 3 in. wide, its floor originally supported on pilæ of square tiles and its walls decorated with red and white plaster. It was served by a flue long enough to provide means for heating a cauldron or warm bath. The whole was probably a minute bath-house. Along with the building in which it stood it had been destroyed, probably in the second half of the fourth century, when it was incorporated in a larger room and the tesseræ from its floor used as road metal for the road leading into the east side of the main building through a gate which was provided with sockets and slots for a timber frame.

The whole settlement was bounded on the south and partially on the north by a ditch. That on the south twice crossed the ditch of the early fortlet, the existence of which must have been unknown to its makers. It also underlay the footings of one of the long rectangular buildings, and must belong to an early phase of the civil occupation. Probably contemporary with the corridor house, and to the north of it, the footings of a substantial boundary wall were traced for 320 ft.

Several other structures on the site were of special interest. West of the house and to the north of the buildings just described was a circular building, 15 ft. 9 in. in internal diameter and having a circular patch of paving in the centre. This building is without parallel, and most probably was a horse mill or manual mill. There was a good deal of evidence to indicate that corn production was the principal occupation of the inhabitants. One small room contained a layer of burnt wheat on its floor. Close to this was a rectangular platform, 30 ft. wide and 35 ft. long. Its construction was peculiar. A pit of these dimensions had been dug on the site of an earlier building and filled in with layers of stones and earlier building material, roughly coursed herring-bone fashion, but without clay or mortar. The motive would appear to have been to obtain a dry surface, which suggests that this was the threshing floor. Two kilns, not for pottery, were found on other parts of the site, and these may have been used for drying grain.

The well of the settlement was cleared to its bottom, 44 ft. 6 in. from the surface. With the exception of its top 8 ft., it was cut through rock 6 ft. in diameter. From 13 ft. 6 in. to 20 ft. the filling consisted of sticky black soil with little stone. This marked the final destruction of the site. Below this the well was choked with stones and rubbish, animal bones of horse, ox, sheep, pig, deer, dog, cat, mole, goose, fowl, frog, and small birds and rodents, together with pottery of signal station types. At the very bottom in the black silt were preserved part of an ash bucket, and twigs of oak, alder, walnut, sweet chestnut, willow, sycamore, cherry, elder and heather, half a walnut and several hazel nuts. With these was a complete jar of Crambeck type, fragments of several others, and a coin of Constantine I (*c.* A.D. 335–337) in mint condition. It is clear that the well was either dug or last cleared out soon after A.D. 335, and was in use, if only as a rubbish pit, until the close of the occupation, *c.* A.D. 395 or later.

The Crambeck Pottery.[4]

In 1923 the chance discovery of Roman sherds at Jamie's Craggs, Crambeck, about five miles from Malton, by a young geologist from Bootham School, York, led to excavations in the adjoining field by a party from the school under the present writer. In 1926–7 two pairs of pottery kilns, two interments, and a very large quantity of sherds were discovered. The earliest occupation of the site was represented by a coin of Nerva and a little Samian ware of the first half of the second century. The kilns, however, were much later and were working from the end of the third century, their output increasing throughout the fourth up to the troubles of A.D. 370. Pottery manufacture seems to have restarted here during the last thirty years of the century. Since the completion of the excavations Crambeck ware has been identified from many late sites in the north. It was used in great quantities on Hadrian's Wall, and has been found as far north as Traprain. It must be concluded that the kilns excavated represent only a part of a very extensive pottery manufacture.

The kilns were stoked in pairs from a common stoke-hole, a roughly circular pit dug below ground level. From this, stone-lined flue passages, roofed with slabs, led into the furnaces. These were semi-permanent structures consisting of circular or pear-shaped clay-lined pits, roofed at ground level with flat unsupported clay platforms, pierced with numerous small holes to allow the passage of hot gases to the pots stacked above for firing. The ovens must have been temporary structures rebuilt for each firing of the kiln, and their composition is conjectural. They were probably of turf and branches, for the furnaces were not provided with chimneys and all the gases must have passed through the

[4] *The Roman Pottery at Crambeck, Castle Howard.* By Philip Corder, 1928. (Yorks. Arch. Soc.)

oven itself. Rough bricks and tiles formed their furniture, and squat clay cylinders were commonly found, and must have been used as supports and to facilitate the even passage of the gases through the furnace. The pots manufactured were commonly hard well-finished grey ware, but a type of reeded flanged mortaria in pale buff and smooth rose-red ware were also made. Smooth whitish-yellow ware with decoration in red paint was manufactured here in the late fourth century.

Other Sites in East Yorkshire.

Numerous other Roman sites in the Malton area have been partially explored or identified. Among them are the waste heaps of a pottery at Knapton,[5] about seven miles from Malton on the road to Filey. Here extensive manufacture of hand-made cooking pots in calcite-gritted ware was carried on in the third and fourth centuries, but, so far as we know, their distribution was confined to Malton and district.

Another series of pottery kilns, somewhat similar to those at Crambeck, were explored in 1930 at Throlam, near Holme-on-Spalding Moor. Here a great mound about 100 ft. in diameter, locally known as Pot Hill,[6] was composed largely of broken sherds. In its centre were found a series of superimposed kilns. The best preserved of these differed from the Crambeck kilns in having a vertical chimney and two rough pillars supporting its oven floor. The vast quantity of pottery examined mostly fell into five types, of a rather earlier nature than those made at Crambeck. It may be conjectured that the products of this pottery and of other similar pottery sites in the neighbourhood were designed mainly to supply the fort at Brough-on-Humber, though Throlam types have been found at Langton.

X

EDUCATION IN YORK

BY

GEO. H. GRAY,

Secretary for Education, York.

Outstanding amongst the names of the great whose birth or careers are enshrined in the long history of York is that of one, Alcuin, in the eighth century. Alcuin's fame was that of a scholar in days when prowess

[5] *A Roman Villa at Langton, etc.* By Philip Corder and John L. Kirk, 1932, *Appendix.* (Yorks. Arch. Soc.)

[6] *The Roman Pottery at Throlam, Holme-on-Spalding Moor, East Yorkshire.* By Philip Corder, 1930. (Yorks. Arch. Soc.)

was largely confined to activities other than those of the mind. It was at the York St. Peter's School, long established even then, that Alcuin in turn studied, taught, and administered.

It is the aim of the present-day educationists to build not unworthily upon the tradition handed down from their city's past, and to maintain or enhance the reputation as a centre of learning that has been continuously attached to York. It is only comparatively recently that the service of education was placed upon a permanent and broad basis by the formation of statutory authorities for this specific purpose. The credit for the voluntary provision of such education as was available for the general population in pre-Education Act days largely belongs to the Church, and the status of York as a cathedral city was an educational advantage.

On the other hand, the legacy received by the twentieth-century Education Committee, of a large number of small and antiquated school buildings, has been found an embarrassment peculiar to York, and one from which the education authorities of cities of modern growth are free.

It is just over a century ago that in York, as elsewhere throughout the country, a beginning was made in the provision of education upon a general basis that has now fully accomplished its first object in the elimination of illiteracy.

In 1826 it was ascertained by a house-to-house visitation that of the children of the labouring population 25 per cent. of those between the ages of 6 and 10 years and 33 per cent. of those between 10 and 13 did not go to any day school. Of those children between the ages of 12 and 14, 11 per cent. could not read. It is surprising to find that of the total number of children who escaped the day school, 40 per cent. were to be found in the Sunday schools.

In the dame schools of that day it is recorded that the average professional income of the teachers did not equal the wages of a child of 12 years of age in the industrial districts. These schools were generally destitute of proper books—sometimes possessing none at all, and seldom more than mutilated fragments. Yet we find that they catered for 13 per cent. of the whole number under instruction in York.

The first serious attempt to make a general provision was in the opening of schools of the National Society and the British Schools in the years following 1828. The extracts from statistics on p. 63 show the rapid progress from that time.

The pioneer work of the York School Board established in 1889 was energetically followed up by the Education Committee who succeeded them in 1903. To-day it can justly be claimed that the city of York is one of the leading areas in educational progress, an area in which there are provided for the rising generation facilities for education that compare very favourably with those available in any part of the country.

The provision of the type of education corresponding to our present-day secondary education began early in York, but its growth was slow up to quite recent times.

The St. Peter's School has provided education for successive generations since A.D. 627, and is still a school with a national reputation. The

	Year.	Elementary Schools.	Children attending (in thousands).	Population of York (in thousands).
—	1837	8	1	30
First Education Act . .	1870	28	5	43
Appointment of York School Board . .	1889	31	10	67
Appointment of York Education Committee	1903	24	13	77
Present day .	1932	29 *	12	86

* 49 departments.

advanced courses in science and mathematics and other combinations of subjects have received the official recognition of the Board of Education. The majority of the pupils are boarders, and there is a preparatory school attached.

Archbishop Holgate's Grammar School, founded in 1546, is a recognised secondary school and accepts both boarders and day boys. An advanced course in science and mathematics is provided, and there is accommodation for preparatory school pupils.

The next school, in chronological order, is the Bar Convent Secondary School for Girls, opened at St. Mary's Convent, Blossom Street, in 1686, and now recognised by the Government for purposes of grant aid. This is a Roman Catholic school for girls, and there is also a preparatory department.

These schools held the field alone for a long period. They were followed in the early part of the nineteenth century by the two schools of the Society of Friends.

Bootham School was opened in 1823, and is a boarding school attended by children of members of the Society and others, from a wide district. The school has gained a reputation of its own and many of its old boys have made a high mark in their subsequent careers. John Bright was educated here, and a number of men who have attained prominence in the scientific world began their studies at Bootham.

The Mount School s the complementary school for girls, and celebrated its centenary last year. All are boarders, and there is a preparatory school for young children who are all day pupils.

The York College for Girls, conducted by the Church Schools Company, Ltd., in Petergate, was opened in 1908. The boarders are accommodated at Burton Grange, Clifton.

The Queen Anne Secondary School for Girls, Queen Anne's Road, Bootham, the first secondary school built by the local education authority, appeared in 1910. An advanced course in modern studies is provided.

Nunthorpe Secondary School for Boys was opened by the local education authority by converting a mansion with extensive grounds to school purposes in 1920, and the accommodation has been augmented by subsequent additions to the buildings. There are advanced courses in science and mathematics and modern studies.

The Mill Mount Secondary School for Girls, the second girls' school provided by the Education Committee, was also a large residence similarly converted to educational purposes in the year 1920, and the accommodation here is shortly to be increased by the erection of a new wing.

The St. John's Diocesan Training College for men teachers has been in existence since 1846. This college is recognised by, and earns a direct grant from, the Board of Education, the local education authority not being concerned in its management. The college is residential, and houses over 180 students. His Grace the Archbishop of York is Chairman of the Governors of the College. St. John's is in a group of scholastic buildings in Lord Mayor's Walk, and fronts a stately avenue of lime trees planted along the outer edge of the moat of the ancient city wall on the east side of the Minster.

Besides the ordinary academic work of a training college, St. John's is well equipped for games, and its curriculum includes training to an advanced stage in handicraft, a subject that is assuming more importance in the schools. The proximity of the river Ouse provides well-used facilities for rowing, a sport very popular among the students.

St. William's College, near the Minster, founded for the clergy of the Minster, is now a House of Convocation.

In spite of York's long tradition of learning and the development of higher education up to the stage of public school, secondary school, and teachers' training college, the opportunities for the founding of a university in the ancient capital have unfortunately been neglected. The county town and cathedral city of the adjoining shire can boast the Durham University. In Yorkshire the honour of founding universities or university colleges has fallen to the cities of Leeds, Sheffield and Hull. Alderman J. B. Morrell, on the occasion of the coming-of-age celebrations of the Queen Anne School in 1931, is quoted as saying ' York has missed the crowning achievement it ought to have, and that is, a university here.' The city of York provides in very many respects an ideal position for a university centre. The city's long history, its geographical position in the county, the pastoral setting on the banks of a noble river, the ecclesiastical and architectural dignity attaching to the city, and the position of York as a railway centre for the North, all combine to meet the requirements of a site for a university. There is little doubt that, had York in the renaissance of education possessed wealthy citizens imbued with the desire to leave their wealth to found a university in their native city, such as appeared in other parts of the county, York would to-day have been the seat of a university.

