BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

REPORT

OF THE

ANNUAL MEETING, 1935

(105TH YEAR)

NORWICH

SEPTEMBER 4–11

LONDON

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

1935

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OFFICERS & COUNCIL, 1935-36.

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Local Secretary.—F. Leney.

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
—	—	—	1110*	—	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	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
1933, Sept. 6	Leicester	Sir F. Gowland Hopkins, Pres. R.S. ...	185	37
1934, Sept. 5	Aberdeen	Sir James H. Jeans, F.R.S.[14]	199	21
1935, Sept. 4	Norwich	Prof. W. W. Watts, F.R.S...............	191	11

[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.
[6] Including grants from the Caird Fund in this and subsequent years.
[7] Including Foreign Guests, Exhibitioners, and others.

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 / Complimentary[7]	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	722 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	2193 2 1	1929
68	310	1617	97	267	54	2639	2481 15 0	631 1 9	1930
78	656	2994	157	454	449	5702[12]	4792 10 0	1319 9 6	1931
44	226	1163	45	214	125	2024	1724 5 0	1218 13 11	1932
39	236	1468	82	147	74	2268	2428 2 0	562 19 11[13]	1933
30	273	1884	181	280	70	2938	2900 13 6	1423 4 9	1934
29	237	1444	142	197	70	2321	2218 14 6	1649 2 4	1935

[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.
[13] For nine months ending March 31, 1933.
[14] Sir William B. Hardy, F.R.S., who became President on January 1, 1934, died on January 23.

NARRATIVE OF THE NORWICH MEETING.

On Wednesday, September 4, at 8.30 P.M., the Inaugural General Meeting was held in the Agricultural Hall, when the Rt. Worshipful the Lord Mayor of Norwich (Mr. P. W. Jewson, J.P.) welcomed the Association to Norwich. The President of the Association, Prof. W. W. Watts, F.R.S., delivered an address (for which see p. 1) entitled *Form, Drift, and Rhythm of the Continents.*

On Friday, September 6, in the Assembly Room of the Agricultural Hall, at 8.15 P.M., Dr. S. J. Davies delivered an Evening Discourse entitled *Diesel Engines in relation to Coastwise Shipping* (p. 487).

On Tuesday, September 10, in the same room, Dr. C. S. Myers, F.R.S., delivered an Evening Discourse on *The Help of Psychology in the Choice of a Career* (p. 487).

A public lecture was given by Sir Arnold Wilson, M.P., on *Science and Population Problems*, in the Prince's Street Lecture Hall, on Monday, September 9, at 8 P.M.

A children's lecture was given by Prof. W. Garstang on *The Songs of Birds*, in the Haymarket Picture House, on Thursday, September 5, at 11.15 A.M.

External public lectures were given as follows:

Cromer, Lecture Hall, Monday, September 9, at 8 P.M. *Weather Forecasting.*—Mr. A. Corless.

Fakenham, Electric Pavilion, Friday, September 6, at 8 P.M. *Recent Changes in British Agriculture.*—Dr. B. A. Keen, F.R.S.

Great Yarmouth, Town Hall, Friday, September 6, at 8 P.M. *The Unknown North Sea.*—Mr. Michael Graham.

King's Lynn, St. James' Boys' School Hall, London Road, Friday, September 6, at 8 P.M. *Splashes, and what they teach.*—Prof. A. Ferguson.

Lowestoft, Town Hall, Monday, September 9, at 8 P.M. *Splashes, and what they teach.*—Prof. A. Ferguson.

Thetford, Guildhall, Friday, September 6, at 8 P.M. *Scientific Basis of the Gem-cutter's Art.*—Prof. W. T. Gordon.

A summary of Sectional Transactions on September 5, 6, 9, 10, and 11 will be found on pp. 346–473.

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The Lord Mayor and Lady Mayoress of Norwich (Mr. and Mrs. P. W. Jewson) entertained members of the Association at a Reception in the Castle Museum on Thursday evening, September 5.

H.M. Lieutenant for Norfolk (Mr. Russell J. Colman, J.P.) and Mrs. Colman entertained members of the Association at a garden party at Crown Point on Tuesday, September 10.

Garden parties were also given by the Rt. Rev. the Lord Bishop of Norwich at the Palace, and the Misses Colman at Carrow Abbey.

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A special service was held at the Cathedral on Sunday morning, September 8, when officers and other members accompanied the Lord Mayor, the Sheriff, and Corporation of Norwich in state. The preacher was the Rt. Rev. Bertram Pollock, K.C.V.O., D.D., Lord Bishop of Norwich. Special services were also held in other places of worship.

The Very Rev. D. H. S. Cranage, Litt.D., Dean of Norwich, conducted parties of members around the Cathedral and narrated its history on several occasions during the Meeting.

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On Saturday, September 7, general excursions were arranged to the Broads (day and afternoon visits), to Thetford and Castle Acre, to the coast and Walsingham Priory, and to King's Lynn and Sandringham. At Sandringham tea was provided by gracious command of H.M. The King. Among other excursions and visits, those devoted to the interests of special Sections during the Meeting are mentioned among the Sectional Transactions in later pages.

* * * * * *

At the final meeting of the General Committee, on Wednesday, September 11, it was resolved:

That the British Association places on record its warm thanks for the reception afforded to it by the City of Norwich. The generous co-operation of the Lord Mayor and the City Council, and the thorough preparations made by the local officers and committees, have been deeply appreciated. The Association has also to extend most cordial thanks to the scientific, educational, commercial, and industrial institutions in Norwich and the neighbourhood, for the accommodation and facilities so generously provided for meetings, excursions, and visits, and to the citizens of Norwich for their most generous interest and hospitality.

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On Wednesday, September 11, the President and General Officers, Members of the Council, and Presidents of Sections entertained the principal local officers at luncheon.

Geological Excursion preceding the Meeting.

This excursion took place from August 31 to September 4 under the leadership of Prof. P. G. H. Boswell, F.R.S., and Dr. J. D. Solomon. The following features were viewed on September 1 and succeeding days: Coast sections from Happisburgh, Mundesley, Overstrand, to Cromer (Pliocene and Glacial)—Coast sections from East Runton and West Runton to Sheringham, and inland on to Cromer Ridge (Pliocene and Glacial)—Coast sections at Weybourne; inland sections on Cromer moraine at Kelling and Holt; Blakeney esker; Morston raised beach; Hunstanton Boulder Clay at Holkham—Cromer to Norwich by way of Cawston, Heydon, etc.; various glacial deposits.

REPORT OF THE COUNCIL, 1934–35.

JUBILEE OF H.M. THE KING.

I.—The following Address was forwarded to His Majesty The King on the occasion of his Jubilee:—

To the King's Most Excellent Majesty.

May it please Your Majesty :

We the Council of the British Association for the Advancement of Science humbly offer our loyal congratulations on the occasion of the celebration of Your Majesty's Jubilee.

The British Association enjoys the high privilege of carrying on its work under Your Majesty's Patronage. Its most valued possession is the Royal Charter which Your Majesty was graciously pleased to confer upon it; its most cherished memory that of the encouragement given to its labours by four generations of Your Royal Family.

The Council pray that the inspiration of Your Majesty's favour may be long vouchsafed to the Association, which will not cease from its endeavours to promote the welfare of Your Majesty's peoples.

The following acknowledgment was received by the President:—

SIR,—I have been commanded by The King to convey to you His Majesty's thanks for the loyal Address of Congratulation from the Council of the British Association for the Advancement of Science on the completion of the Twenty-fifth Year of His Majesty's Reign and to assure you that His Majesty deeply appreciates the sentiments of loyalty and affection to which it gives expression.

I am, Sir,
Your obedient Servant,
JOHN GILMOUR.

OBITUARY.

II.—The Council during the year under review have had to deplore the loss by death of four past Presidents of the Association, namely, Sir Edward Sharpey-Schafer, F.R.S. (President, 1912; General Secretary, 1895–1900); Sir Arthur Schuster, F.R.S. (1915); Sir Horace Lamb, F.R.S. (1925); Sir Alfred Ewing, K.C.B., F.R.S. (1932).

The Association was represented at the funeral of Sir Edward Sharpey-Schafer by Sir T. Hudson Beare (on behalf of Sir Thomas Holland, K.C.S.I., K.C.I.E., F.R.S.); at that of Sir Arthur Schuster by Sir James Jeans, F.R.S.; at that of Sir Horace Lamb by Sir Joseph Thomson, F.R.S., and Lord Rutherford, F.R.S.; and at that of Sir Alfred Ewing by Prof. W. W. Watts, F.R.S., and Prof. F. J. M. Stratton.

The Association has also suffered the loss of the following office-bearers and supporters:—

Sir John Adams
Prof. H. B. Baker, F.R.S.
Sir Robert Blair
Dr. A. Bramley
Dr. R. W. Brock
Prof. E. Cannan
Mr. C. Carus-Wilson
Mr. Geoffrey R. R. Colman
Miss E. R. Conway
Mr. J. T. Cunningham
Prof. O. V. Darbishire
Dr. Shepherd Dawson
Dr. F. A. Dixey, F.R.S.
Mr. G. Fletcher
Dr. Michael Grabham
Prof. W. L. Grant
Lady Keith
Prof. H. M. Macdonald, F.R.S.
Prof. J. J. R. Macleod, F.R.S.
Prof. R. A. Robertson
Dr. R. F. Scharff
Prof. W. de Sitter
Mr. C. E. Stromeyer
Dr. H. H. Thomas, F.R.S.
Prof. Arthur Thomson
Prof. H. de Vries
Prof. Sir James Walker, F.R.S.
Prof. J. A. Wilkinson

At the funeral of Prof. H. M. Macdonald, F.R.S., the Association was represented by Lt.-Col. E. W. Watt (his fellow local secretary for the Aberdeen Meeting last year) and Dr. J. F. Tocher.

Representation.