To ensure that the more brilliant pupils in the schools of the city shall not be prevented by lack of means from proceeding to a university, the

Education Committee every year award four major scholarships, each worth £65 per annum.

From the St. Peter's School are given three leaving exhibitions, value £50 per annum. The Education Committee also make direct grants to the university of Leeds of about £500 per annum.

Elementary Education.

With regard to the elementary schools, when the York School Board came into being in the year 1889 there were in the city 16 Church of England schools, 4 Roman Catholic, and 3 Wesleyan schools, some of these school buildings dating back to the year 1832. All the new elementary schools built since that date have been, with one exception, the work of the local authority, first the School Board and now the Education Committee. The new St. Aelred's School on the Tang Hall housing estate has been provided by the Roman Catholic community. Much, however, has been done to improve the old voluntary school buildings by extensions and adaptations. The Manor C.E. School was transferred from schoolrooms adjoining the Yorkshire School for the Blind at King's Manor into the block of buildings in Marygate that formerly housed the Boys' Industrial School.

The old premises were absorbed by the Yorkshire School for the Blind, and, with appropriate alterations to the Marygate buildings, the premises of the old Industrial School were made to serve admirably the purposes of the Manor C.E. Boys' School, first as an ordinary elementary and later as a higher grade school. In the Walmgate area the old George Street Wesleyan School was purchased by the managers of the adjoining St. George's R.C. School, to extend the R.C. School accommodation. To this school was added a new wing containing woodwork and science centres.

The issue of the Hadow Report in 1926 gave the lead for drastic and far-reaching changes in organisation of elementary schools throughout the country.

The York Education Committee had been considering, during two years, schemes of reorganisation for their elementary schools, in which between 12,000 and 13,000 children are taught. Their selected scheme was submitted to the City Council, and approved in general principle without any commitment to details, one month before the issue of the Hadow Report. The central principle of the new organisation is the recognition of the age period 11–12 years as a definite pyschological turning point in the mental growth of child life. It is intended that at this point a break shall be made by a transfer from junior school education, irrespective of the individual child's attainments. These, however, as shown by examination and school records, decide the type of school to which the transfer should be made, whether to secondary school, central selective (higher grade) or to central non-selective (senior) school. The conventional school organisation formerly obtaining was that of the infants' school for the age groups from under five years up to the eighth or ninth year, and mixed schools thereafter up to Standard VII at 14 years of age. In York an early start was made, but for such comprehensive and far-reaching changes it was found necessary to spend a good deal of time in negotiating with the managers of the voluntary schools before agreement could be reached. The first instalment of the York Reorganisation Scheme was put into operation after the midsummer vacation of 1927. The complete scheme, which is on the lines of the Hadow Report, and now in complete operation, provides that with a few exceptions of infants schools pure and simple, there shall be junior schools for children from 5 to 11 years of age, and thereafter the choice of (*a*) secondary school, (*b*) higher grade, that is, central selective, or (*c*) senior, that is, central non-selective school. In the higher grade and senior schools the classes are not allowed to exceed 40 scholars. The future type of school for the developing child in his eleventh year is settled in an annual general examination held throughout the city. The direction then taken is not made irrevocable, as provision is made in order that children who prove to be 'late developers' may change their school at a later age.

The first instalment of the York scheme provided eight higher grade schools, that is, schools of the type known as Central Selective. It was possible to do this without special building operations, except as regards extension work, by using existing buildings with the necessary adaptation, and without displacing any existing scholars. This consideration necessarily meant a transition stage of four years, which has now been completed. The schools of this type are planned to provide a four years' course for children from 11 to 15 years of age. No obstacle, however, is placed in the way of children leaving after the third year, at the age of 14 years, but every encouragement is offered for them to stay and complete the fourth year. After the second year the curriculum takes on a bias towards either commercial or technical studies, and science is given a place of importance in the time-table.

The Board of Education, in conveying their approval to the York Education Committee's scheme of reorganisation, stated that they 'desired to record their appreciation of the comprehensive nature of the scheme which had been carried out.'

In January 1930 the non-selective central schools were organised, to be known as senior schools. The present number of senior schools is seven, and it is the aim of the Education Committee to give in these schools a type of instruction directed to the needs of the child whose manual ability is more pronounced than the academic. Woodwork and metalwork for the boys, housecraft for the girls, and handicrafts for both, have their appropriate share in the spacing of time in the curriculum. Laboratories for science in the branches of chemistry and physics are provided for all the seniors whether in the senior, higher grade, or secondary school. The remaining schools have been organised as junior schools, that is, to take all children from 5 to 11 years of age, or, in a few cases, as purely infants' schools.

The eight higher grade or central selective schools are organised in four boys', three girls', and one mixed schools. There are two Church of England, two Roman Catholic, one Wesleyan, and three Council schools.

The seven senior or non-selective central schools are all mixed, and include one Church of England, one Roman Catholic, and five Council schools.

The junior schools are organised as follows :—

6 Junior mixed only (8 to 11 years).
16 Junior mixed with infants (5 to 11 years).
10 Infants schools with Std. I. (5 to 8 years).

Private Adventure Schools.—Schools of this type which formerly played an important part in education have fallen in number from twenty to about half-a-dozen schools.

Blue Coat and Grey Coat Schools.—Another type of school is found in York in the Blue Coat Charity School, formerly known as the Blue Coat Boys' and Grey Coat Girls' Schools. These schools were established in 1705 and are controlled by their own trustees and a committee, but are recognised by the Board of Education as efficient and grant-earning. They are chiefly supported by subscriptions and endowments. The boys are housed and educated at St. Anthony's Hall, Peaseholme Green, a building with a long history dating from its erection in the year 1450 by one of the ancient city guilds. It has at different times served a variety of purposes, having been used as a hospital, where the wounded from the battle of Marston Moor were received, a workhouse, playhouse, and prison.

School Architecture.

The educational progress in organisation, curriculum, and teaching power has been accompanied by an equal improvement from the architectural point of view. The large solidly-built schools of two storeys which still stand as a monument to the progressive efforts of the School Board forty years ago are not being duplicated in modern school building. The maximum of sunlight and air is now a primary consideration, and the schools recently built conform to this ideal in their design and structure. They are mostly one-storey buildings, and in the Queen Anne Secondary School for Girls (1910) the Knavesmire Council Schools (1916), the Tang Hall Council Schools (1928), and St. Aelred's Roman Catholic School (1932) the process of development is seen.

The classrooms of the Tang Hall School, which all face south, can be opened out fully on two sides to the air and sunshine, according to the weather conditions. Glass-covered verandahs run along the south side of each classroom.

The demolition of slum property and the gradual transfer of city dwellers to the suburbs will, no doubt, result in schools being erected in healthy and, if possible, beautiful surroundings.

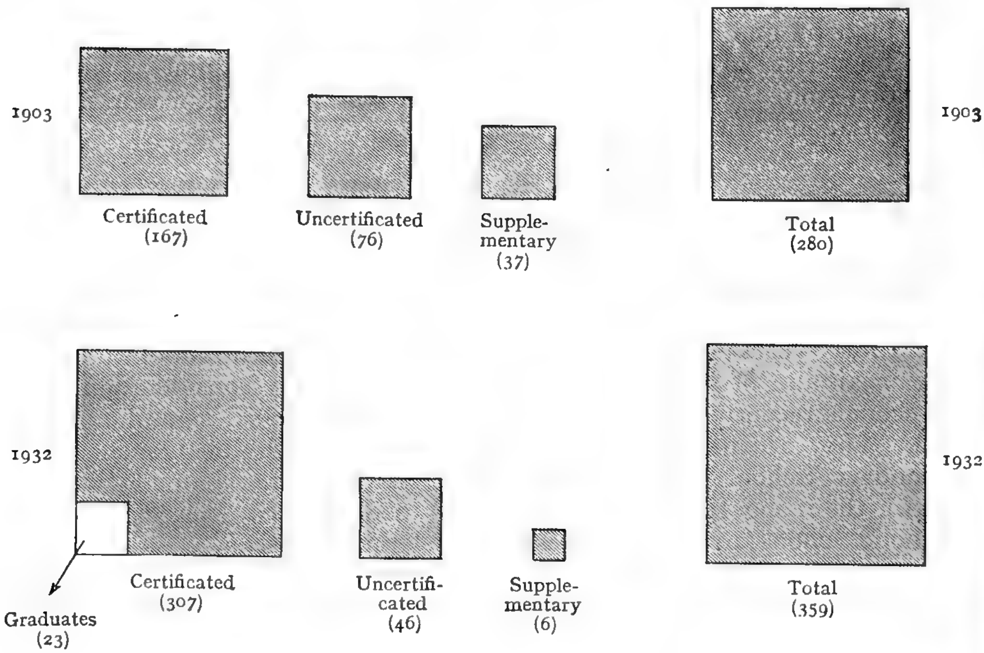
It is probable that, in time, many of the old city schools will become obsolete.

Teaching Staff.

A comparison, useful in showing the increased value of the education of the city's children since the formation of the Education Committee under the Act of 1902, is in the quality of the teaching staffs as evidenced by the training and academic qualifications of the present members of school staffs, and the reduction that has taken place in size of class. The following are the numbers of teachers engaged in elementary education in York, then and now. The reduction in number of scholars in elementary schools is partly accounted for by the transfer of large numbers of children to the secondary schools :—

Year.	Certificated.	Uncertificated.	Supplementary.	Total No. of Teachers.	Scholars (thousands).
1903	167	76	37	280	13
1932	307	46	6	359	12

The following graph illustrates the comparison :—



To help towards ensuring an adequate flow of recruits to the teaching profession the Education Committee encourage young people who wish to become trained teachers by pre-training facilities of secondary and higher education, and by the grant of financial assistance in the two years before the age of entry to college or university. Under the scheme of pupil-teacher probationers now in operation, fifteen girls and boys who have satisfactorily completed their secondary school course at 16 years of age are selected for appointment as probationers for the two years before their entry to a training college or university at the age of 18 years. When circumstances necessitate, persons 17 years old are accepted for one year.

Care of Sub-Normal Children.

Twelve years ago the Education Committee began to make special provision for children unable by reason of physical or mental defect to keep pace in the ordinary school classes. A large residence in its own grounds at Fulford Cross, Fulford Road, was purchased and adapted for the purposes of special schools. An Open Air School for delicate children (120) is conducted in hutments in the grounds. The permanent building is used for classes of children (110) who are too backward mentally to profit by ordinary class instruction in the elementary schools. Both sets of special scholars receive meals at school, and under these conditions it is possible to make the special arrangements necessary for the welfare of these types of children. Children whose defect is that of eyesight and who, whilst far removed from actual blindness, are still so weak-sighted that they also are unable to benefit in the ordinary school class are organised in a special class for myopic children held on the premises of the Castlegate Council School. Those whose handicap is more pronounced are sent to one or other of the residential institutions available in different parts of the country. At present blind children from York are in the Yorkshire School for the Blind (York) and in the Sheffield Institution for the Blind. York children suffering from deafness are educated at special schools at Doncaster, at Manchester and at Boston Spa, and arrangements are made for epileptic children at Stornthwaite, near Kendal, and Lees Moss, near Manchester. Children requiring institutional treatment for mental defects are sent to the Beacon School at Lichfield.

Now that an orthopædic hospital has been opened at Kirbymoorside, near York, the crippled children in our schools found to require operative and residential treatment are sent there.

The child whose defect is that of nonconformity to moral and ethical standards, or whose home circumstances are such as to make it hopeless for him to develop in any wholesome manner in his home environment, is sent away to some industrial or truant school.

In 1894 we had 110 children in these schools which are scattered up and down the country. The total has now been reduced to 13. It is gratifying to know that the falling off in the number of committals to industrial schools is not peculiar to York, as 200 industrial and reformatory schools throughout the country have been closed in the last decade. This improvement is probably due to (i) the happier school conditions; (ii) improvements in the homes; (iii) restrictions placed on the sale of intoxicants.

The Fairfield Special School consists of a class conducted by the Health Committee of the Corporation in their Fairfield Sanatorium, situated some three miles north of the city, on the Skelton Road. In this class the children from time to time resident in the sanatorium are able to continue their elementary education during the process of their restoration to health. In these circumstances the number of scholars in the class is variable, but there are generally about twenty children of different ages.

Medical Inspection.

For two years before the medical inspection of school children was made compulsory by Act of Parliament (1907) the York Education Committee had been carrying out a voluntary scheme of medical inspection of their scholars, and had taken steps to lay the foundation of the school medical service as it exists to-day.

The children's health and physical welfare become, on their first admission to school, the concern of the school medical staff. The school doctor examines every child on at least three occasions in the course of his or her school career, viz. :—on first admission to school, between the ages of 7 and 8 years, and, finally, on attaining the age of 12 years. Medical inspection is also continued in the secondary schools. Physical defects or disease found in the course of inspection are dealt with as may be appropriate. Minor ailments of all kinds are treated at the school clinic, which is at present housed in temporary premises in Piccadilly. It is hoped that very shortly, the exact date depending upon considerations of finance, fresh premises, more nearly adequate for this important branch of school work, will be secured. There is a dental section, opened ten years ago, which carries out this important branch of work in the conservation of general health. Defects of eyesight and related trouble are treated at the clinic, and where spectacles are prescribed these are supplied under contract at the expense of the parents, who are permitted to pay by instalments where desired.

Comparative figures taken over a period of 20 years show that cases of defective teeth were reduced from 89 per cent. to 67 per cent. of the children examined, defective vision from 14 per cent. to 13 per cent., and cases of ringworm of the scalp from 284 to 59.

Feeding of Necessitous Children.

The malnutrition of children consequent upon poverty of the parents has become the concern of the Education Committee, because it was found that an ill-nourished child was unable to assimilate the instruction provided and that, apart from other considerations, it would be a waste of the public money spent upon elementary education to attempt to teach hungry children. At five meals centres in different parts of the city, hot dinners prepared on the premises are provided at noon on five days each week throughout the year, including school holidays. Last year, over one hundred thousand free meals were served for the benefit of 500 to 600 children. In the interests of child nourishment the Education Committee at the beginning of 1932 inaugurated a self-supporting scheme to provide pure fresh milk to the children requiring it. Under this scheme, which is managed by the head teachers, sealed bottles containing one-third of a pint, for which each child pays 1*d*., are delivered to the schools every morning. From a return compiled after the first three months it was shown that over three thousand children were taking the milk each morning.

Playing Fields and Organisation of Games.

Efforts are being made to provide the elementary school children with suitable playing fields, and four large playing areas have been secured in different districts. Three are in use and the fourth is in preparation.

The Schools' Athletic Association render splendid service in organising and training the scholars, and the teachers give a large part of their own time to this work.

York has produced Association football teams which have beaten teams from such large centres of population as Manchester, Sheffield, Hull and Leeds. Swimming is also taught, over 400 new swimmers being added to the list each year.

Secondary Schools.

Very few cities of similar size are so well provided with secondary schools either in number, quality or variety. The Education Committee have provided three :—

	No. on Register.	
(1) Nunthorpe Secondary School for Boys . .	410	
(2) Queen Anne Secondary School for Girls . .	400	
(3) Mill Mount Secondary School for Girls . .	250	
		1060

and in addition, officially recognised by the Board of Education as 'efficient,' there are :—

* St. Peter's Public School for Boys . . .	238	
Bootham, Friends' Boarding School for Boys .	143	
* The Mount Friends' Boarding School for Girls	176	
Archbishop Holgate's Grammar School . .	444	
York College for Girls, Petergate . . .	130	
* Bar Convent Secondary School . . .	187	
		1318
		2378

* Including preparatory department.

There is also Elmfield School, just over the city boundary, but this school is to be closed this summer.

It is gratifying to know that arrangements have been made for city minor scholarships to be tenable at eight of the schools referred to.

Each year the local education authority award about 200 scholarships tenable at secondary schools.

Science Instruction in York Schools.

Science has long occupied an important place in education in this city. Before the appointment of the Education Committee in 1903, two schools of science and art were conducted by a technical instruction committee working under the City Council. The principal part of the work of these schools was, however, on the art side.

For the students in the present evening institutes there are classes in experimental science and in workshop science as part of the Preparatory Trades Course. At the Technical Institute, Clifford Street, there are five laboratories, for chemistry, physics, electrical engineering, mechanical engineering and building science, respectively. These laboratories are used in connection with classes in the following subjects :—chemistry, including courses in pharmacy and in bakery science, physics, applied mechanics, machine design, engineering science, electrical engineering science, magnetism and electricity, telephony, mechanical engineering and building trades.

Adequate provision for scientific studies is made at the various secondary schools in the city, of which brief details are given below.

St. Peter's School.—The chief subjects taught in the science work of this school are chemistry and physics. The work is begun in the preparatory department, where boys are introduced to some of the more elementary parts of each subject. In addition, a certain amount of natural history is done at this stage. At 13 to 14 years of age boys enter the senior school, where they continue the study of chemistry and physics up to school certificate standard, most of the boys taking these two subjects in the certificate examinations of the Northern Universities Joint Board.

After the school certificate stage, boys begin to specialise. In the Modern VI form chemistry and physics are studied in preparation for the Higher Certificate and university scholarship examinations. Botany and zoology may be studied and facilities for work in these two subjects are given to boys who wish to take their first medical examination while still at school. In addition to the ordinary work of the curriculum, the school possesses a Scientific Society of about 50 members. They hold frequent meetings during the two winter terms, at which lectures are given either by the boys themselves or by members of the staff. Triennially the Society organises a large scientific exhibition in the school, the object of which is to illustrate some of the advances and discoveries made in as many branches of natural science as possible. The demonstrations arranged are for the most part carried out by the boys themselves. During the summer term an excursion is organised to some interesting part of the country within 30 miles of York. An attempt is made to learn something of the natural history and geology of the region visited, while note is also made of anything of archæological interest. The Society publishes annually an account of its doings under the title *Proceedings of the St. Peter's School Scientific Society*.

Bootham School (Boys).—There are laboratories for chemistry, physics and biology, with a well-equipped observatory, and meteorological instruments which are read daily by the boys.

The sixth form work for the Higher Certificate, Inter B.Sc., University scholarships, first M.B. examinations, the science subjects being chemistry, botany and zoology. The fifth form take chemistry and biology to the school certificate and matriculation standard, and it is hoped to add physics to the curriculum next year.

In the lower forms the boys take chemistry, physics, biology, nature study, elementary zoology and botany, and practical gardening.

The School Natural History Society was founded in 1834, and has had a continued and successful career, producing many eminent scientists and field naturalists. It has regular meetings in winter and will shortly hold its 800th meeting. In summer many excursions are arranged.

The Mount School (Girls).—There is one laboratory at this school, and an observatory with an excellent telescope which is found of great assistance in certain scientific studies.

Biology is now being substituted for botany as the main science subject up to the school certificate standard. Those pupils who so desire will take chemistry in addition, but in any case work in elementary physics and chemistry is included in the biology course. The work after matriculation is arranged according to the needs of the individual, whether working for College Entrance, Higher Certificate, or the first M.B. examination.

Girls who are taking advanced physics join classes at Bootham School. Pupils proceeding to careers such as those of nursing, physical training or massage often take a general course for one or two years after matriculation, and this course may include zoology, botany, mechanics, or anatomy.

A Scientific Society organised by staff and pupils gives opportunities for out-of-school work in natural history, field botany and scientific experiment. Meteorology is part of the work of the Scientific Society, and records taken in the observatory are kept.

Archbishop Holgate's Grammar School (Boys).—The science work at this school includes nature study and general elementary science in the junior school; physics, pure and applied mathematics, inorganic and organic chemistry in the middle and upper forms. The standard reached is that of the Higher School Certificate of the Northern Universities and the Intermediate Science of the London University. Scholarships or exhibitions in mathematics and science have been gained directly from the school to Oxford, Cambridge, Leeds, Sheffield and Edinburgh universities.

Bar Convent Secondary School (Girls).—At this school there is one laboratory for science subjects. In the fourth and fifth forms the science syllabus of the School Certificate Examination of the Joint Board of the Northern Universities is followed, covering chemistry, physics and botany. In the lower forms the curriculum gives a progressive course in elementary science.

York College for Girls.—There is one laboratory at this school for chemistry and physics, and pure and applied mathematics are taken to the stage of the Higher School Certificate of the Joint Board of the Northern Universities. Physics is taken to the subsidiary stage of the same examination. One of the advanced courses conducted on the lines of those recognised in other secondary schools by the Board of Education is in science and mathematics.

Queen Anne School (Girls).—The school is provided with three well-equipped laboratories for chemistry, physics and botany, respectively, and the curriculum includes a substantial course of science as part of the general education of every pupil. Chemistry or botany, or both, are taken by the entrants for the First School Examination, the necessary physics and biology being included in the work of the lower forms. Those who show taste and aptitude for science proceed to an advanced course which includes botany, chemistry, physics and mathematics. State scholarships in science were won in 1929 and 1931. The objective of the science curriculum is to train the girls to understand and to apply the methods of scientific reasoning and investigation and to appreciate the wide field of interest opened out by the study of natural science.

Mill Mount School (Girls).—There is at present one science laboratory, for chemistry, physics and botany. A new laboratory, for biology and physics, is included in the plan of extensions that are to be proceeded with as soon as the official sanction recently applied for has been received.

The fourth form take chemistry and botany in the syllabus for the School Certificate Examination of the Joint Board of the Northern Universities.

The science pupils in the fifth and sixth forms take chemistry, botany and physics, generally grouped with mathematics for the Higher School Certificate Examination.

In the first three years the science part of the curriculum is devoted to the preliminary stages. The science side of the school is being built up by the gradual substitution of biology for botany in the second year.

Nunthorpe School (Boys).—At this school there are four laboratories, the last having recently been provided for advanced physics. The ordinary school course in science is one of four years and leads up to the School Certificate Examination in chemistry and physics conducted by the Joint Board of the Northern Universities. The boys of the fifth and sixth forms taking the advanced course in science and mathematics, study chemistry and physics according to the syllabus of the Higher School Certificate Examination.

Apart from the formal work in classroom and laboratory there is a school Scientific Society which hears lectures delivered by visitors or by the pupils themselves, holds discussions, and arranges visits to places of scientific interest.

So far as the public elementary schools are concerned, a general science training is provided for in the curricula of the higher grade (central selective) and senior (central non-selective) schools. For the use of science classes in the higher grade schools six laboratories have been provided within the past few years, and the scholars of one of the schools have the privilege of using a laboratory on adjoining premises. All the seven senior schools have either had laboratories provided or rooms adapted for the purpose.

Diocesan Training College (St. John's).—Those students who wish to take advanced science can choose between a two-year course in advanced chemistry and a similar course in advanced physics, both these courses being based upon practical work in the college laboratories. There is also a two-year course in gardening, the practical side of which is developed in the gardens of the new hostel at Heworth Green. For those students who have only a little knowledge of biology but desire to be able to teach nature study, a one-year course in elementary biology is available. Finally, in the education course, lectures are given to all students on the teaching of science. There are two laboratories provided for the use of the students.

Further Education.