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

Royal Scottish Geographical Society, 50th Anniversary	Prof. R. N. Rudmose Brown.
Nottingham: Memorial Service for Principal Stewart, of the University College .	Prof. H. S. Holden.
American Association for the Advancement of Science, Pittsburgh Meeting .	Prof. Hugh Taylor, F.R.S.
International Botanical Congress, Amsterdam	Mr. F. T. Brooks, F.R.S., Dr. A. B. Rendle, F.R.S., Sir John Russell, F.R.S., Prof. A. C. Seward, F.R.S.
Muséum National d'Histoire Naturelle, Paris, Third Centenary	Mr. J. Ramsbottom.
Opening of Geological Museum, South Kensington, and Centenary of Geological Survey	Prof. W. W. Watts, F.R.S., President.
Deputation to Air Ministry on protection of Chesil Bank, etc.	Prof. W. W. Watts, F.R.S., and Prof. P. G. H. Boswell, F.R.S.

Resolutions and Recommendations.

IV.—Resolutions and recommendations referred by the General Committee to the Council for consideration and, if desirable, for action, were dealt with as follows. The resolutions will be found in the Report for 1934, p. xlviii.

(*a*) A further resolution concerning Inland Water Survey, from Sections A (Mathematical and Physical Sciences), C (Geology), E (Geography), and G (Engineering), together with a resolution from Section C concerning the compulsory registration of wells, borings, and excavations, were before the Council. It was ascertained that the Institution of Civil Engineers was prepared to co-operate in respect of the first of these resolutions; but before action was taken the Minister of Health announced the intention of H.M. Government to appoint a committee on Inland Water Survey, as had been urged by a deputation representing the Association and the Institution (Report, 1934, p. xxix). On the appointment of this committee, the Council expressed their satisfaction to the Minister, and transmitted to him, for communication to the committee, the resolution on compulsory registration of wells, etc., referred to above, and also a memorandum by the Association's committee on Inland Water Survey, concerning the objects of such survey.

(*b*) The Council enquired into the absence of provision for the free importation of films for the teaching of science in universities, etc. Information was received from the British Film Institute that an international convention was expected to be concluded during 1935, and to cover such cases as the example brought before the Council. Further information is awaited. (Resolution of Section D, Zoology.)

(*c*) The Council brought to the notice of the Lord President of the Council and the Minister of Agriculture the desirability of accelerating the revision of large-scale maps of the Ordnance Survey. It was learned that the Chartered Surveyors' Institution was taking similar action, and that institution was kept informed of the Council's action. It was understood that the matter was receiving the attention of the Minister and of H.M. Government. (Resolution of Section E, Geography, supported by other sections.)

(*d*) The Council brought to the notice of the Board of Education and the Scottish Education Department the desirability of continuing the production of the Atlas of Geographical Types of the British Isles. (Resolution of Section E, Geography.)

(*e*) The Council brought to the notice of the Board of Education and the Scottish Education Department the need for instruction in schools concerning the preservation of amenities, etc. (Resolution of Section K, Botany.)

Finance.

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

VI.—The Association has received a legacy of £500 under the will of the late Sir Alfred Ewing, K.C.B., F.R.S., past President. The Council have postponed consideration of the disposal of this legacy, in view of the impending changes in general officerships, and they ask the sanction of the General Committee to deal with this matter during the ensuing session.

VII. *Grants.*—The Council made the following grants from funds under their control :—

From the Caird Fund.

	£
Committee on Seismology	100
,, ,, Plymouth Table	50
,, ,, Zoological Record	50
,, ,, Naples Table	50

From the Bernard Hobson Fund.

Such part as the income allows of a contingent grant of £40 to the Committee on Critical Geological Sections, and of a grant of £30 to the Committee on Thermal Conductivity of Rocks.

From the Leicester and Leicestershire Fund.

Committee on Routine Manual Factor in Mechanical Ability . . £30

From General Funds (by authority of the General Committee).

Committee on Mathematical Tables (additional grant) . . . £50

VIII. *Guarantees.*—Grants by way of guarantee have been made (i) of £50 toward the expense of publishing two sheets of the Land Utilisation Survey map for East Anglia, it being understood that a contribution would be forthcoming also from the local committee for the Norwich Meeting, and that the sheets would be ready before the meeting ; (ii) of £25 toward the publication of a book on the antiquities of Macedonia by Mr. W. A. Heurtley.

The Council approved in principle a proposal for the establishment of a 'revolving' fund from which guarantees such as the above might be made.

IX.—An anonymous donation of £50 was received for the purpose of erecting an inscription, which it did not appear to be within the power of the Association to carry out. Attempts to get into touch with the donor have been unsuccessful.

President (1936), General Officers, Council and Committees.

X.—The Council's nomination to the Presidency of the Association for the year 1936 (Blackpool Meeting) is Sir Josiah C. Stamp, G.C.B., G.B.E.

XI.—The Council have learned with great regret that Prof. F. J. M. Stratton is unable to offer himself for re-election as a General Secretary.

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

General Treasurer, Prof. P. G. H. Boswell, F.R.S.

General Secretaries, Mr. F. T. Brooks, F.R.S., Prof. Allan Ferguson.

XII. *Council.*—The retiring Ordinary Members of the Council are: Sir James Henderson, Sir P. Chalmers Mitchell, F.R.S., Dr. N. V. Sidgwick, F.R.S., Sir G. C. Simpson, K.C.B., F.R.S., Mr. H. T. Tizard, C.B., F.R.S.

The Council have nominated as new members Prof. W. G. Fearnsides, F.R.S., Prof. R. Robinson, F.R.S., Sir Gilbert Walker, F.R.S. ; leaving two vacancies to be filled by the General Committee without nomination by the Council.

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

Prof. F. Aveling
Sir T. Hudson Beare
Prof. R. N. Rudmose Brown
Prof. F. Balfour Browne
Dr. W. T. Calman, F.R.S.
Sir Henry Dale, C.B.E., Sec. R.S.
Prof. J. Drever
Prof. W. G. Fearnsides, F.R.S.
Prof. A. Ferguson [1]
Prof. R. B. Forrester
Prof. W. T. Gordon
Prof. Dame Helen Gwynne-Vaughan, G.B.E.
Mr. H. M. Hallsworth, C.B.E.
Dr. H. S. Harrison
Prof. A. V. Hill, F.R.S.
Prof. G. W. O. Howe
Dr. C. W. Kimmins
Prof. R. Robinson, F.R.S.
Prof. A. M. Tyndall, F.R.S.
Dr. W. W. Vaughan
Dr. J. A. Venn
Sir Gilbert Walker, F.R.S.
Prof. F. E. Weiss, F.R.S.

XIII. *Assistant Secretary.*—Mr. D. N. Lowe has been appointed Assistant Secretary of the Association in the room of Mr. H. Wooldridge, who resigned on accepting another appointment.

XIV. *General Committee.*—The following have been admitted as members of the General Committee, on the nomination of the Organising Sectional Committees under Regulation 1 :—

Dr. J. R. Airey
Mr. T. C. Angus
Mr. J. N. L. Baker
Prof. B. T. P. Barker
Mr. C. O. Bartrum
Miss E. F. Bellamy
Prof. M. E. Bickersteth
Mr. E. G. Bilham
Mr. H. Binns
Dr. G. Bond
Prof. W. L. Bragg, O.B.E., F.R.S.
Mr. J. M. Caie
Prof. G. D. Hale Carpenter
Prof. J. A. Carroll
Dr. R. E. Chapman
Dr. L. J. Comrie
Prof. G. Cook
Mr. E. G. Cox
Dr. Brysson Cunningham
Prof. C. G. Darwin, F.R.S.
Mr. L. J. Davies
Dr. S. J. Davies
Dr. J. Burtt Davy
Mr. A. G. H. Dent
Mr. A. F. Dufton
Mr. E. Wyllie Fenton
Prof. J. J. Findlay
Dr. Margaret Fishenden
Mr. A. P. M. Fleming
Dr. P. Ford
Mr. G. E. H. Foxon
Prof. R. H. Fowler, O.B.E., F.R.S.
Dr. R. G. J. Fraser
Dr. H. Godwin
Dr. A. W. Greenwood
Dr. Mary J. F. Gregor
Mr. R. Griffiths
Mr. E. R. Gunther
Prof. B. P. Haigh
Prof. A. C. Hardy
Prof. A. Hemmy
Dr. J. Henderson
Prof. J. Hendrick
Dr. R. A. Houstoun
Dr. E. L. Ince
Mr. G. V. Jacks
Miss P. M. Jenkin
Prof. W. W. Jervis
Dr. K. Jordan
Prof. K. D. Kay
Dr. G. W. C. Kaye
Dr. D. Kennedy-Fraser
Prof. C. H. Lander, C.B.E.
Mr. C. A. Mace
Mr. R. J. Mackay
Brig. M. N. MacLeod, D.S.O
Mrs. E. Mellanby
Prof. J. Mellanby, F.R.S.
Mr. W. J. M. Menzies
Dr. J. C. P. Miller
Mr. C. A. Oakley
Mr. F. W. Ogilvie

[1] Subject to appointment as General Secretary.

Dr. A. Parker
Mr. C. C. Paterson, O.B.E.
Mr. F. T. K. Pentelow
Prof. J. C. Philip, O.B.E., F.R.S.
Dr. E. P. Poulton
Dr. F. L. Pyman
Mr. A. Radford
Dr. R. O. Redman
Dr. L. F. Richardson, F.R.S.
Mr. R. R. Robbins, C.B.E.
Capt. J. C. A. Roseveare
Mr. D. H. Sadler
Prof. R. A. Sampson, F.R.S.
Dr. H. Sandon
Mr. J. T. Saunders
Mr. F. J. Scrase
Dr. G. Seth
Capt. H. Shaw
Dr. W. F. Sheppard
Principal J. Cameron Smail
Mr. A. D. Buchanan Smith
Prof. R. V. Southwell, F.R.S.
Dr. L. Dudley Stamp
Prof. G. C. Steward
Mr. J. A. Steers
Prof. J. Tait
Prof. G. I. Taylor, F.R.S.
Dr. A. J. Thompson
Prof. G. P. Thomson, F.R.S.
Prof. M. W. Travers, F.R.S.
Mr. W. B. Turrill
Dr. P. E. Vernon
Rt. Hon. Lord Wakehurst
Miss M. D. Waller
Prof. R. Whiddington, F.R.S.
Dr. F. J. W. Whipple
Mr. R. S. Whipple
Brig. H. St. J. L. Winterbotham, C.M.G.
Prof. W. Wilson, F.R.S.
Dr. N. C. Wright
Dr. Dorothy Wrinch

XV. *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, Sir Richard Gregory, F.R.S., Sir David Prain, F.R.S., Dr. A. B. Rendle, F.R.S., Prof. W. M. Tattersall, Dr. R. E. Mortimer Wheeler.