The School of Art, which has now 327 pupils on register, provides group courses of instruction in junior art, industrial art, architecture, painting, sculpture, design and crafts, and the teaching of art. The courses of instruction aim at giving a sound training in the subjects suitable to the needs of the artistic profession, trade, or craft in which the student is engaged or is interested, and to develop individual artistic ability. The school is working on modern lines and every effort is made to link up art with industry.

The Day School of Commerce, which was first opened in the year 1920, in temporary premises in Bootham, now meets at the Technical Institute. The school provides specialised courses of instruction for students who desire to obtain positions in the commercial world. The curriculum, however, has not been confined within narrow limits, and it has been the aim of the school to give a liberal education to all its students in addition to a training in commerce. The steady growth of the school testifies to its usefulness. There are now 120 students on register. Qualified pupils from this school seldom fail to find employment.

The Technical Institute, Clifford Street, provides day courses of instruction for engineers, railway carriage builders, and others, and evening courses for those engaged in the building trades, mechanical engineering, electrical engineering, motor engineering, carriage and wagon building, telegraphists, chemists, printers, bakers and confectioners, and for those wishing to prepare for the A.M.I.M.E. Examination, Matriculation or the Inter B.Sc. There are 135 day students, and 457 attending evening classes.

Evening Institutes are held on the premises of four of the large Council schools, namely, Fishergate, Park Grove, Scarcroft Road, and Poppleton Road, where group courses of instruction are provided leading up to the trade courses at the Technical Institute and to the senior commercial classes at the Evening Institute of Commerce. Recreative classes are also held at Layerthorpe Evening Institute. The Evening Institute of Commerce is held at the Castlegate Council School and on the Queen Anne Secondary School premises. Advanced classes are held in commercial subjects, languages, economics, banking, etc. Provision is also made at this institute for retail traders' apprentices, butchers and grocers, etc. The number of students in attendance last session was over 660.

The York University Extension Society was formed over fifty years ago as a voluntary organisation making itself responsible for organising, during the winter months, courses of evening lectures by lecturers eminent in their particular spheres. The subjects are of social, historical, literary and scientific importance and are held in the Tempest Anderson Hall. His Grace the Lord Archbishop of York is President of the Society.

The Workers' Educational Association has an active branch in York, of which his Grace the Lord Archbishop is also President. Classes of university tutorial standing in courses of one or more years' duration are conducted for adults each winter at as many as four centres. The subjects of the courses and arrangements generally are decided in advance by the prospective students.

A Juvenile Employment Bureau is conducted by the Education Committee and exists for the purpose of assisting school-leavers to find employment in suitable occupations and to ensure that, so far as possible, working conditions are reasonable for young people. The age range covered by the bureau is 14 to 18 years. For those over 16 years the work has to be carried out under the Unemployment Insurance Acts. The supervision and licensing of street traders and of child artistes are additional duties of the Education Committee in this department.

XI.

INDUSTRIES OF YORK

The following table has been kindly supplied by Mr. A. N. Shimmin to indicate the chief industrial activities of York.

Estimated Insured Population (1931 Returns).

Cocoa, Chocolate and Sugar Confectionery	7106
Distributive Trades	4147
Building	2707
Railway Carriage and Wagon Building	2403
Railway Service	1380
Printing, Publishing, Bookbinding	978
Tramway, Bus and other Road Transport	821
Local Government Service	807
Hotel, Restaurant, Club Service	670
National Government Service	652
Gas, Water, Electricity	621
General Engineering and Iron-founding	479
Professional Services	458
Scientific and Photographic Apparatus	453
Public Works Contracting	452
Drink	281
Laundries, Dyeing, Dry-cleaning	278
Repair of Motor Vehicles and Cycles	261

Bread, Biscuit, Cake-making	237
Entertainments and Sport	218
Glass Bottles	201
Furniture, Upholstery	183
Bricks, Tiles, Fireclay Goods	164
Canal, River and other Transport	149
Tailoring, Dressmaking and Millinery	143
Tanning, Currying, Leather Dressing	142
Total	26,391
[1] Other Industries	1,649
Total Insured Workers	28,040

XII.

FEATURES OF ENGINEERING INTEREST IN YORK AND DISTRICT

BY

H. R. LUPTON.

YORK having been for centuries the most important city on the route from the English capital to the Scottish Border, it is natural that in the railway should now be centred her main features of engineering interest. Accordingly a brief description of the L. & N.E.R. carriage works, signalling school and museum, all in York, will first be given, followed by a short note on the permanent way to Darlington and some other features which will be available for inspection by Section G (Engineering).

Other local engineering features of interest are the Buckingham Works of Messrs. Cooke, Troughton & Simms, Ltd. (the subject of a separate notice), and of Messrs. Adams Hydraulics, Ltd., the power plant at Messrs. Rowntree's and at Messrs. Terry's Chocolate Works, and the City Electric Power Station.

Going rather farther afield, the Section has arranged excursions to the Cleveland Bridge & Engineering Co. Ltd., of Darlington ; to the Blackburn Aeroplane & Motor Co. Ltd., of Brough ; and in the Leeds district to the Savile and Whitwood collieries of Messrs. Henry Briggs, Son & Co. Ltd. ;

[1] This group covers 44 industries represented by firms employing less than 100 operatives each.

In York there are 1,202 firms, and more than half of these employ 20 workers or less. Sixty-seven firms employ between 21 and 50 operatives each ; forty-three firms from 51 to 250 operatives, and seven firms more than 250 operatives each.

to the Rescue Station of the Yorkshire Coal-Owners' Association; to the new grid power station at Kirkstall, and to the works of the *Yorkshire Post*, each among the most modern of their kind in the kingdom. Notes on each of the above are appended, and it is only regretted that space does not admit of descriptions of the countless other items of engineering interest which the district affords.

York Carriage and Wagon Works.

The York Carriage and Wagon Works were opened in 1884, but since this date several extensions have been made, and the works now cover an area of 62 acres, including 18 acres of roofed buildings. The number of hands at these works is normally about 2,750, but owing to the present trade depression and forced economies this number has been reduced, and is now a little over 2,000.

Until the amalgamation of the various railway companies now forming the London & North Eastern Railway in 1923, the whole of the carriages and the greater portion of the wagons required for the North Eastern Railway were constructed at these works, and also the maintenance of this stock was undertaken here. Since the amalgamation the carriage works have been considerably developed, and now permit of the larger portion of the carriages and special wagons required for the London & North Eastern Railway being built here, in addition to a greater number of carriage repairs, and the erection of new steel bogies and underframes for the other sections of this Company. The machinery is everywhere of the most modern type; processes have been radically altered wherever productiveness can be thereby improved—as evidence, the rapid increase in the use of welding; components are made to jig throughout, and assembly is carried out on the progressive system, each receiving in the course of its route through the shops the attentions of successive gangs, all in accordance with a definite time-table. As a result, great savings have been made. The time taken from the laying down of the floor of a vehicle to its leaving the shops has been reduced from 5½ weeks to 10 days, while the 'heavy repairs' of a carriage now take 20 days in place of 12 weeks. Carriage wheels are re-turned in three-eighths of the time formerly required, and that often without removing as much metal as formerly, thus prolonging life.

The Carriage Works are now capable of giving an output of four new complete 61 ft. 6 in. vestibuled bogie carriages, and the repairing of 77 carriages (17 heavy and 60 light repairs) per week; also, in order to avoid duplication of expensive plant being laid down, and thus reducing overhead charges at the Company's different carriage works, all carriage underframes complete with bogies are built here, and delivered to the various centres.

The Wagon Works, where only repairs are now undertaken, are connected to the Carriage Works by a footbridge over the main goods line, and turn out between 500 and 600 repaired wagons each week.

The Carriage Works contain:

Forge and Smiths' Shops, with drop hammers, presses, steam hammers, etc.

Acetylene Welding Shop, the use of this process having greatly increased both for welding and cutting.

Punching and Shearing Shed.

Iron Machining Shop, containing an interesting 'Landis' type screwing machine, probably the only one in the country capable of screwing, direct off the die-head, a 2-start $\frac{3}{4}$ in. pitch knuckle form thread.

Interesting drilling and milling machines—the last process is being widely extended—and turret lathes are also to be seen.

Frame Shop, where the components, assembled on jigs, are erected into complete underframes.

Channel Straightening Shed.

Hair-teasing Shed.

Timber Drying Shed. Tests are now being carried out with a view to adopting the artificial method and so reducing the amount of timber to be held on stock.

The following are some of the woods used for carriage building and stocked in this shed:

English Oak.
American Oak from the United States and Canada.
Dantzic Oak from Stetting.
Oak from the Polish forests, and Wainscot from Austria.
Honduras Mahogany from Central America.
Mahogany from Tabasco and Cuba.
Teak from East India and Burmah.
Walnut from South Europe.
Sycamore from our own country.
Hungarian and British Ash.
Kaurie Pine from New Zealand and Jarrah from Australia.

These are all what are termed hard woods.

Soft Woods :

Yellow Pine from Canada.
Dantzic Fir from Poland and Russia.
Pitchpine from North America.
Spruce, commonly known as white wood, from Norway and Russia.

Sawmill—entered after passing through the Timber Log Yard, and containing some very fine wood-working machinery. The Log Bandsaw has a cutting speed of 30 ft. per minute through a 24 in. diameter log of oak. The Band Re-saw has speeds running up to 120 ft. per minute, depending on the depth of cut. In both cases the saws are thinner than formerly, this not only doubling the speed, but also lessening the waste of timber.

The new planing and moulding machine works at about four times the speed of the old type of plant, all the five cutting heads being separately motor-driven.

Other notable machines are the Automatic Finger-Feed Planing Machine, which, despite its somewhat ominous-sounding name, in fact renders much safer a previously rather dangerous operation; a Triple Drum Sander and a Wadkin's Wood Milling Machine or Recessor, which automatically performs no fewer than nine operations.

Building Shop, where, as already mentioned, the work is carried out in a series of progressive stages, which has resulted in a 70 per cent. saving of time.

There are seven different stages, consisting of:

Stage 1. Building the floor on the underframe.
,, 2. Assembling body-sides or quarters fully glazed, body ends and partitions.
,, 3. Roof fitted.
,, 4. Roof made waterproof by covering with canvas and white lead.
,, 5. Hanging platform doors.
,, 6. Varnishing exterior.
,, 7. Again varnishing the exterior.

At Stage 3 the interior work begins and continues until the body reaches Stage 7, when the coach is ready for going into the Varnish Shop for final varnish. The gangs preparing the component parts are arranged adjacent to the stage at which the parts are required, the labourage thus being reduced to a minimum. The panelling is given two coats of varnish prior to being erected at Stage 2. All the body platform doors are first fitted into a steel jig, which is an exact replica of the standard doorway, thus making all body doors interchangeable.

Paint Shop.

Repair Shop, run, as in the case of the Building Shop, on a progressive system.

Brake Shop.

Lifting Shop, where all running gear is overhauled, containing a wheel balancing machine, two Journal Live-Centre Turret Lathes, two remarkable Craven Wheel Lathes and a spring-testing machine.

Electric Shop. Lighting is now almost universally electric.

Plumbers' and Brass-finishers' Shop.

From the bloom and the log to the finished carriage—the complete metamorphosis is here performed. Everything has been speeded up, yet standards have been imposed which more than maintain quality. Thus are ensured the safety and comfort of the travelling public, for which the British railways have always held a most enviable reputation.

The L. & N.E.R. Signalling School.

The rapidly extending use of electrical signalling methods has brought with it an ever-increasing difficulty in finding men with the necessary knowledge and experience to maintain the new electrical installations as they are brought into use. The mechanical signal fitter previously in charge of the mechanical installation at a given place has rarely sufficient technical knowledge to be put in charge of the new electrical installation; consequently an electrical signal fitter from the electrical construction gang has to be stationed at the new installation for maintenance purposes; as there may be also in the same locality a telegraph lineman to maintain the telegraph and telephone installation, it is possible to have in the same neighbourhood three men of different grades dealing respectively with the closely allied works of the maintenance of mechanical signalling, electrical signalling, and telegraphs.

It would obviously open up a much wider and more attractive field of effort for the staff, and be an economy from the Company's standpoint as well, if men could be trained to carry out all three classes of work in any given locality, and it is with the object of giving such training that the Railway Signalling School has been formed. The school is also used for the lectures on Block Rules and Regulations hitherto held in the old classroom on Toft Green.

The objects of the school are therefore :

1. (Technical) To give to the staff dealing with the construction and maintenance of signal, telegraph and telephone installations instructions in the principles of electrical and mechanical signalling and of telegraphy and telephony.

2. (Operating) To enable the students attending the lectures on block rules and regulations and general rules to become conversant with the operating side of signalling.

With the above objects in view, the school has been equipped with a model railway layout incorporating five signal boxes designed to show every possible use that can be made of track circuiting. There are also full-size working models of various apparatus met with in signalling and telegraph installations.

To describe within the limits of the present article the system of working and of instruction would be impossible, but a short explanatory demonstration will be given at the School.

The Railway Museum, York.

The Railway Museum is in two sections, viz. :

(1) The small exhibits section, consisting of three main rooms and an ante-room, in which are preserved the smaller and more perishable relics, including prints, photographs, books and time-tables.

(2) A large building, formerly a locomotive fitting shop, in which are preserved the more bulky exhibits, including historic engines, early railway carriages, the world's first iron railway bridge, and much early signalling apparatus; also what is probably the finest collection in existence of early rails and obsolete permanent-way equipment.

In the Small Exhibits Section are preserved the original survey and plan of the Stockton and Darlington Railway prepared by George Stephenson, tools used by him in building his early locomotives, and a number of Stephenson letters. In this section are also preserved a number of petitions on parchment containing many hundreds of signatures of inhabitants of the North of England, praying that the houses of Parliament should pass the Bill for the Stockton and Darlington Railway. Here are also to be seen a large number of prints, prospectuses, booklets, time-tables, railway tickets, signalling apparatus, seals and small relics relating to the numerous railways promoted in the North of England during the early part of the nineteenth century.

A room is devoted to the Briggs Collection, bequeathed by Mr. Isaac Briggs of Wakefield, consisting of prints and books relating to the civil engineering side of railway development.

In the Large Exhibits Section are preserved an engine (partly rebuilt) constructed by George Stephenson in 1822 for the Hetton Colliery

Railway, also (re-erected) an iron girder bridge designed by George Stephenson in 1824–5 for the horse-worked portion of the Stockton and Darlington Railway. This is claimed to have been the first iron railway bridge in the world.

Other engines to be seen include a single-wheeled passenger engine designed by Patrick Stirling for the Great Northern Railway in 1870; the 'Gladstone' engine built to the design of William Stroudley (1882) for the London, Brighton and South Coast Railway, and the 'City of Truro,' designed by C. J. Churchward for the Great Western Railway, which, on May 9, 1904, is claimed to have achieved the highest authentic speed ever recorded for a railway train, viz. 102·3 m.p.h.

The permanent way exhibits, rails, etc., form an especially fine collection and include examples of types of rails used from the time of Outram (1797) to the present day, notably portions of cast-iron rails from the original Stockton and Darlington Railway; specimens of rack rail (with pinion wheels) used for the Blenkinsop engines of 1812, and portions of cast-iron and wrought-iron rails used by George Stephenson for the Stockton and Darlington Railway in 1825. The specimens of early rolling stock include two carriages from the Bodmin and Wadebridge Railway (1834)—one open and one closed—and some examples of early chaldron wagons.

Another of George Stephenson's inventions—the dandy cart, of which a life-size model is shown—is interesting, partly from a humanitarian point of view. The open-backed dandy cart was attached to the rear of a set of horse-drawn trucks. When the top of an incline was reached the horse was uncoupled from the front, to step into the dandy cart at the rear and so to secure a well-earned ride downhill.

The Permanent Way, York—Darlington.

The main portion of the York Station is built on a curve of 17 chains radius and the main line platforms are a third of a mile in length.

On leaving York Station on the west side will be seen a new coaling plant, comprising a reinforced concrete bunker situated above the two railway tracks; loaded coal wagons are raised up an inclined hoist and tipped in the bunker. Engines are coaled on the tracks below.

Three miles north of York, the river Ouse is crossed on a stone viaduct, and one section of the work of doubling the main line tracks begins, one track on each side. This section terminates at Beningbrough Station, 5½ miles from York.

At Alne, 11 miles from York, is the junction with the Easingwold Light Railway, on the east side.

From this point and for some miles it is possible to see the White Horse cut in the hillside near to Coxwold, looking forward to the right at a distance of 8 miles.

A second portion of the widening of the main line begins at Alne, an additional line being constructed on the west side as far as Pilmoor Junction, 16 miles from York.

Otterington, 26½ miles from York, is the starting point of a further section of widening. An additional line is being constructed on the west side. This section terminates at Northallerton, where an additional line has been constructed to connect the low-level Leeds to Stockton line with the up main line. This necessitated the construction of a bridge under the main line without interruption of traffic.

At 2 miles north of Northallerton water troughs are constructed between the rails. From these the engines may collect water while travelling at speed by lowering a scoop, the water being replenished by a supply pumped from a nearby stream into a control tank.

At Croft Spa, 3 miles farther on the journey, the river Tees is crossed, and on the west side at a lower level may be seen a single track railway, which formed part of the original Stockton and Darlington Railway now used as a goods branch for Croft village.

Darlington is now reached, and on the east side will be seen the line to Middlesbrough, etc., and beside it and the main line are the works of the Cleveland Bridge & Engineering Co. Ltd.

In Darlington Station is mounted Locomotive No. 1, which George Stephenson drove when opening the Stockton and Darlington Railway in 1825.

Messrs. Adams Hydraulics, Ltd.

Messrs. Adams Hydraulics, Ltd., specialise in all manner of plant in connection with sewerage and sewage-disposal. This mainly falls under three heads :

(*a*) Sewerage Ironwork—mainly manhole covers, gully grates, vent columns and sewer-flushing syphons.

(*b*) Sewage Lifting Plant—automatic compressed-air sewage ejectors, automatic sewage lifts and sewage pumping plant.

(*c*) Sewage Works—all types of valves and fittings used on sewage disposal works, revolving distributors, sludge plant, mechanical screening apparatus, detritus lifting plant, penstocks, etc.

Cleveland Bridge & Engineering Co. Ltd.

Established over fifty years ago, the Cleveland Bridge & Engineering Co. Ltd., of Darlington, have for many years been one of the largest and most important bridge-building companies in the United Kingdom. The business of the company is primarily that of bridge-building, and the reputation of the company has largely been built up in this connection, but in addition to bridges they carry out the construction of all structures in steel, such as workshops, power stations, pipe lines and dock gates. The company are contractors as well as structural engineers, and when they undertake a contract they carry out the whole of the work, including foundations and all building work, themselves. They are, in fact, specialists in all kinds of foundations.

Two well-known bridges manufactured and erected by them, including the foundations, are the King Edward Bridge over the river Tyne at Newcastle, and the Victoria Falls Bridge over the Zambezi river. Among more recent contracts may be mentioned :

Two airship sheds at Cardington, and also the steelwork for the mooring-masts in Cardington, Egypt and India.

The floating landing-stage for the Port of London Authority at Tilbury (which was opened by the Prime Minister on May 16, 1930). This stage is 1,100 ft. long and will accommodate ocean-going liners.

The supply and erection of steel pipes for carrying the water supply for the Corporation of Calcutta, the diameter of the pipes varying from 3 ft. to 5 ft., the weight involved being about 17,000 tons.

The Coventry Power Station, which was designed and built by the Cleveland Bridge & Engineering Co. Ltd., of Rugby; and

A new wagon works for the London & North Eastern Railway at Faverdale, Darlington, the contract for which included all site levelling, drainage, foundations, roads and buildings.

A new bridge over the Nile, near Alexandria, has just been completed for the Egyptian State Railways.

Later contracts, on which the firm is now engaged, include a ferro-concrete bridge over the Thames at Chiswick and a bridge over the Zambezi in Portuguese East Africa, of a total length, bank to bank, of 2¼ miles, with about 30 miles of approach railway. This bridge being founded mainly on sand, the piers have to be sunk 110 ft. below low-water level.

The Blackburn Aeroplane & Motor Company, Ltd.

Originally established in Leeds, the above company has now moved its whole works to its erection and test base at Brough, where the exceptional facilities for both land and sea-plane tests are of great advantage.

The success of the company's products last year, including the winning of the King's Cup Air Race and the Grosvenor Cup, are an indication of the quality of their machines, while the record time (thirty working weeks) in which they delivered a new 'Iris III' Flying Boat to the Royal Air Force indicates efficiency in manufacture.

City of York Electric Lighting Department.

At the Foss Islands generating station there are four turbo-generating sets, two of 6,000 kw. and two of 3,400 kw. each, with the appertaining steam-raising plant, switch gear, etc.

At the Linton Hydro-electric Works there are two water turbines of 500 and 250 kw. respectively, a visit to which, by motor launch, has been arranged.

Messrs. Rowntree's Cocoa Works.

The power plant services at Messrs. Rowntree's cocoa works comprise:

(1) *Electricity.*—Obtained from the York Corporation at 3,000 volts A.C. and mostly converted to 230 volts D.C.

(2) *Steam.*—There are three boiler houses, in the newest of which two large water-tube boilers are at present being erected.

(3) *Refrigerating Plant.*—Six ammonia compression units cool brine for circulation in the factory.

(4) *Water Supply.*—Partly obtained by pumping from artesian wells and partly from the city supply.

MESSRS. J. TERRY & SONS, LTD.

The power plant services at Messrs. Terry's works comprise :

(1) *Electricity*.—Obtained from the York Corporation at 6,000 volts A.C.

(2) *Steam*.—For process work, etc., provided from water-tube boilers of the Babcock type.

(3) *Refrigerating Plant*.—Two ammonia compressor units together with water cooling towers.

(4) *Air Conditioning Plant* of the Premier type.

(5) *Water Supply Services*.—Partly from city supply and partly obtained by means of centrifugal pumps from the river.

MESSRS. HENRY BRIGGS, SON & CO. LTD., WHITWOOD COLLIERIES. SAVILE PIT.

Modern screening plant, new headgear and Heapstead winding engines, ambulance room, etc. Air locks where the ordinary air of the surface is kept separate from air which has travelled round the mine workings. At the pit bottom a new method is employed for supporting the roadways by means of steel arches and reinforced concrete. In some parts of the actual coal face compressed air driven coal-cutting machines are employed. A visit has been arranged to this pit, for an inspection underground, for a limited number only.

MESSRS. HENRY BRIGGS, SON & CO. LTD. WHITWOOD SILKSTONE PIT.

The new power house at this colliery contains two turbo alternators generating power at 3,300 volts, one a mixed-pressure unit and the other a high-pressure unit. There is also in the power house one of the latest 12-stage turbo air compressors. Simultaneous decking is in use in the large shaft, whereby a great saving of time and consequent increase in the capacity of the shaft is obtained. There are four main jigging screens which are fed by power-driven tipplers. The washery is used for washing medium-sized coal, and an Ariel flight is used for taking away the dirt rejected during the process of washing. Some idea of the magnitude of this colliery is given by the fact that its sidings aggregate about 40 miles.

YORKSHIRE COAL OWNERS' ASSOCIATION. WAKEFIELD RESCUE STATION.

From this station, which has its permanent staff with a resident superintendent, a rescue team complete with self-contained breathing apparatus can proceed to a colliery at a moment's notice. The apparatus for dealing with underground fires and for the actual rescue work after colliery explosions can be seen, and there are also model underground galleries representing a mine, which are used for training men in this dangerous work.