Future Annual Meetings, etc.

XVI.—The Council have to report that correspondence has passed relating to the possibility of the Association participating in the jubilee of the Indian Science Congress Association in 1938, and of a meeting of the Association in Australia in 1939 or subsequent year. They have also to report receipt of an invitation from Belfast for 1940 or 'any of the years immediately following.'

Miscellanea.

XVII. *Corporation Membership.*—The Statute on corporation membership, adopted by the General Committee at the Aberdeen Meeting, was submitted to the Privy Council authorities in accordance with the Charter. The Privy Council authorities indicated that the use of the phrase 'corporation membership' was not strictly consonant with other Statutes, and sanctioned the following amended wording :—

> Any British corporate body approved by the Council shall, on payment of the sum of thirty guineas, be entitled in perpetuity to appoint one representative to attend each Annual Meeting as an annual member of the Association, or on payment of the sum of fifty guineas, two representatives, and on payment of each further sum of fifteen guineas, an additional representative. Such subscription shall entitle the corporation or each of its representatives to receive the Annual Report on demand.

The Privy Council did not require that the Statute as amended should be again referred to the Committee of Recommendations and the General Committee, as the effect of the original version was not altered. It was therefore resolved that the Statute as above should be incorporated in the Statute-book forthwith, and that the matter should be reported to the General Committee.

XVIII. *Science and the Life of the Community.*—The Council circulated a memorandum to all Organising Sectional Committees, further to that referred to in Report, 1934, p. xxi, on the desirability of continuing to include in their programmes subjects bearing upon the relations between the advance of science and the life of the community. It was indicated that 'the efforts of the Association in this direction' at the Aberdeen Meeting had been 'widely recognised and esteemed.'

It was resolved that a suggestion, brought forward in General Committee at the Aberdeen Meeting, that a collection of communications bearing on the above subject might be published by the Association, should not be given effect at present; but without prejudice to future reconsideration of the suggestion.

XIX. *Aberdeen Local Fund.*—The Council were informed of a decision by the Local Committee at Aberdeen on the disposal of the balance remaining from the local fund :—

> That, after a *pro rata* return of their donations is made to all contributors who indicate they desire such, any balance remaining should be distributed equally among the following institutions : the University, the Rowett Institute, the Macaulay Institute, the College of Agriculture and Robert Gordon's Technical College, with the recommendation that the payments made should be applied by these institutions for the purpose of paying the travelling expenses of students or junior workers there to future meetings of the British Association, or for purposes of a kindred character.

It was resolved that the Local Committee be thanked for this decision, and for their courtesy in communicating it to the Council.

XX. *Town and Country Planning.*—In pursuance of the Association's interest in the planning of areas, etc., which may appear to require protection for scientific reasons (Report, 1934, p. xxix), the Council formed a panel of persons who might advise them in the event of requests to the Association to make recommendations in this connection.

XXI. *Sub-standard Films.*—It was reported that proposed new Home Office regulations for the use of sub-standard films were causing concern to educational and other bodies, and the Council has requested the Home Office to afford them an opportunity of considering these regulations in draft.

XXII. *Section-room Equipment.*—With a view to relieving difficulties sometimes encountered by local committees the Council have purchased some projection lanterns and other equipment for the use of Sections. They have to thank Prof. W. T. Gordon and Prof. A. O. Rankine for their interest and help in this matter.

XXIII. *Quinquennial Reports.*—The Council have considered suggestions for the publication by the Association of (*a*) a quinquennial report on the advancement of science, and (*b*) a short statement for general distribution, summarising the various activities of the Association. It is intended to give effect to these proposals, and that the first issue of both publications should appear next year and cover the period 1931–35 (from the opening of the second century of the Association).

XXIV. *Galapagos Islands.*—The Council have received communications concerning the intention of the Government of Ecuador to protect the fauna of the Galapagos Islands, and have appointed representatives of the Association to serve on any joint committee which may be set up to consider this matter.[2]

Down House.

XXV. The following report for the year 1934–35 has been received from the Down House Committee :—

The number of visitors to Down House during the year ending June 6, 1935, has been 6,658, compared with 8,536 in 1933–34, and 7,022 in 1932–33.

Among gifts to the house during the past year, two call for special mention :—

The Linnean Society, at the instance of Dr. S. E. Chandler, has presented a bronze copy of the medal struck on the occasion of the Darwin-Wallace Celebration held by the Society in 1908, together with a finely-bound copy of the proceedings.

There was recently found, and presented to the house by Mr. Bernard Darwin, an interesting relic of Darwin, namely, a box containing some seventy packets of seeds of flowering plants and vegetables. Endorsements on many of the packets indicate that they were sent to Darwin from various parts of the world, and some came from Kew Gardens. Some are dated, the earliest 1855, and the latest 1876. Some of the seeds have been tested at Kew Gardens for germination. Concerning these, the Director of Kew Gardens, Sir Arthur W. Hill, F.R.S., has kindly communicated with the Secretary. He has stated that the following species of *Trifolium* have germinated :—

Trifolium fragiferum, Kew 17A. 141 seeds sown, 15 germinated.
Trifolium ochroleucum, Kew. 102 seeds sown, 4 germinated.
Trifolium pannonicum, Kew 17C. 140 seeds sown, 8 germinated.

Sir Arthur Hill's communication continues :—

'The other genera tested, *Brassica*, *Convolvulus*, *Mimulus*, *Nicotiana*, *Antirrhinum*, *Nolana*, *Viscaria*, *Lathyrus*, *Anchusa*, *Papaver*, *Melilotus*, *Ononis*, *Lotus* and *Iberis*, failed to germinate.

'We do not appear to have any reference to the date when the seeds marked "Kew" were sent to Charles Darwin, but they must be at least 53 years old. It is interesting to note that Ewart obtained negative results with 54-year-old seeds of *Trifolium fragiferum*, whilst the germination of 54-year-old seeds of *T. ochroleucum* and *T. pannonicum* appears to be a record for those species.'

The box contained also an original letter from Alphonse de Candolle (presumably to Darwin, though not actually bearing his name) : it has been published recently in the *Journal of Botany*.

A generous gift of plants for the garden has been made recently by Sir Daniel Hall, K.C.B., F.R.S., from the John Innes Horticultural Institution.

Opportunity has been taken to identify the apple-trees in the orchard (some of which are very old) through the kindness of the Imperial Bureau of Fruit Production, East Malling.

[2] See further under 'Resolutions and Recommendations,' later.

The Genetics Society met at Down House on June 30, 1934, and the committee received the thanks of the Society for permission to do so.

The following financial statement, showing income and expenditure on account of Down House for the years ending March 31, 1934 and 1935, is unfavourable on account of the very high charges necessitated in respect of repairs during the latter year. Two items were the major causes of this. The flint-and-brick wall at the end of the kitchen garden (evidently one of the oldest pieces of building on the estate) was found to be in urgent need of pointing, filling, and buttressing. More serious was the discovery that death-watch beetle had attacked the roof of the bay on the garden front of the house. An expert from the Forest Products Research Laboratories made an inspection, and repairs were carried out in accordance with his advice. There now appears no reason to doubt that the damage has been localised and arrested.

Income

	1933–34			1934–35		
	£	s.	d.	£	s.	d.
By Dividends on endowment fund and income tax recovered	978	17	6	1,013	3	6
,, Grant from Pilgrim Trust	150	0	0	150	0	0
,, Rents	140	15	0	141	0	0
,, Donations	6	0	11½	4	14	0
,, Sale of Postcards and Catalogues	34	14	2½	24	15	2
,, Balance, being excess of expenditure, as below, over income		—		84	13	1½
	£1,310	7	8	1,418	5	9½

Expenditure (running costs)

	1933–34			1934–35		
	£	s.	d.	£	s.	d.
To Wages and National Insurance	831	18	8	797	13	2
,, Rates, Land Tax, Insurances	57	4	10½	62	3	8½
,, Coal, Coke, etc	103	12	5	126	14	6
,, Water	15	4	1	14	16	7
,, Lighting and Drainage Plants (including petrol and oil)	62	18	3½	81	6	7
,, Repairs and Renewals :—						
Miscellaneous	35	9	0	73	9	10
Kitchen garden wall		—		35	1	0
Damage by death-watch beetle		—		77	8	8
,, Garden materials	56	14	8	41	1	7
,, Tree guards and boiler installation		—		24	3	4
,, Household Requisites, etc.	17	6	10½	30	12	7½
,, Transport and Carriage	2	1	1	3	18	10
,, Auditors	19	1	2	19	16	9
,, Printing, Postages, Telephone, Stationery, etc.	41	6	4	24	13	7½
,, Donations to Village Institutions	5	5	0	5	5	0
,, Legal Charges (lease of 'Homefield')	7	5	6		—	
,, Purchase of Darwin's dining table (net)	9	10	0		—	
,, Balance, being excess of income over expenditure	45	9	8½		—	
	£1,310	7	8	1,418	5	9½

It may be appropriate at this time to restate the financial position in relation with the general funds of the Association (i.e. as apart from the Down House Endowment Fund). The total expenditure which fell upon general funds as so-called 'capital' expenditure was £3,292 15*s*. 2*d*., as stated in the report for 1932–33. Apart from this, the actual excess of expenditure over income from 1929 down to March 31 of the present year stands at £458 5*s*. 4*d*. The Council last year resolved, on the recommendation of the committee, that any subsequent balance on the side of receipts should be placed in a suspense or maintenance fund for the house. It will be seen, however, that owing to the heavy repairs necessitated during the past year the balance is still adverse, and the prospect of forming any substantial maintenance fund under existing conditions may be discounted. The committee have also to bear in mind that the Pilgrim Trust grant of £150 per annum for five years will expire after the payment in 1937, and though a review of the position thereafter is promised by the Trust, the committee hope that all those friends of Down House who may be in a position to aid in the maintenance of this unique charge will not fail to do so.