CITY OF LEEDS ELECTRICITY DEPARTMENT, KIRKSTALL POWER STATION.

The new Kirkstall Power Station of the Leeds Corporation is a 'selected' generating station under the auspices of the Central Electricity Board.

The ultimate capacity for which the station is designed is 200,000 kw., but at present only two units have been installed, each of 25,000 kw. The site is most favourably placed as regards fuel supply and the provision of ample cooling water and has exceptional rail and canal facilities.

Pulverised fuel is used, mainly for the following reasons :

(*a*) It enables a very cheap grade of fuel to be burnt.

(*b*) It confers a flexibility in steam generation almost equal to that obtainable with oil.

(*c*) It allows of the use of very large and efficient boiler units (15,000 kw. each).

(*d*) Combustion is so perfect that atmospheric pollution by carbon is impossible.

(*e*) The fact that the pulveriser plant is on a separate site of large area allows of the adoption of coal-treatment plant for the extraction of bye-products should this be found in the future to be desirable.

The boilers are of the Stirling type and work at a pressure of 475 lbs. per sq in. They are provided with superheaters giving a temperature of 750° F. The combustion chambers have water-cooled rear and side walls with a water-screen above the ash pit to cool the ash particles below fusing point before they settle. Economisers and regenerative air-pre-heaters are provided. Dust-extractors of the centrifugal type preserve the high standard of atmospheric purity obtaining in the locality.

The generating units are of 25,000 kw. each and run at 3,000 R.P.M. The high-pressure stages (16 in number) are of the impulse type and the lower pressure reactive. The low-pressure stages are arranged on the double-flow principle so as to secure axial balance.

The alternators generate at 11,000 volts, but some of the power is transformed to 6,600 volts for linking up with the older station at Whitehall Road, while a portion is raised to 132,000 volts in the adjacent Central Electricity Board Transformer Station.

Yorkshire Post : Works and Offices.

The following are the chief departments :

Telegraph Room—containing Murray-Multiplex machines on which five different news stories are received simultaneously over a single private wire from London.

Telephone Room—where telephonists take news stories direct from district correspondents on to the typewriter.

Sub-Editors' Office—where copy is received from the reporters and from the telephone and telegraph rooms by overhead automatic conveyors and arranged by the sub-editors in the form to appear in the paper.

Half-Tone Room—where blocks are made for reproduction of news pictures, cartoons, etc.

Case Room.—Here the news is set in type on 56 linotype machines, which are available for complete explanation and demonstration. There is also a Ludlow machine on which large display type headlines for news columns and advertisements are set. In this room galley proofs are taken of everything that is set, and when these have been checked by the readers any necessary corrections are made. The galleys of type, blocks for illustrations and advertisements are then assembled into the complete page forme.

Stereo Room.—An impression of each page forme is taken, and the resulting mould is used for casting the semi-cylindrical plates which are to be mounted on the rollers of the rotary presses. Plates are cast on the junior auto-plate machine and trimmed to uniform thickness on the auto-shaver. The plates are cast at such a speed that a special water supply is necessary for cooling them.

Machine Room.—The plates which have been sent down on a lift from the stereo room are assembled on the rollers of the rotary presses. The paper enters a machine from reels, and after passing between the rollers, where it receives the ink impression of all the pages, it emerges from the folders in the form of complete newspapers, folded and counted. From here the papers are sent to the Dispatch Department.

XIII.

BUCKINGHAM WORKS, YORK [1]

THE foundation of the firm long known as Troughton & Simms dates back to Newtonian times. The new investigations into natural laws then made gave great stimulus to the working scope of instrument makers. The first owner is thought to have been Thomas Wright, though he may have taken over the business from John Rowley, for whom he had made orreries (for demonstrating the motion of planets). He was succeeded by Benjamin Cole (1751–82), who manufactured instruments chiefly for navigation, some of which can be seen in the Science Museum, South Kensington. During Cole's period Edward and John Troughton, uncle and nephew, were in business as chamber masters employed principally in dividing and engraving for the trade. A second Edward Troughton, brother of John, and afterwards Fellow of the Royal Society, was apprenticed to his relatives, and in 1782 the two brothers took over the business of Cole. After the death of John, Edward Troughton remained proprietor till 1826, during which time the celebrated transit instrument was constructed for Pond, the Astronomer Royal. He also constructed the famous dividing engine now housed at the Science Museum. In 1826 the firm amalgamated with William Simms, senior, who carried on a

[1] Summarised from information supplied by Messrs. Cooke, Troughton & Simms, Ltd.

similar business in Aldersgate Street, London, and became established at 136–138 Fleet Street. During this partnership the historic 36-in. theodolite was constructed for the great Trigonometric Survey of India. The firm retained the name of Troughton & Simms through the partnerships which followed up to 1916, when it became incorporated. It is probable that the introduction of the micrometer microscope by Edward Troughton was the most important advance ever made in the scientific comparison of measures of length. The instrument, although of simple construction, was capable of determining differences of length of one ten-thousandth part of an inch. Troughton's 5-ft. scale also has become historical owing to its great accuracy.

Of Thomas Cooke, founder of the branch of the firm bearing his name, Samuel Smiles relates that as an amateur he made his first object glass out of the bottom of a thick glass tumbler. He began the manufacture of refracting telescopes in 1836 at York. About 1852 he commenced making turret clocks and effected many improvements in them. In 1855 Buckingham Works were established. In 1868–70 he constructed what was then by far the largest equatorial refractor in the world (25-in. aperture). This instrument, the Newall telescope, is still in regular use at Cambridge Observatory. Cooke early turned his attention to the design and manufacture of surveying instruments; the first important meridian instruments made by him were a pair of 5-ft. transits for the Trigonometric Survey of India.

The 'Cooke' photographic lens is known all over the world; his surveying instruments have played their part in connection with such engineering achievements as the Forth Bridge, the Assouan Dam, etc. Captain Scott located the South Pole with a Cooke theodolite. The Franklin-Adams star charts owe their excellence to the fact that they were taken by means of Cooke astro-photographic lenses on an equatorial mounting of the English type specially made by this company.

In 1922 a fusion was effected between these two old-established firms under the name of Cooke, Troughton, & Simms, Ltd., with works at York and at Charlton, London, S.E. 17.

Opportunities will be given to the members of the British Association to visit the works at York. All the optical work of the firm is done at the York factories, and a representative selection of the following optical glass work will be on exhibition: Mangin mirrors, heliograph mirrors, spherical mirrors, astronomical objectives, small telescope objectives, microscope objectives, various types of lenses and prisms. A general selection of surveying instruments will also be shown, including the 'Tavistock' double-reading theodolite, and a new transit instrument (under construction) for Greenwich Observatory.

XIV.

AGRICULTURE

INTRODUCTION

BY

JAMES STRACHAN, M.A., B.Sc.

THE aim of this chapter is to supply a few notes on the agriculture around York, which may be of use to members of the Association interested in agriculture.

York, as indicated in earlier chapters, is built on the great central plain of Yorkshire that lies between the uplands of the Wolds and the Hambleton Hills in the east, and the low slopes of a belt of Magnesian Limestone country in the west that runs almost north and south in a line west of Tadcaster. Behind, still further west, rise the shoulders of the Pennines. This great plain lies so low that the rise and fall of the tides of the sea are felt many miles inland along some of the great rivers that flow through its fertile acres, such as the Ouse, Aire, Don and Derwent. Drainage is often a problem, and in very wet seasons much of the land is liable to become water-logged or even flooded.

In character the soil is very variable. There are sands, clays, peats and warps, but the lighter types of soil predominate. In this region is grown the bulk of Yorkshire's potatoes, carrots, peas (for picking green) and sugar-beet. For the first three products a great market is at hand in the industrial area in the west, and for the sugar-beet there are factories at York and Selby.

Agriculture in the plains differs in some respects from that of the surrounding country. The contrast between its fertile fields and the wild moors of the Hambleton Hills is enormous. The rolling uplands of the Wolds in the east look pleasant enough with huge arable fields of corn, clover and turnips, but the shallow soil is generally not suited for sugar-beet—which is subsidised—nor for potatoes and carrots, which by their bulk are protected to some extent from foreign competition, the full force of which the products of the Wold farmer have had to meet. In the west of Yorkshire there is more grass land and more dairying. The farmer in the plains is usually primarily interested in his crops.

Marshall, in 1788, in his book *The Rural Economy of Yorkshire*, writes as follows :

> 'The Vale of York is various in fertility. The fens at its base and a heathy plain, part of the ancient forest of Galtres, north-eastward of the city of York, are drawbacks upon its productiveness. In a general view, however, it has not in this country its equal. The vales of Gloucester and Evesham are more fertile but less extensive.

The wide flat which lies between the hills of Surrey and Kent and the Downs of Sussex may vie with it in extent but not in general fertility. If we estimate the Vale of York by the number and copiousness of its rivers and by the richness of its marginal banks, it would perhaps be difficult in any country to equal it.'

THE SOILS OF THE VALE OF YORK

BY

H. T. JONES, M.Sc.

The whole of the Vale of York is covered by transported material, except for a few outcrops of Jurassic and Triassic rocks, and in some parts the depth of the drift exceeds 150 feet. The relations of the glaciation of this area, to which reference has been made in earlier sections, are therefore of first importance.

The Teesdale glacier terminated at the Wheldrake moraine, which sweeps in a crescent form from Stamford Bridge to Bolton Percy. On the retreat and subsequent advance of this glacier, another moraine was formed extending from Sand Hutton in the east to Healaugh in the west, and passing through York and the University Farm at Askham Bryan. The first moraine consists of a ridge of boulder-clay of a reddish colour and derived mainly from Triassic material; the other contains a large proportion of gravel consisting of Shap Granite, Bunter and Carboniferous Limestone. The melt-waters from the glacier were hemmed in on the east by the North Sea glacier covering Holderness and the mouth of the Humber; consequently a large lake was formed in the southern part of the Vale. The deposits of this lake are of such a depth as to obscure the Wheldrake moraine along portions of its length, especially in the neighbourhood of Escrick. The soil so formed shows enormous variation in texture, soil reaction and other characteristics. Within a very small compass, representatives of the lightest and the heaviest soils may be found. This variation is most pronounced in the district south of Escrick and in the neighbourhood of Everingham, and is naturally reflected in the cropping capacity of the soil.

The sandy soils (post-glacial sands), containing between 3 per cent. and 8 per cent. of the clay fraction and about 4 per cent. organic matter, are deficient in lime and require liberal manuring. They depend for their fertility on a fairly high water table, for their water-holding capacity is very low. With adequate manuring, they are suitable for potatoes, this being the most important crop in the Selby area. Sugar-beet, however, is to some extent displacing potatoes, but can be grown successfully only if the soil be limed.

The heavy soils (lacustrine clay) almost invariably contain a high percentage of calcium carbonate (about 10 per cent.). Owing to difficulties of cultivation only a relatively small proportion of the clay is under the plough, and the area under grass is increasing annually. On a few farms this material is used for marling the sandy sour soils, as much as 80 tons per acre being applied.

The warp area in the southern part of the country and along the banks of the Derwent, Ouse, and Humber contains perhaps the most fertile soil in Yorkshire. Except on the oldest warps, liming is not necessary, and with the new warp several good crops may be obtained without manuring. Along the banks of the Derwent and the Ouse, and especially of the Don, flooding causes serious damage periodically, the land being only 10 to 20 ft. above sea-level.

In the northern half of the Vale of York, boulder clay and glacial sand and gravels form the chief soils. The sandy soils are very deficient in lime, and until soil sourness is corrected, cropping is confined to oats, rye, and potatoes. When lime is applied, however, it is possible to grow good samples of barley of high malting quality. Good crops of sugar-beet also are possible under these conditions, but the area under this crop is comparatively small. In these soils, as in the sandy soils south of York, iron pans are common. These pans have developed under forest conditions and occur in hard layers 2 or 3 inches thick at a depth of a foot or 18 inches below the surface.

The boulder clay of this area is reddish-brown in colour, and although it contains material originating in Scotland and Cumberland, the biggest proportion is of Triassic origin, and has probably been churned up by the glacier from the solid rock beneath. This soil does not contain a very high percentage of the clay fraction, and is amenable to cultivation. It is also fairly well supplied with lime, and is therefore suitable for most crops.

The mechanical analysis table following illustrates the wide variation in physical composition shown by the soils in the Vale of York:

MECHANICAL ANALYSIS OF SOME SOILS IN THE VALE OF YORK (1928 METHOD).[1]

	1	2	3	4	5	6
Coarse sand	56·09	8·97	1·50	15·88	0·50	2·74
Fine sand	29·81	45·91	10·51	67·27	45·25	26·27
Silt	2·88	15·97	14·45	3·52	29·35	26·15
Clay	6·12	18·83	52·45	9·23	9·65	24·60
Moisture	0·76	2·19	4·51	1·17	2·55	2·66
Loss on ignition	3·09	6·22	10·40	1·79	11·01	10·84

Key to Soils.

1 = Glacial sand soil (Thirsk).
2 = Boulder clay soil (Thirsk).
3 = Boulder clay soil (Wheldrake).
4 = Post-Glacial sand (Wheldrake).
(Nos. 3 and 4 occur in adjacent fields.)
5 = New warp (artificial).
6 = Old natural warp.

1 "Introduction to the Scientific Study of the Soil," 2nd edition, p. 152 (N. M. Comber).

THE NORTH-EAST OF YORK

BY

D. H. FINDLAY, B.Sc.

To the north-east, the low-lying basin of the Vale of York is bounded by the low ridge of boulder clay already mentioned, which extends in a curve from York through Stamford Bridge and northwards towards Sheriff-Hutton and Brandsby. Beyond this ridge, in the north-east, runs the higher oolitic limestone ridge of the Howardian Hills. In this north-east sector there is an enormous variation in the soil, from lightest sand to heavy clay, and corresponding differences are found in the crops.

In the low-lying basin, nearest to York, the soil of which is mainly of lacustrine origin, the general average is a medium to light soil, comparatively easy to cultivate, but there is a wide divergence from the mean. Towards the north, the proportion of sand increases, and in the districts of Strensall, Sutton-on-Forest, Stillington and Raskelf there are areas of very light blowing sand which soon tend to become acid and under natural conditions revert to moorland. A serious problem in this basin is drainage, as much of it is at a low level. With the silting-up of its chief drainage stream—the river Foss, a tributary of the Ouse—a large area is becoming waterlogged.

On the glacial ridge mentioned above, which lies behind the basin, boulder clay predominates, but patches of glacial sand occur, and in the vicinity of Stamford Bridge it is not uncommon to find a light land crop such as rye or carrots in one field and a crop of wheat or beans in the next.

It cannot be said that the farming of the area is specialised in any particular direction. The market of York, with its proximity to the industrial West Riding, offers an outlet for a great variety of agricultural commodities. Of recent years, the York farmer has been provided with an additional string to his bow by the erection of a sugar-beet factory a few miles from the city. On the whole, mixed farming is the rule, there being few farms which have not a fair proportion of grass, and arable farming is combined with stock husbandry.

With such a wide variation in soil, it is not unexpected to find that practically all the common agricultural crops are represented. Of the cereals, oats and barley are widely grown, whilst wheat and rye are also common. Of the fallow crops, swedes, turnips and mangels are grown extensively for stock feeding, and considerable areas of potatoes and sugar-beet are grown for sale. The beet crop is scarcely so popular since the price was reduced, but there is still quite a large area. On the sandy soils occasional crops of carrots may be seen. Pulse crops are not grown extensively, but there are a few crops of beans and occasional crops of green peas. The ' seeds ' ley is usually for one year only, and in most cases is mown, two cuts often being obtained.

In regard to live stock, dairying, cattle-feeding and pig-keeping are the most important sections. Sheep are also kept, mainly as ' flying flocks,' but it is on the higher ground of the limestone hills and the Wolds that the sheep become of greater importance.

York is a consuming centre for liquid milk, and there is a number of dairy herds around the city. Pork butchers abound in York, and in many other Yorkshire towns, and so provide an outlet for large quantities of pig meat. It is unfortunate that a co-operative attempt to provide an outlet for bacon pigs at the Sherburn-in-Elmet Bacon Factory has met with comparative failure.

THE NORTHERN PORTION OF THE VALE OF YORK

BY

W. S. GIBSON, B.Sc.

North-west of York extends a portion of the Vale of York about 30 miles long and 10 miles broad, varying in altitude from 50 to 150 ft. above mean sea-level. In most of this area the soil is light and the boundaries are fairly clearly defined. Northallerton, the capital of the North Riding, stands midway along its northern edge, a belt of Magnesian Limestone, continuous except where eroded by such rivers as the Ure, lies along its western side, and the heather-clad Hambleton Hills rise steeply to form a boundary in the east. On these hills are pastured mountain sheep, usually of the Scotch Blackface and Swaledale breeds.

Beyond Northallerton lies a belt of heavy boulder clay, cold, wet, and difficult to work. Much of it is at present under permanent grass, which responds well to phosphatic manuring, but if neglected, rapidly grows thorns and soon deteriorates.

The limestone on the western edge is quarried at intervals and burnt for agricultural and other purposes. It is therefore interesting to record that the Lower as well as the Upper Magnesian Limestone occurs near the soil surface. The latter produces when burnt a quicklime containing less than 5 per cent. of magnesia, but the magnesia content of the former may be as high as 40 per cent., and must be used with caution on certain classes of soil. The soils overlying these limestones vary in depth, but the farms have a large proportion of arable land. The thinner soil is ' barley and sheep land,' and is farmed on a four or five course rotation, the sheep often being grazed in summer on special one-year leys, consisting almost entirely of clovers, and folded in winter on roots. Clover sickness and ' finger and toe ' are troublesome, and the soil requires a periodic liming despite its origin. On the deeper soils potatoes are an important crop that combine good yield and quality. West of this limestone belt lie the foothills of the Pennines.

The northern portion of the Vale of York is drained by the river Swale, which is joined by the Ure to form the Ouse. The Ouse is later met by the Nidd. Of these rivers, the Swale in particular is liable to rise rapidly after rain in the uplands, and when a rapid rise is accompanied by a south-east wind serious flooding occurs. The Swale is embanked throughout its length in the Vale, and on account of the low level of the surrounding land, there is little fall over wide areas for the field drains. These rivers have left extensive deposits of alluvium in the past, and much of this land is under permanent pasture which will fatten cattle, but wet seasons are very troublesome.

In some areas, e.g. Sessay district, there is rye and potato land of a very hungry type, deficient in lime and organic matter, but, if lime is applied, the quantity must be regulated with care, as excess, besides encouraging common scab in potatoes, may so accelerate the breakdown of organic matter as to cause a deficiency. In fact, there is a danger that over-liming may lead to the ground becoming waste land, carrying perhaps only a few silver birch saplings.

The sands near Thirsk which overlie clay do not drought badly and are very productive when well managed. In this district some farms have recently had as much as 60 per cent. of their total acreage under root crops, including carrots and sugar-beet. Rotations here, as in other parts of the Vale, are not followed closely, but of late there has been a tendency to introduce three-year leys in order that the following potato crop should require less farmyard manure, since for economic reasons fewer cattle are now purchased for feeding than formerly. On one farm in this area the rotation is potatoes, sugar-beet, barley, three years ley. Large quantities of fertilisers are used on this land and shoddy is much esteemed. Liming is carried out systematically, and more particularly since sugar-beet has come into prominence.

Cattle are reared to some extent on most farms throughout the district, and large numbers of cattle are bought in for feeding throughout the year. Many are brought from Cumberland and Westmorland, from other cattle-rearing districts of Yorkshire, and from Ireland. The majority are of the Shorthorn type. Dairying is not a main feature.

Of the pure breeds of sheep the most important is the Wensleydale, which is crossed with the Swaledale or Scotch Blackface to produce the Masham. The Masham is often crossed again with the Wensleydale ram to produce the 'twice-crossed' sheep much used for folding on roots. Many half-breds (Border Leicester × Cheviot) are also bought in from the North, and both these and the Mashams are often crossed with a Down ram for the production of early lamb, Suffolks and Oxfords being principally used as tups for this purpose.

Pigs also are to be found on most farms, the majority being Large Whites and their crosses. A local blue and white breed, sometimes known as the Durham breed, still survives, principally on the northern and eastern boundaries of the area. Poultry are kept extensively, Thirsk being one of the principal markets in the North of England for poultry produce.

The whole area is predominantly agricultural and there are no large towns. Much produce goes northwards to the Teeside industrial area and the bulk of the remainder to the manufacturing towns of the West Riding. The local market towns serve as clearing centres for this purpose and include Northallerton, Bedale, Thirsk, Ripon, Boroughbridge and Easingwold.

THE SOUTHERN PORTION OF THE VALE OF YORK

BY

W. E. GELLING, B.Sc.

Bounded on the north by the terminal moraine from Stamford Bridge to Tadcaster, on the west by the Magnesian Limestone series, and on the south by an intermittent series of chalk and limestone, lies the most fertile area in the county, probably second only to the East Midland counties in England.

Transport is facilitated by the number of navigable rivers and uniting canals. The Ouse, Derwent, Wharfe, Aire flow over this highly cultivated area of low-lying mead and ploughland. Each of these rivers is tidal many miles from its mouth. Boats from the Humber, sailing up the Ouse to York, pass by Goole and Selby, two towns that have developed into important marketing and distributing centres for the disposal of the produce of this productive area.

The soil varies from heavy clay to sand so light that it can be blown by the wind into heaps in sheltered spots, but for the most part it is light in texture and very permeable to water, but resists drought fairly satisfactorily owing to a high water table. Much of the land is liable to be waterlogged in a very wet season, and in the past two years a great deal of damage has been caused by flooding. The absence of walls and hedges and the scarcity of fences indicate that stock-raising is of secondary importance.

Adjoining the Ouse, the banks of which are on the average about 8 ft. above soil level, is an exceedingly fertile area of warp known locally as 'Ings Land.' It has been drained by the banking of the Ouse, into which water is pumped during excessive rainfall. An extensive area of warp occurs south of Howden and around Goole. Much of it is 'natural' warp, so called because it has been laid down without man's intervention, but there is some 'artificial' warp, particularly south of Staddlethorpe, which has been built up bit by bit through controlling, by means of sluices or lock-gates, the entry and exit of tidal waters charged with silt on to the area to be warped. The land must of course lie below high-water level. A bank is raised round the area selected, which must not be too big for the warping drain, as the speed with which the water is run on and off has an important effect on the texture of the warp. After warping, full crops may often be obtained for ten years and over without the addition of any manure whatsoever. This fact gives some idea of the fertility of virgin warp.

There is a wide gulf between these rich new soils and some of the poor hungry sands met with in other parts of the Vale, which are naturally deficient in plant food, humus and lime, all of which are abundant in the virgin warp.

It has been claimed that all kinds of crops are to be found in the area except hops, and that even hops were grown at one time. The neighbourhood of Selby is noted for its excellent potato land. Maincrop varieties are chiefly grown. Ten tons per acre is quite a common yield. With earlies, there is some danger of damage from late spring frosts. For marketing, the tubers are classified according to variety and the class of soil on which they are grown—limestone, sand, warp. In certain fields, in recent years, potato eelworm (*Hederodera Schachtii*) has become a scourge.

Peas for pulling green in pod are grown on a large scale, and upwards of three hundred bags, forty pounds in weight, have been pulled per acre, but the crop is a great gamble, both as regards yield and price. There is a small acreage of peas for canning, which has been slightly increased in recent years owing to the opening of a small canning factory at Hambleton.