GENERAL TREASURER'S ACCOUNT, 1934–35

The resumption this year of the practice of showing in the accounts comparative figures for the preceding year (interrupted in consequence of the alteration of the Association's accounting period) reveals an increase of nearly £700 in membership subscriptions. This improvement is attributable mainly to the large attendance at the Aberdeen Meeting, for which 2,938 members enrolled, the most since 1928 (Glasgow Meeting), excepting the Centenary Meeting; but also partly to the encouraging response to the General Officers' appeal two years ago for regular annual subscriptions by banker's order, irrespective of actual attendance at the annual meeting in any year. Maintenance and extension of the Association's service in aid of scientific research will be best assured by a stable income from membership subscriptions. By March 31 this year 235 members had adopted the labour-saving method of subscription by banker's order, and I hope this promise of growth will be fulfilled, for, in spite of much economy and the free services of a host of volunteers, the need for greater financial resources still hinders the Association's work.

Josiah C. Stamp,
General Treasurer.

Balance Sheet as

Corresponding Figures 31st March, 1934. £ s. d.	LIABILITIES	£ s. d.	£ s. d.	£ s. d.
	GENERAL PURPOSES :—			
	Sundry Creditors		117 8 2	
	Hon. Sir Charles Parsons' gift (£10,000) and legacy (£2,000) .		12,000 0 0	
	Yarrow Fund			
	As per last Account	£5,731 14 8		
	Less Transferred to Income and Expenditure Account under terms of the gift .	258 0 0		
			5,473 14 8	
	Life Compositions			
	As per last Account.	2,490 12 2		
	Add Received during year . . .	273 0 0		
		2,763 12 2		
	Less Transferred to Income and Expenditure Account .	15 0 0		
			2,748 12 2	
	Contingency Fund			
	As per last Account	769 17 11		
	Add Amount transferred from Income and Expenditure Account . .	454 8 3½		
			1,224 6 2½	
	Accumulated Fund		16,488 9 0	
37,549 7 6				38,052 10 2½
	SPECIAL PURPOSES :—			
	Caird Fund			
	Balance at 1st April, 1934 . .		9,767 11 0	
	Add Excess of Income over Expenditure for year		38 12 10	
				9,806 3 10
	Cunningham Bequest			
	Balance at 1st April, 1934 . .		2,284 19 1	
	Less Excess of Expenditure over Income for the year		735 15 9	
				1,549 3 4
	Toronto University Presentation Fund			
	Capital		178 11 4	
	Revenue		4 7 6	
				182 18 10
	Carried forward . .			49,590 16 2½

at 31st March, 1935

Corresponding Figures 31st March, 1934. £ s. d.	ASSETS	£ s. d.	£ s. d.
	General Purposes :—		
	Investments as scheduled with Income and Expenditure Account, No. 1	37,920 1 11	
	Catalogues in Stock, at cost (Down House)	— — —	
	Sundry debtors and payments in advance	82 15 11	
	Cash at bank	41 17 5	
37,549 7 6	Cash in hand	7 14 11½	38,052 10 2½
	Special Purposes :—		
	Caird Fund		
	Investments (see Income and Expenditure Account, No. 2)	9,582 16 3	
	Cash at bank	223 7 7	9,806 3 10
	Cunningham Bequest		
	Investments (see Income and Expenditure Account, No. 3)	1,501 7 2	
	Cash at bank	47 16 2	1,549 3 4
	Toronto University Presentation Fund		
	Investments (see Income and Expenditure Account, No. 4)	178 11 4	
	Cash at bank	4 7 6	182 18 10
	Carried forward		49,590 16 2½

Balance Sheet as

Corresponding Figures 31st March, 1934. £ s. d.	LIABILITIES (*continued*)	£ s. d.	£ s. d.	£ s. d.
	Brought forward			49,590 16 2½
	Bernard Hobson Fund			
	Capital		1,000 0 0	
	Revenue—Balance per last Account	22 10 6		
	Add Excess of Income over Expenditure for year	22 5 6		
			44 16 0	
				1,044 16 0
	Leicester and Leicestershire Fund, 1933			
	Capital		1,000 0 0	
	Excess of Income over Expenditure for year		34 4 2	
				1,034 4 2
	Down House			
	Endowment Fund		20,000 0 0	
	Sundry Creditors and Credit Balances		150 12 8	
34,331 13 3½				20,150 12 8
	Total of Special Funds		£33,767 18 10	
71,881 0 9½				£71,820 9 0½

NOTE.—There are contingent Liabilities in respect of grants voted to Research Committees at Aberdeen in 1934, but not claimed at 31st March, 1935, amounting to £509 6*s*. 1*d*.

The amount which should, in accordance with Council's resolution, have been in the Contingency Fund at 31st March, 1935, was £1,375, but the surplus income available for this purpose has been insufficient by £150 13*s*. 9½*d*. to meet the full annual amount transferable.

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

Approved.
ARTHUR L. BOWLEY
ALLAN FERGUSON } *Auditors.*
23 Queen Victoria St.,
London, E.C. 4.

at 31st March, 1935 (*continued*)

Corresponding Figures 31st March, 1934. £ s. d.	ASSETS (*continued*)	£ s. d.	£ s. d.	£ s. d.
	Brought forward . . .			49,590 16 2½
	Bernard Hobson Fund			
	Investments (see Income and Expenditure Account, No. 5) .		1,000 0 0	
	Cash at bank		44 16 0	
				1,044 16 0
	Leicester and Leicestershire Fund, 1933			
	Investments (see Income and Expenditure Account, No. 6) .		1,000 0 0	
	Cash at bank		34 4 2	
				1,034 4 2
	Down House			
	Endowment Fund Investments (see Income and Expenditure Account, No. 7)		20,000 0 0	
	Cash at bank		— — —	
	Cash in hand		10 0 0	
	Sundry debtors and payments in advance		36 14 3	
	Stock of catalogues . . .		64 15 0	
	Suspense Account			
	Balance at credit 1st April, 1934 .	45 9 8½		
	Less Excess of Income over Expenditure for year to date .	84 13 1½		
			39 3 5	
34,331 13 3½				20,150 12 8
71,881 0 9½				£71,820 9 0½

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

W. B. Keen,
Chartered Accountant.

INCOME AND EXPENDITURE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH, 1935.

No. 1. General Income and Expenditure

Corresponding Figures 31st March, 1934. £ s. d.	Investments:		£ s. d.	
	£6,749 12s. 2d.	Consolidated 2½ per cent. Stock, at cost	5,142 3 3	
	£3,600 0s. 0d.	India 3 per cent. Stock, at cost	3,522 2 6	
	£879 14s. 9d.	Great Indian Peninsula Railway 'B' Annuity £43, at cost	827 15 0	
	£52 12s. 7d.	War Stock (Post Office Issue), at cost	54 5 2	
	£1,400 0s. 0d.	3½ per cent. War Loan Bonds, at cost	1,393 16 11	
	£7,679 6s. 6d.	3½ per cent. War Loan Inscribed Stock, at cost	7,703 10 8	
	£11,134 16s. 6d.	4½ per cent. Conversion Stock, at cost	10,835 12 4	
	£6,368 15s. 7d.	3½ per cent. Conversion Stock, at cost	5,304 8 11	
	£94 17s. 0d.	4½ per cent. Conversion Stock (Post Office Issue), at cost	62 15 0	
	£4,184 18s. 2d.	3 per cent. Local Loans, at cost	3,073 12 2	
		Second Mortgage on Isleworth House, Orpington, Kent	Repaid	(Value of Stocks at 29/3/35,
36,770 1 11	(*Value of Stocks at 29/3/34, £40,170 3s. 11d.*)		£37,920 1 11	£42,886 0s. 11d.)

EXPENDITURE

Corresponding Figures 31st March, 1934. £ s. d.		£ s. d.	£ s. d.
35 1 7	To Heat, Lighting and Power	32 5 5	
83 19 2	,, Stationery	70 8 10½	
1 0 0	,, Rent	1 0 0	
229 1 0	,, Postages	173 6 0	
180 13 9	,, Travelling expenses	251 2 8½	
37 8 8	,, Exhibitioners	133 0 4	
127 6 7	,, Badges		
40 16 10	,, Audit and Accountancy	38 12 3	
205 0 6½	,, Sundries	350 4 8½	
940 8 1½		1,050 0 3½	
1,964 11 0	,, Salaries and wages	1,993 4 9	
75 0 0	,, Pension contribution	75 0 0	
1,395 10 8	,, Printing, binding, etc.	1,276 8 5	
4,375 9 9½			4,394 13 5½

INCOME

Corresponding Figures 31st March, 1934. £ s. d.		£ s. d.	£ s. d.
110 7 0	By Old Annual Regular Members	95 0 0	
1,513 11 0	,, Annual members for Meeting only	1,928 7 0	
367 0 0	,, Annual members, with Report	478 0 0	
102 10 0	,, Transferable Tickets	242 3 0	
73 10 0	,, Student members	122 2 6	
2,166 18 0			2,865 12 6
51 0 0	,, Life compositions: amount transferred on expiry of membership		15 0 0
474 16 2½	,, Sale of Publications		476 3 9
285 3 1	,, Advertisements in B.A. publications		265 10 11
65 9 6	,, Unexpended balances of grants, returned		12 5 0
22 10 0	,, Liverpool Exhibitioners		22 10 0

Previous year	Expenditure		
	To Grants made to Research Committees by General Committee 1933, 1934:		
	Cretaceous and Tertiary London Rocks	15 0 0	
	Inland Water Survey	14 12 11	
	Petrographic Classification	1 14 3	
	Kent's Cavern	5 0 0	
	Retinae of Animals	10 0 0	
	Freshwater Biological Station	75 0 0	
	Transplant Experiments	5 0 0	
	Human Geography of Inter-Tropical Africa	11 10 8	
	Anatomy of Timber-producing trees	10 0 0	
	Seismology	50 0 0	
	Ainu Studies	50 0 0	
	Pen Dinas	45 0 0	
	Chronology of World Crisis	17 0 0	
	Mathematical Tables	147 11 6	
	Reduction of Noise	10 0 0	
294 7 0			467 9 4
	,, Grant to Parsons Memorial Fund	100 0 0	
	,, Expenses of Noise Committee's Demonstration	13 0 0	
			113 0 0
394 17 11	,, Balance, being excess of income over expenditure for the year carried down		454 8 3½
5,064 14 8½			£5,429 11 1
394 17 11	To transfer to Contingency Fund		£454 8 3½
293 18 3	Grants voted at 1934 Meeting, but not claimed to date		£253 10 7
100 0 0	*Amount voted to Parsons Memorial Fund not yet paid*		
393 18 3			

Previous year	Receipts	
105 0 5	By Income Tax recovered	63 17 2
1,477 0 8	,, Interest on investments	1,432 15 9
5 16 10	,, Donations	17 16 0
411 0 0	,, Sir Alfred Yarrow's Gift: amount transferred	258 0 0
5,064 14 8½		£5,429 11 1
394 17 11	By balance brought down	£454 8 3½

No. 2. Caird Fund

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

Corresponding Figures 31st March, 1934. £ s. d.	*Investments :*		£ s. d.	
	£2,627 0s. 10d.	India $3\frac{1}{2}$ per cent. Stock, at cost	2,400 13 3	
	£2,100 0s. 0d.	London Midland and Scottish Railway Consolidated 4 per cent. Preference Stock, at cost	2,190 4 3	
	£2,500 0s. 0d.	Canada $3\frac{1}{2}$ per cent. Registered Stock, 1930/50, at cost	2,397 1 6	
	£2,000 0s. 0d.	Southern Railway Consolidated 5 per cent. Preference Stock, at cost	2,594 17 3	
9,582 16 3	*(Value at 29/3/34, £8,876 0s. 3d.)*		£9,582 16 3	(Value at 29/3/35, £8,819 7s. 6d.)
	Cash at bank, £184 14 9			Cash at bank, £223 7 7

Corresponding Figures 31st March, 1934. £ s. d.	EXPENDITURE	£ s. d.	£ s. d.	Corresponding Figures 31st March, 1934. £ s. d.	INCOME	£ s. d.
	To Grants paid—			*287 13 8*	By Dividends and Interest	302 6 10
	Naples Table Committee	50 0 0		*68 7 5*	,, Income Tax recovered	65 5 0
	Routine Manual Factor Committee	20 0 0				
	Noise Reduction Committee	24 0 0				
	Zoological Record Committee	50 0 0				
	Seismology Committee	100 0 0				
	Plymouth Table Committee	50 0 0				
	Human Geography of Inter-Tropical Africa Committee	4 19 0				
	Sir J. B. Harrison's Monograph 'Katamorphism of Igneous Rocks under Tropical and Temperate Conditions'	30 0 0				
330 5 0			328 19 0			

25 16 1	To Balance, being excess of income over expenditure for the year . .	38 12 10		
356 1 1		£367 11 10	356 1 1	£367 11 10
155 0 0	Grants to research authorised, but not yet claimed	200 0 0		
30 0 0	*Grant towards Sir J. B. Harrison's Monograph, 'The Katamorphism of Igneous Rocks under Tropical and Temperate Conditions,' not yet paid*			
185 0 0				

No. 3. Cunningham Bequest

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

Corresponding Figures 31st March, 1934. £ s. d.			£ s. d.	
	Investments :			
	£1,187 6s. 10d.	Consolidated $2\frac{1}{2}$ per cent. Stock	653 0 9	
	£300 0s. 0d.	Port of London $3\frac{1}{2}$ per cent. Stock, 1949/99	216 0 0	
	£100 0s. 0d.	Commonwealth of Australia $4\frac{3}{4}$ per cent. Stock	93 0 0	
	£100 0s. 0d.	New Zealand 5 per cent. Stock, 1946	103 0 0	
	£862 13s. 3d.	Local Loans 3 per cent. Stock, at cost	436 6 5	
2,151 7 2	*Value at 29/3/34*		£1,501 7 2	(Value at 29/3/35, £2,352 3s. 0d.)
133 11 11	*Cash at bank*		Cash at bank, £47 16s. 2d.	

Corresponding Figures 31st March, 1934. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1934. £ s. d.	INCOME	£ s. d.
550 0 0	*To Purchase of Calculating Machine (capital charge)*		551 12 0	*By Transfer from capital*	
1 12 0	,, *Loss on redemption of India 6 per cent. Stock (capital charge)*		103 10 6	,, Interest	94 1 3
114 12 0	,, Grants for preparation of tables	271 17 6	11 11 1	,, Income Tax recovered	8 12 6
132 8 9	,, Printing	566 12 0	131 19 2	,, Excess of Expenditure over Income for the year	735 15 9
798 12 9		£838 9 6	798 12 9		£838 9 6

No. 4. Toronto University Presentation Fund

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

Corresponding Figures 31st March, 1934. £ s. d.			
	Investment :		
178 11 4	£175 $3\frac{1}{2}$ per cent. War Stock at cost	£178 11 4	(Value at 29/3/35, £183 15s. 0d.)
	Value at 29/3/34, £182 0s. 0d.		
4 7 6	*Cash at bank*	Cash at bank	£4 7s. 6d.

Corresponding Figures 31st March, 1934. £ s. d.	EXPENDITURE	£ s. d.	Corresponding Figures 31st March, 1934. £ s. d.	INCOME	£ s. d.
6 2 6	To awards	£6 2 6	6 2 6	By Interest	£6 2 6

No. 5. Bernard Hobson Fund

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

Corresponding Figures 31st March, 1934. £ s. d.	*Investments:*	£ s. d.	
	£450 0s. 0d. 4 per cent. Victory (Bearer) Bonds at cost	491 13 6	
	£601 9s. 0d. 3 per cent. Local Loans at cost	508 6 6	
1,000 0 0	(*Value at 29/3/34, £1,051 14s. 2d.*)	£1,000 0 0	(Value at 29/3/35, £1,080 12s. 3d.)
£22 10 6		(Cash at bank, £44 16s. 0d.)	

	EXPENDITURE	£ s. d.		INCOME	£ s. d.
	To Grants Paid	14 4 6		By Interest	32 0 0
22 10 6	" Excess of income over expenditure for the year	22 5 6	22 10 6	" Income Tax Recovered	4 10 0
22 10 6		£36 10 0	22 10 6		£36 10 0
30 0 0	(Grant authorised, not yet claimed, £25 15s. 6d.)				

No. 6. Leicester and Leicestershire Fund, 1933

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

Corresponding Figures	*Investments:*	£	
	£487 2s. 11d. 3½ per cent. Conversion Stock at cost	500	
	£490 5s. 11d. 3½ per cent. War Stock at cost	500	
1,000 0 0	(*Value at 29/3/34, £1,011 8s. 4d.*)	£1,000	(Value at 29/3/35, £1,025 16s. 4d.)
		(Cash at bank, £34 4s. 2d.)	

EXPENDITURE	£ s. d.	INCOME	£ s. d.
To Amount carried forward	£34 4 2	By Interest	£34 4 2
(Grant authorised, not yet claimed, £30.)			

No. 7. Down House

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

Corresponding Figures 31st March, 1934. £ s. d.			£ s. d.	
	Investments :			
	Down House Endowment Fund			
	£5,500	India 4½ per cent. Stock, 1958/68, at cost	5,001 17 4	
	£2,500	Commonwealth of Australia 5 per cent. Stock, 1945/75, at cost	2,468 19 0	
	£3,000	Fishguard and Rosslare Railway and Harbours 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	
	£3,340	Great Western Railway 5 per cent. Guaranteed Stock, at cost	3,436 7 5	
	£2,500	Birkenhead Railway 4 per cent. Consolidated Stock, at cost	2,013 9 9	
20,000 0 0			£20,000 0 0	(Value of Stocks at 29/3/35, £24,502 12*s.* 0*d.*)
	(Value at 29/3/34, £23,882 8s. od.)			
37 0 3	*Cash at bank*			
14 11 10½	*Cash in hand*			
51 12 1½		Cash in hand	10 0 0	

Corresponding Figures 31st March, 1934. £ s. d.	EXPENDITURE	£ s. d.	£ s. d.	Corresponding Figures 31st March, 1934. £ s. d.	INCOME	£ s. d.
831 18 8	To Wages of Staff		797 13 2	140 15 0	By Rents Receivable	141 0 0
57 4 10½	,, Rates, insurance, etc.		62 3 8½	171 2 6	,, Income Tax recovered	186 15 0
103 12 5	,, Coal, Coke, etc.		126 14 6	807 15 0	,, Interest and Dividends	826 8 6
62 18 3½	,, Lighting and Drainage (including oil and petrol)		81 6 7	6 0 11½	,, Donations	4 14 0
7 5 6	,, *Legal charges on lease of 'Homefield'*		— — —	34 14 2½	,, Sale of Postcards and Catalogues	24 15 2
15 4 1	,, Water		14 16 7	150 0 0	,, Pilgrim Trust grant	150 0 0

	To Repairs and Renewals—					
	Miscellaneous . .	73 9 10				
	Kitchen Garden Wall .	35 1 0				
	Damage by Death Watch					
35 9 0	beetle . . .	77 8 8				
			185 19 6			
56 14 8	,, Garden Materials, etc. .		41 1 7			
	,, Tree Guards and Boiler Installation . .		24 3 4			
5 5 0	,, Donations . . .		5 5 0			
17 6 10½	,, Household Requisites, etc.		30 12 7½			
2 1 1	,, Transport and carriage .		3 18 10			
19 1 2	,, Accountants' Fees . .		19 16 9			
41 6 4	,, Printing, Postages, Telephone, and Stationery .		24 13 7½			
	,, *Purchase of Darwin's*					
	12 10 0 dining-table					
	3 0 0 Less *sale of old*					
9 10 0	*table*					
45 9 8½	,, *Balance, being excess of income over expenditure for the year, transferred to Suspense Account*				By Balance, being excess of expenditure over in ome for the year, transferred to Suspense Account	84 13 1½
1,310 7 8			£1,418 5 9½	*1,310 7 8*		£1,418 5 9½

RESEARCH COMMITTEES, Etc.