Carrots is an important crop, particularly in the Pocklington and Market Weighton areas, and, grown in rows 14 in. apart, as many as twenty-eight tons of roots per acre have been weighed off the land.

Through the erection at York and Selby of two sugar-beet factories, sugar-beet now occupies an extensive acreage, but owing to climatic factors there appears to be only a limited scope for remunerative increased yields in response to the parental attention offered in its cultivation. Sugar-beet has been introduced largely at the expense of swedes and mangels, which for feeding purposes have been replaced by sugar-beet pulp.

Flax growing has been subject to many vicissitudes and is at a standstill once again. Good-bodied soils suit this plant best, and, manured without the inclusion of quick-acting nitrogenous manures (which are said to reduce the quality of the fibre) two tons per acre of flax straw may be regarded as a moderate yield. Mustard is grown for seed fairly extensively on the warp areas near Howden and Goole, where good quality is obtained. The seed is used largely for making the well-known condiment.

Of the cereals, wheat is confined principally to the heavier soils and warps, but not entirely, for 'Little Joss' is to be found on the sandy areas where rye predominates. Winter oats, both black and white, take a fair share of the cereal area, but only a small amount of barley is grown. Autumn-sown cereals are becoming increasingly popular as they tend to check certain weeds that are troublesome and they can be harvested earlier than spring corn. Greater opportunity is thus given for autumn cultivation.

No fixed rotation is followed. A one-year 'seeds' mixture is introduced very often primarily with the object of benefiting the potato crop that is generally taken after it. Odd acres of lucerne are found, but usually the small yields obtained restrict its popularity.

The smaller villages near the Ouse, such as Naburn, Cawood, Hemingbrough and Howden, are noted for their market-garden crops, particularly celery, broccoli and beetroot. In the bend of the Ouse in its western bank just north of Selby is some of the richest land in Yorkshire, known as Wistow Lordship. Here are to be found bulb-fields of daffodils, narcissi and tulips. At Crocky Hill, near York, hard and soft fruits are extensively grown, and some good fruit is also produced in Church Fenton and district. At Osgoby, near Selby, is situated the county Demonstration Fruit Centre. Howden is the best locality for glass-house plants, tomatoes being a speciality.

The farmer concentrates on the output of the arable land over this area as a whole. Very few cattle are fattened on grass in summer. There is little dairying, and stock rearing is of minor importance, but a large number of cattle, chiefly Irish, are fattened in the fold-yards in winter, in order to supply manure for maintaining the humus content and the fertility of the land. Little or no straw is sold off the farms. Large numbers of sheep, principally cross Down hogs, are folded on the beet tops and swedes where grown to consolidate the lighter land and to manure it, and pigs and poultry find a place on most farms.

XV.

THE FIRST MEETING OF THE BRITISH ASSOCIATION, YORK, 1831

BY

O. J. R. HOWARTH, Ph.D.

When David Brewster, in 1831, made the first concrete proposal for the foundation of a ' British Association of Men of Science,' and for calling a meeting of the ' cultivators of science ' for that purpose, he addressed it to John Phillips, the Secretary of the Yorkshire Philosophical Society, on the grounds that York was centrally situated for a general meeting such as was contemplated, and that the society already established there was flourishing and well managed. He himself, and others who, under his inspiration, took active part in the foundation of the Association, lived and worked in Edinburgh, but that was obviously not a geographical centre from which to launch a British national scheme. Nor, for that matter, was London ; moreover, it was desired to avoid the appearance of invading the ground occupied by the major learned societies whose headquarters were in the capital. Therefore Brewster chose York, and he chose well.

The origin of the Yorkshire Philosophical Society in 1821 is traced to the scientific examination of the bones of various extinct animals which were recovered from the floor of Kirkdale Cave, near Kirkby Moorside, beneath the hills of the North Riding. A number of these specimens came into the hands of James Atkinson (1759–1839), an eminent surgeon of York, and certain fellow-citizens of his, who took action to ensure that they should form the nucleus of a Yorkshire museum of natural history and antiquities. The Yorkshire Philosophical Society was brought into existence to maintain the museum, and received from the Crown a grant of land in York which had been part of the site of a palace built by James I. Here the museum still stands, adjacent to some of the famous Roman fortifications of the city, and the beautiful ruins of the Abbey of St. Mary.

In 1831 it was thus described: 'The collections of natural history are distributed in five apartments, the three largest of which are arranged round the lecture-room and lighted from above. In one of these are the cabinets of minerals, in another a suite of 12,000 geological specimens disposed in the order of the strata, and the third contains collections in the various departments of zoology. The lecture-room affords seats for 300 persons.' Roman and other antiquities were also exhibited, and there were a library and a laboratory.

The creation of an institution of this nature in ten years was evidence of successful organisation, and the Council of the Society, in acting upon Brewster's proposal, did so promptly and efficiently. And enthusiasm for science in Yorkshire was not confined to its capital, for when the Committee of Management set to work to circularise all the scientific institutions known to them concerning the proposed meeting, they discovered thirteen in London and twenty-six in the rest of the country, of which nine were in Yorkshire—a laudable proportion.

Here, then, in the premises of the Yorkshire Philosophical Society, the British Association was brought to birth on September 26, 1831, and continued its meetings on following days. More than that, it annexed the existing officers of the Society as its own. The first President of the Association was the President of the Society, Viscount Milton, afterwards third Earl Fitzwilliam. The first Vice-President, William Vernon Harcourt, the treasurer, Jonathan Gray, the secretaries, John Phillips and William Gray,[1] held those offices respectively in the Yorkshire Society. To two of them, Harcourt and Phillips, our grateful remembrances are especially due to-day.

William Vernon, born in 1789, was a son of the then Archbishop of York. The family assumed the name of Harcourt when the archbishop succeeded to the famous Harcourt estate of Nuneham, near Oxford. William Vernon Harcourt was destined for the navy, and served as a midshipman, but left the service to take holy orders, and became a Canon of York in 1824. He was also a man of high scientific attainments at a period when these were still a not uncommon accompaniment of distinction in the Church. He was initiated into the study of chemistry by Isaac Milner, Dean of Carlisle, who also was successively Professor of Chemistry and of Mathematics in the University of Oxford. Harcourt was intimate with Wollaston and Humphrey Davy, and imbibed an interest in geology from Buckland. He maintained his own chemical laboratory, and carried out researches in such subjects as the long-continued action of heat on minerals, and the refractive power of variously compounded glasses. To his scientific accomplishments there was added administrative ability of no mean order. He took a leading part in the working of various important philanthropical institutions in York; and as for the British Association, he was from the first its chief organiser and law-giver. He subsequently was one of its honorary general secretaries for several years, and its President in 1839. It was Harcourt who at the first meeting of the Association in York took the lead in formulating the objects of the

[1] These two held the office corresponding to the present local secretaryship; Phillips was subsequently appointed Secretary of the Association.

Association, laying down rules for its guidance, and assembling its mechanism, and the speech in which he did so is a masterpiece in its appreciation of the then position and the future of science, as well as in the grasp it revealed of the organisation of the Association, which remains to-day fundamentally as Harcourt conceived it. The objects of the Association, as now stated in its first statute, are in Harcourt's own words: 'to give a stronger impulse and a more systematic direction to scientific enquiry; to promote the intercourse of those who cultivate science in different parts of the British Empire with one another and with foreign philosophers.' Perhaps the use of the comparative degree in the opening phrase would not have been adopted to-day; perhaps the term 'philosophers' would not (the more is the pity) have been used as synonymous with men of science; but essentially Harcourt's statement of objects is that which the Association has pursued, unvaried, for a century.

John Phillips came to York as an orphan boy with his uncle William Smith, a land agent and the founder of English stratigraphical geology. In Phillips the love of science was born of a scientific environment. He helped Smith to hang his maps and diagrams when lecturing in York, and he thus came under the influence of Harcourt and other members of the Yorkshire Philosophical Society. In 1826 he was appointed keeper of the Society's museum, and he arranged collections and lectured in other local museums such as Scarborough. In later years he was Professor of Geology in King's College, London, and subsequently in the University of Oxford, succeeding to the chair which had been Buckland's. His services to the Association culminated in his Presidency in 1865.

At the Jubilee meeting of the Association in York in 1881 Archdeacon Hey gave a paper on the foundation in 1831, and his reference to the family of Gray may be appropriately quoted here. 'Our notice of the York Founders of the British Association would be incomplete without reference to one who was associated with Professor Phillips as one of its secretaries at the first York meeting, and held the office of treasurer to the Yorkshire Philosophical Society up to the time of his death. William Gray was the only son of Jonathan Gray, first treasurer of the British Association, an Alderman of York, much respected for his personal character, and perhaps slightly dreaded for the pungency of his wit. He was the grandson of William Gray, a man whose name deserves to be held in remembrance as the earnest and munificent promoter of every good work, the friend of William Wilberforce, the firm ally of that little band which broke down the cruel system prevailing in our lunatic asylums; one of the first founders of and workers in our Sunday schools. He outlived his son Jonathan, and died in 1845 in his ninety-fifth year. William Gray the younger was a man who through life was engaged in active professional duties. For some years he was a member of the Corporation, and served the office of Lord Mayor. Through life he was a lover of science and a cultivator of literature.'

To Phillips fell the honour of delivering the first lecture to the Association; during the opening evening he addressed the audience extempore upon the geology of Yorkshire, and exhibited specimens. From this until the closing day, the following Saturday, some twenty-six scientific papers were read to the meeting, and generally appear, in the phrase of a contemporary newspaper account, to have 'elicited much interesting conversation.' Not unnaturally their subjects depended largely upon the chance of individual men of science attending the meeting and coming prepared with something to say; but the classification of subjects is not without interest. Six of the communications were on geology and mineralogy, five on magnetism and electricity, four on optics, three on light and lighting, three were physiological, two meteorological, two chemical, one astronomical. Zoology and botany were notably unrepresented, while the other fields of science which have since come within the purview of sections of the Association were as yet explored by few, if any, inquirers.

On the Tuesday evening there was a dinner in the York Tavern, which began at five o'clock, an hour mercifully out of fashion now. There was a long list of toasts, mostly of distinguished members present and the institutions represented by them; and it is recorded that the toasts of Lord Milton and Harcourt, and the Council of the Yorkshire Philosophical Society were 'drunk with three times three.' It is a point of some significance that there was a general toast of provincial scientific societies, and also one of mechanics' institutes, for these exemplify the far-sighted views of the founders of the Association. They were aiming at co-operation with local scientific institutions, and that co-operation was in future years to be achieved, through the establishment of the system of corresponding societies, and that of public lectures given during the annual meetings, which in accordance with the spirit of the Victorian era were initiated in 1867 as 'lectures to the operative classes.' Later in the week the members were entertained to a 'grand concert,' and also were hospitably received by the Archbishop of York.

It was, therefore, no matter for wonder that at the conclusion of the meeting, Murchison, the President of the Geological Society and one of those, outside York, most active in the establishment of the Association, said that to the city of York, 'as the cradle of the Association, they should ever look back with gratitude; and whether they met thereafter on the banks of the Isis, the Cam, or the Forth, to this spot, to this beautiful building, they would still fondly revert, and hail with delight the period at which in their gyration they should return to this, the point of their first attraction.' He moved 'that the cultivators of science here assembled do return their most grateful thanks to His Grace the Archbishop of York, the Patron, and to the Officers and Members of the Yorkshire Philosophical Society, for the very liberal manner in which, by the use of their Halls and Museum, and by their obliging and unwearied efforts to provide every accommodation and comfort to the visitors, they so essentially contributed to the success and prosperity of this Association.' The motion was seconded by Brewster and supported by Dalton, and may fitly be echoed at the 100th meeting of the Association.[1]

[1] The Annual Meetings were intermitted during two years of the Great War.

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References to addresses, reports, and papers printed in extended form are given in italics.

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