APPOINTED BY THE GENERAL COMMITTEE, MEETING IN NORWICH, 1935.

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

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

Seismological investigations.—Dr. F. J. W. Whipple (*Chairman*), Mr. J. J. Shaw, C.B.E. (*Secretary*), Prof. P. G. H. Boswell, O.B.E., F.R.S., Dr. A. T. J. Dollar, Prof. G. R. Goldsbrough, Dr. Wilfred Hall, Dr. H. Jeffreys, F.R.S., Mr. Cosmo Johns, Mr. A. W. Lee, Prof. E. A. Milne, M.B.E., F.R.S., Mr. R. D. Oldham, F.R.S., Prof. H. H. Plaskett, Prof. H. C. Plummer, F.R.S., Prof. A. O. Rankine, O.B.E., Rev. J. P. Rowland, S.J., Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Capt. H. Shaw, Sir Frank Smith, K.C.B., C.B.E., Sec. R.S., Dr. R. Stoneley, F.R.S., Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S. **£150** (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, Prof. R. A. Fisher, F.R.S., Dr. J. Henderson, Dr. E. L. Ince, Dr. J. O. Irwin, Dr. J. C. P. Miller, Mr. F. Robbins, Mr. D. H. Sadler, Dr. A. J. Thompson, Dr. J. F. Tocher, Dr. J. Wishart. **£200** (£150 Caird Fund grant).

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

The direct determination of the thermal conductivities of rocks in mines or borings where the temperature gradient has been, or is likely to be, measured.—Dr. Ezer Griffiths, F.R.S. (*Chairman*), Dr. E. C. Bullard, Dr. H. Jeffreys, F.R.S. (*from Section A*); Mr. E. M. Anderson, Prof. W. G. Fearnsides, F.R.S., Prof. G. Hickling, Prof. A. Holmes, Dr. D. W. Phillips, Dr. J. H. J. Poole. **£35.**

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

The possibility of quantitative estimates of sensory events.—Prof. A. Ferguson (*Chairman*), Dr. C. S. Myers, C.B.E., F.R.S. (*Vice-Chairman*), Mr. R. J. Bartlett (*Secretary*), Dr. H. Banister, Prof. F. C. Bartlett, F.R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houstoun, Dr. J. O. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, F.R.S., Dr. R. H. Thouless, Dr. W. S. Tucker, O.B.E.

SECTION B.—CHEMISTRY.

To advise the Sectional Committee as to the best method of meeting the wishes of Council as expressed in the memorandum on the relation between the advance of science and the life of the community.— (*Chairman*), (*Secretary*), Dr. N. V. Sidgwick, C.B.E., F.R.S., Prof. J. F. Thorpe, C.B.E., F.R.S., Mr. H. T. Tizard, C.B., F.R.S.

SECTION C.—GEOLOGY.

To excavate critical geological sections in Great Britain.—Prof. W. T. Gordon (*Chairman*), Prof. W. G. Fearnsides, F.R.S. (*Secretary*), Prof. E. B. Bailey, F.R.S., Mr. H. C. Berdinner, Mr. W. S. Bisat, Dr. H. Bolton, Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. W. S. Boulton, Dr. E. S. Cobbold, Prof. A. H. Cox, Miss M. C. Crosfield, Mr. E. E. L. Dixon, Dr. Gertrude Elles, M.B.E., Prof. E. J. Garwood, F.R.S., Mr. F. Gossling, Prof. H. L. Hawkins, Prof. G. Hickling, Prof. V. C. Illing, Prof. O. T. Jones, F.R.S., Dr. Murray Macgregor, Dr. F. J. North, Dr. J. Pringle, Dr. T. F. Sibly, Dr. W. K. Spencer, F.R.S., Prof. A. E. Trueman, Dr. F. S. Wallis, Prof. W. W. Watts, F.R.S., Dr. W. F. Whittard, Dr. S. W. Wooldridge. **£40** (Contingent grant, part on Bernard Hobson Fund).

To investigate the reptile-bearing oolite of Stow-on-the-Wold, subject to the condition that suitable arrangements be made for the disposal of the material. —Sir A. Smith Woodward, F.R.S. (*Chairman*), Mr. C. I. Gardiner (*Secretary*), Prof. S. H. Reynolds, Mr. W. E. Swinton. **£20** (Bernard Hobson Fund grant).

To investigate the bone-bed in the glacial deposits of Brundon, near Sudbury, Suffolk.—Prof. P. G. H. Boswell, O.B.E., F.R.S. (*Chairman*), Mr. Guy Maynard (*Secretary*), Mr. D. F. W. Baden-Powell, Prof. W. B. R. King, O.B.E., Mr. J. Reid Moir, Mr. K. P. Oakley, Dr. J. D. Solomon, Sir A. Smith Woodward, F.R.S. **£30** (Bernard Hobson Fund grant).

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

The collection, preservation, and systematic registration of photographs of geological interest.—Prof. E. J. Garwood, F.R.S. (*Chairman*), Prof. S. H. Reynolds (*Secretary*), Mr. H. Ashley, Mr. C. V. Crook, Mr. G. Macdonald Davies, Mr. J. F. Jackson, Mr. J. Ranson, Prof. W. W. Watts, F.R.S., Mr. R. J. Welch.

To consider and report upon petrographic classification and nomenclature.— Mr. W. Campbell Smith (*Chairman*), Dr. A. K. Wells (*Secretary*), Prof. E. B. Bailey, F.R.S., Prof. P. G. H. Boswell, O.B.E., F.R.S., Prof. A. Brammall, Dr. R. Campbell, Prof. A. Holmes, Prof. A. Johannsen, Dr. W. Q. Kennedy, Mr. A. G. MacGregor, Prof. P. Niggli, Prof. H. H. Read, Prof. S. J. Shand, Prof. C. E. Tilley, Dr. G. W. Tyrrell, Dr. F. Walker.

To make recommendations to the International Geological Congress for the formation of a committee to consider geological evidence of climatic change.— Dr. W. B. Wright (*Chairman*), Mr. M. B. Cotsworth (*Secretary*), Prof. E. B. Bailey, F.R.S., Prof. W. N. Benson, Prof. J. K. Charlesworth, Sir Lewis L. Fermor, O.B.E., F.R.S., Dr. G. W. Grabham, Dr. E. M. Kindle, Dr. Murray Macgregor, Dr. A. Raistrick, Dr. S. W. Wooldridge.

SECTIONS C, E.—GEOLOGY, GEOGRAPHY.

To administer a grant in support of a topographical and geological survey of the Lake Rudolph area in E. Africa.—Sir Albert E. Kitson, C.M.G., C.B.E. (*Chairman*), Dr. A. K. Wells (*Secretary*), Mr. S. J. K. Baker, Prof. F. Debenham, Dr. V. Fuchs, Prof. W. T. Gordon, Brig. H. S. L. Winterbotham, C.M.G., D.S.O. **£35** (Unexpended balance).

SECTION D.—ZOOLOGY.

To nominate competent naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.—Prof. J. H. Ashworth, F.R.S. (*Chairman and Secretary*), Prof. H. Graham Cannon, F.R.S., Prof. H. Munro Fox, Prof. J. Stanley Gardiner, F.R.S. **£50.**

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

To make an ecological survey of the Mollusca of the Upper Amazon.—Dr. W. T. Calman, F.R.S. (*Chairman*), Miss A. M. Laysaght (*Secretary*), Mr. G. C. Robson. **£15.**

To investigate British immigrant insects.—Sir E. B. Poulton, F.R.S. (*Chairman*), Dr. C. B. Williams (*Secretary*), Prof. F. Balfour-Browne, Capt. N. D. Riley. **£10.**

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, Prof. E. W. MacBride, F.R.S., Miss M. McNicol, Miss A. J. Prothero, Prof. W. M. Tattersall, Dr. E. N. Miles Thomas.

The progressive adaptation to new conditions in *Artemia salina* (Diploid and Octoploid, Parthenogenetic *v.* Bisexual).—Prof. R. A. Fisher, F.R.S. (*Chairman*), Dr. F. Gross (*Secretary*), Dr. J. Gray, F.R.S., Dr. E. S. Russell, O.B.E., Prof. D. M. S. Watson, F.R.S.

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, F.R.S. (*Chairman and Secretary*), Prof. J. Barcroft, C.B.E., F.R.S., Prof. E. W. MacBride, F.R.S., Dr. Margery Knight. **£50** (Caird Fund grant).

SECTIONS D, K.—ZOOLOGY, BOTANY.

To aid competent investigators selected by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere.—Prof. F. E. Fritsch, F.R.S. (*Chairman*), Prof. P. A. Buxton (*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 inquire into the present state of knowledge of the human geography of Tropical Africa, and to make recommendations for furtherance and development.—Prof. P. M. Roxby (*Chairman*), Prof. A. G. Ogilvie, O.B.E. (*Secretary*), Dr. A. Geddes (*Assistant Secretary*), Mr. S. J. K. Baker, Prof. C. B. Fawcett, Mr. W. Fitzgerald, Prof. H. J. Fleure, Mr. E. B. Haddon, Mr. R. H. Kinvig, Mr. J. McFarlane, Brig. M. N. MacLeod, D.S.O., Prof. J. L. Myres, O.B.E., F.B.A., Mr. R. A. Pelham, Mr. R. U. Sayce, Rev. E. W. Smith, Brig. H. S. L. Winterbotham, C.M.G., D.S.O. **£16** (Unexpended balance).

To study the land forms of the North-East Land.—Prof. F. Debenham, Prof. R. N. Rudmose Brown, Dr. K. S. Sandford. **£25.**

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

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Chronology of the world crisis from 1929 onwards.—Prof. J. H. Jones (*Chairman*), Dr. P. Ford (*Secretary*), Prof. G. C. Allen, Mr. H. M. Hallsworth, C.B.E., Mr. R. F. Harrod, Mr. A. Radford, Prof. J. G. Smith. **£10** (Leicester and Leicestershire Fund grant).

SECTION G.—ENGINEERING.

Earth pressures.—Mr. F. E. Wentworth-Sheilds, O.B.E. (*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, F.R.S., Dr. R. E. Stradling, C.B., Dr. W. N. Thomas, Mr. E. G. Walker, Mr. J. S. Wilson. **£6 13s. 10½d.** (Unexpended balance).

To review the knowledge at present available for the reduction of noise, and the nuisances to the abatement of which this knowledge could best be applied.—Sir Henry Fowler, K.B.E. (*Chairman*), Wing-Commander T. R. Cave-Browne-Cave, C.B.E. (*Secretary*), Mr. R. S. Capon, Dr. A. H. Davis, Prof. G. W. O. Howe, Mr. E. S. Shrapnell-Smith, C.B.E. **£5** (Leicester and Leicestershire Fund grant).

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

SECTION H.—ANTHROPOLOGY.

To carry out the excavation of Palæolith cave deposits on Mt. Carmel and other sites in Palestine.—Prof. J. L. Myres, O.B.E., F.B.A. (*Chairman*), Mr. M. C. Burkitt (*Secretary*), Miss G. Caton-Thompson, Miss D. A. E. Garrod. **£20.**

To co-operate with the local committee in the excavation of Pen Dinas hill fort, Cardiganshire.—Sir Cyril Fox (*Chairman*), Mr. V. E. Nash-Williams (*Secretary*), Prof. V. Gordon Childe, Prof. C. Daryll Forde, Rt. Hon. Lord Raglan, Dr. R. E. M. Wheeler. **£20.**

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

To co-operate with the Torquay Antiquarian Society in investigating Kent's Cavern.—Sir A. Keith, F.R.S. (*Chairman*), Prof. J. L. Myres, O.B.E., F.B.A. (*Secretary*), Mr. M. C. Burkitt, Dr. R. V. Favell, Miss D. A. E. Garrod, Mr. A. D. Lacaille. **£10.**

To excavate the Roman fort at Brancaster, Norfolk.—Mr. M. C. Burkitt (*Chairman*), Mr. V. E. Nash Williams (*Secretary*), Mr. K. H. Jackson. **£25.**

To investigate blood groups among primitive peoples.—Prof. H. J. Fleure (*Chairman*), Prof. R. Ruggles Gates, F.R.S. (*Secretary*), Dr. J. H. Hutton, C.I.E., Mr. R. U. Sayce. **£10.**

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. **£25.**

To carry out research among the Ainu of Japan.—Prof. C. G. Seligman, F.R.S. (*Chairman*), Mrs. C. G. Seligman (*Secretary*), Dr. H. S. Harrison, Capt. T. A. Joyce, O.B.E., Rt. Hon. Lord Raglan.

To report on the classification and distribution of rude stone monuments in the British Isles.—Mr. H. J. E. Peake (*Chairman*), Dr. Margaret A. Murray (*Secretary*), Mr. A. L. Armstrong, Mr. H. Balfour, F.R.S., Prof. V. Gordon Childe, Sir Cyril Fox, Mr. T. D. Kendrick.

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

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

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

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

SECTION I.—PHYSIOLOGY.

To deal with the use of a stereotactic instrument.—Prof. J. Mellanby, F.R.S. (*Chairman and Secretary*).

To investigate the alleged differences in distribution of rods and cones in the retinæ of various animals.—Prof. H. E. Roaf (*Chairman*), Dr. F. W. Edridge-Green, C.B.E. (*Secretary*), Prof. J. P. Hill, F.R.S., Dr. F. W. Law, Dr. S. Zuckerman. **£10** (Caird Fund grant).

SECTION J.—PSYCHOLOGY.

To develop tests of the routine manual factor in mechanical ability.—Dr. C. S. Myers, C.B.E., F.R.S. (*Chairman*), Dr. G. H. Miles (*Secretary*), Prof. C. Burt, Dr. F. M. Earle, Dr. Ll. Wynn Jones, Prof. T. H. Pear. **£30** (Leicester and Leicestershire Fund grant).

The nature of perseveration and its testing.—Prof. F. Aveling (*Chairman*), Dr. W. Stephenson (*Secretary*), Prof. F. C. Bartlett, F.R.S., Dr. Mary Collins, Mr. E. Farmer, Dr. P. E. Vernon.

To consider definite lines of research in social psychology.—Prof. J. Drever (*Chairman*), Mr. R. J. Bartlett (*Secretary*), Prof. F. Aveling, Prof. F. C. Bartlett, F.R.S., Prof. C. Burt, Dr. Mary Collins, Mr. E. Farmer, Miss E. J. Lindgren, Dr. C. S. Myers, C.B.E., F.R.S., Prof. T. H. Pear, Dr. R. H. Thouless, Mr. A. W. Wolters.

SECTION K.—BOTANY.

Transplant experiments.—Sir Arthur Hill, K.C.M.G., F.R.S. (*Chairman*), Dr. W. B. Turrill (*Secretary*), Prof. F. W. Oliver, F.R.S., Prof. E. J. Salisbury, F.R.S., Prof. A. G. Tansley, F.R.S.

SECTION L.—EDUCATIONAL SCIENCE.

To consider and report on the possibility of the Section undertaking more definite work in promoting educational research.—Dr. W. W. Vaughan, M.V.O. (*Chairman*), Miss H. Masters (*Secretary*), Prof. H. R. Hamley, Mr. E. R. B. Reynolds, Mr. N. F. Sheppard. **£5** (Leicester and Leicestershire Fund grant).

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, O.B.E., F.R.S. (*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, Mr. C. G. T. Morison (*from Section M*), 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, Sir Richard Gregory, Bt., F.R.S., Sir David Prain, C.I.E., C.M.G., F.R.S., Dr. A. B. Rendle, F.R.S., Prof. W. M. Tattersall, Dr. R. E. Mortimer Wheeler.

RESOLUTIONS & RECOMMENDATIONS.

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

From the General Committee.

That the Council be authorised to publish, either by printing *in extenso* in the Annual Report or otherwise, certain contributions to the discussion on the Galapagos Islands (*Section D, Zoology*).

From Sections A (Mathematical and Physical Sciences), C (Geology), E (Geography), and G (Engineering).

In view of the importance of co-operation with the Ministry of Health Committee on Inland Water Survey and with the joint Committee of the two Houses on Water Resources and Supplies, it is suggested that a Committee of the Council of the British Association be appointed with representatives from Sections A, C, E and G.

From Sections A (Mathematical and Physical Sciences), and G (Engineering).

(Recommendation for communication by the Council to the Ministry of Transport) :

In connection with the demonstration given at the Aberdeen Meeting, a year ago, of effective silencers made for the engines of bicycles, the Association understands that the general problem of the noise of motor transport is still under consideration by a Committee appointed by the Minister of Transport, and that until that Committee reports, no information about its work or proposals can be communicated.

While recognising that there are administrative difficulties in giving practical effect to the improvements which technically are possible, the Association expresses a hope that the Minister will make an arrangement whereby new motor vehicles may be type-tested to ensure that they comply with a certain standard of silence, even though that standard may initially be a very lenient one.

In doing so the Association draws attention to the great popular desire for improvement and also to the great extent by which many vehicles do exceed any noise level which could reasonably be defended as scientifically or technically necessary.

From Section D (Zoology).

The Committee of Section D recommends to the Council that the British Association, in view of its connection with the memory of Charles Darwin, should take the initiative in summoning a Committee of British bodies interested in the preservation of the fauna of the Galapagos Islands to discover what steps can be taken in co-operation with similar bodies in other countries, to assist in giving effect to the legislation of the Government of Ecuador in this matter.

From Section F (Economics), supported by Section J (Psychology).

The Committee recommends that the Association might indicate the importance which it attaches to the development of the social sciences by appointing a third General Secretary, who would be specially associated with this group of studies. This emphasis would convey to the public that the Association has always regarded this form of scientific inquiry as it regards the mathematical, physical, and biological sciences.

From Section G (Engineering).

Section G recommends that the desirability of adding, for those who desire to use it, a definition and specification of the lower yield-point to the specification of other properties of mild and moderately high tensile steel be brought to the notice of the British Standards Institution.

The Section submits the following specification for consideration by that Institution :

'After yield has commenced in a tensile test on a standard piece (comprising a portion that is tolerably uniform in section) and before it has spread along the whole of the portion of uniform section, the load shall be readjusted to a new, steady value (being reduced if necessary) so that yield spreads along the uniform portion while the machine continues to elongate the piece slowly. The stress value deduced by dividing the readjusted load by the initial cross-sectional area of the uniform portion of the test-piece shall be known as the lower yield-point.'

From Section H (Anthropology).

That the Council of the Association be asked to approach H.M. First Commissioner of Works with a view to the immediate scheduling of the Pin Hole Cave at Creswell Crags, Derbyshire, as an Ancient Monument, and to a proper protection of the site. At the same time it was recommended that the following cave sites in the neighbourhood be also scheduled, namely, Mother Grundy's Parlour and Langwith Cave.

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

(1) That the attention of the respective Councils for the Preservation of Rural England, Scotland and Wales be called to the serious effects upon the insectivorous bird population through the cutting of hedgerows during the breeding season, and the consequent destruction or desertion of the birds' nests ; and recommends that the said Councils urge upon local administrative authorities the desirability of suspending such operations during the nesting period.

(2) That this Conference of Delegates of Societies in correspondence with the British Association for the Advancement of Science assembled at Norwich welcomes the facilities afforded by the Town and Country Planning Act, 1932, for the preservation of individual sites and objects of scientific interest, but views with grave apprehension the indiscriminate building development over wide areas of exceptional natural beauty and scientific importance ; and requests the Council of the Association to represent to H.M. Government the urgent necessity for taking immediate steps to schedule such areas, as recommended by the National Parks Committee (Report, Section 28 b), 1931, to be developed as national parks.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.
NORWICH, 1935.

THE PRESIDENTIAL ADDRESS

FORM, DRIFT, AND RHYTHM OF THE CONTINENTS

BY

PROFESSOR W. W. WATTS, LL.D., Sc.D., F.R.S.,

PRESIDENT OF THE ASSOCIATION.

It is now sixty-seven years since the British Association enjoyed the hospitality of the city of Norwich, a privilege which is being renewed to-day under the most happy auspices.

At that meeting we find the scientific community was particularly interested in underground temperatures and tidal phenomena, in the application of the spectroscope to celestial objects, and in the discovery of the oldest Cambrian fossils and the earliest fossil mammals then known. Many papers were read on local natural history, including those on Norfolk farming and the drainage of the County and of the Fens.

In his address at the meeting the President, Sir Joseph D. Hooker, made special reference to the work of Charles Darwin : not to the *Origin of Species* which had been acrimoniously discussed by the Association on previous occasions, and notably at Oxford in 1860, but to some of the work that followed.

It should be remembered that Hooker was one of the three scientific men, representing botany, zoology and geology, whom Darwin had selected as judges with whose opinion on the soundness of his theory of the origin of species he would be content. The others were Huxley and Lyell ; and of the three Lyell was the hardest to convince, chiefly because the record of life in the past then furnished by the rocks was manifestly so incomplete and unsatisfactory that its evidence was insufficient to warrant a definite verdict.

Lyell had set out to ' treat of such features of the economy of existing nature, animate and inanimate, as are illustrative of geology,' and to make 'an investigation of the permanent effects of causes now in action which may serve as records to after ages of the present condition of the earth and its inhabitants.' By laborious study of the work of others, and by his own extensive travel and research, he had been able to enunciate, for the inorganic world, the principle of uniformitarianism, which in its original form we owe to Hutton. This principle involved that the history revealed by the rocks should be read as the effect of the slow but continuous operation of causes, most of them small, such as could be seen in action in some part or other of the world to-day. This was set in opposition to the opinion of the older geologists who had postulated a succession of catastrophes which, by flood, fire and convulsion, had periodically wrecked the world and destroyed its inhabitants; each catastrophe necessitating a new creation to provide the succession of life on the earth as it then was known.

But in the organic world Lyell, like Hutton, had failed to detect any analogous principle, and, as he rejected all the theories of transmutation of species then in vogue, he had to accept their absolute fixity; and to suppose that, as species became extinct one after another, replacement by special creations followed. And yet the reading to-day of the chapters devoted to this branch in the earlier editions of Lyell's great work produces the haunting feeling that a better explanation had only just eluded him. It was the story revealed in Lyell's work, Darwin tells us, the new conception that the earth had been in existence for vast æons of time, the proof that it had been continuously peopled by animals and plants, and that these had steadfastly advanced and improved throughout that time, which showed him the necessity for an explanation of the progression of life, and gave him the first hints of his theory. When he had enunciated this he was enabled to repay his master with the principle of organic evolution, which brought changes in the animate world into harmony with those of the inanimate.

His *Antiquity of Man* shows that by 1863 Lyell had become a convert, and he afterwards rewrote much of the second volume of his *Principles* accepting the new point of view. This change earned from Hooker a testimonial in the 1868 address which, if not unique, must certainly be one of the most magnificent ever awarded to a scientific work:

> 'I know no brighter example of heroism, of its kind, than this, of an author thus abandoning, late in life, a theory which he had regarded as one of the foundation stones of a work that had given him the highest position attainable amongst contemporary scientific writers. Well may he be proud of a superstructure, raised on the foundation of an insecure doctrine, when he finds

that he can underpin it and substitute a new foundation : and, after all is finished, survey his edifice, not only more secure, but more harmonious in proportions than before.'

Although infinitely richer than when Darwin wrote, the Geological Record still is, and must from its very nature remain, imperfect. Every major group of animal life but the vertebrates is represented in the Cambrian fauna, and the scant relics that have been recovered from earlier rocks give very little idea of what had gone before, and no evidence whatever as to the beginnings of life.

But, from Cambrian time onward the chain of life is continuous and unbroken. Type after type has arisen, flourished, and attained dominion. Some of them have met extinction in the heyday of their development ; others have slowly dwindled away ; others, again, have not finished their downhill journey, or are still advancing to their climax.

Study of the succession of rocks and the organisms contained in them, in every case in which evidence is sufficiently abundant and particularly among the vertebrates and in the later stages of geological history, has now revealed that the great majority of species show close affinities with those which preceded and with those which followed them ; that, indeed, they have been derived from their predecessors and gave origin to their successors. We may now fairly claim that palæontology has lifted the theory of evolution of organisms from the limbo of hypothesis into a fact completely demonstrated by the integral chain of life which links the animals and plants of to-day with the earliest of their forerunners of the most remote past.

Further, the rocks themselves yield proof of the geographical changes undergone by the earth during its physical history ; and indicate with perfect clearness that these changes have been so closely attendant on variation in life, and the incoming of new species, that it is impossible to deny a relation of cause and effect.

Indeed, when we realise the delicate adjustment of all life to the four elements of the ancients which environ it, air, water, earth and fire ; to their composition, interrelationships and circulation ; it is perhaps one of the most remarkable facts established by geology that, in spite of the physical changes which we know to have occurred, the chain of life has never snapped in all the hundreds of millions of years through which its history has been traced.

The physical changes with which Lyell and his successors were most closely concerned were, firstly, the formation of stratified rocks on horizontal sea-floors, situated in what is now often the interior of continents, far removed from the oceans of the present day, and thus indicating important and repeated changes in the position of land and water; and, secondly, the deformation of these flat deposits till they were rucked and ridged to build the mountain ranges.

Before and since Lyell's time geologists have devoted themselves to working out the exact and detailed succession of these stratified rocks, translating their sequence into history and their characters into terms of geography; the succession of physical conditions prevailing at the time of their formation. Further, although animals and plants migrate from place to place, the time occupied by the migrations of suitable forms is so negligible when compared with the length of the chapters of geological history that their fossil remains have proved to be the best means for correlating strata over broad stretches of the earth's surface. This correlation has converted the fragments of local history thus revealed into at least the outlines of the geological story of the world.

It was not till 1885, however, that the accumulation of data of this type was sufficient to enable the great geologist, Suess, an Austrian but born in this country, to assemble and correlate them, and to deduce from them further principles which have been the mainstay and inspiration of his successors. We owe to Hertha Sollas and her father the rendering of this great work, *The Face of the Earth*, into English; and to Emmanuel de Margerie and his colleagues a French translation enriched with a magnificent series of maps and sections such as could only have been brought together by one with the most remarkable bibliographic knowledge; a veritable recension of the original.

The nature and associations and the distribution in time and space of modern changes in the relative levels of land and sea, as detected at sea-margins and by altitude survey, and of older changes betrayed by such evidence as submerged forests and raised beaches, had convinced geologists that the unstable element was not the fickle and mobile sea, but the solid if elastic earth-crust. They naturally applied the same explanation to those encroachments of the sea in the past which had resulted in the formation of our stratified rocks. But while some investigators were content with one form of movement—that due to lateral pressure—to explain both the formation of mountains and the rise and fall of the land, others called in a different cause for the latter. Without entering into a discussion of causes it may be well for us to distinguish the orogenic or mountain-forming from the epeirogenic or continental movement.

The evidence collected by Suess proved that these last great land and sea changes had occurred simultaneously over whole continents or even wider regions. Such great submergences as those to which the Cambrian Rocks, the Oxford Clay, and the Chalk are due were of this character; while, in between, there came times of broad expansions of continental land and regressions of the sea. These changes were in his view on far too grand a scale to be compared with, or explained by, the trivial upheavals and depressions of land margins of the present day, which he showed could mostly be correlated with volcanoes or earthquakes, or with such incidents as the imposition or relief of ice-sheets on an elastic crust in connexion with glacial conditions.

It became necessary for him to replace or supplement oscillations of the earth-crust by a world-wide periodic ebb and flow of the oceans, to and from the continents; positive movements of transgression carrying the sea and its deposits over the lands, drowning them and their features under tens or hundreds of fathoms of water; and negative movements or regressions when the oceans retreated to the deeps, leaving the continents bare or encrusted with recently formed sediments.

Although the facts cried out for this generalisation Suess was at a loss to supply any mechanism competent to produce the wonderful rhythm. The problem was difficult because a liquid must maintain a horizontal, i.e. an equipotential, surface. It was manifestly impossible to withdraw from the earth, and later to replace upon it, the vast quantity of water that would be required; and, though a shifted water-level, or even a varied water-surface relative to the continents, might be caused by polar ice-caps, by redistribution of the continents carrying their local effects on gravitation, by variations in the rate of the earth's rotation, or other far-reaching causes, none of these would supply an explanation that fitted all the facts. Regressions of the sea could be to some extent explained if Suess's main postulate, that the great ocean basins had been slowly sinking throughout geological time, were granted. But this explanation only rendered more impotent the raising of ocean levels by deposits of sediment, and this was almost the only valid cause for transgressions that he had been able to suggest.

Further, it is not possible to ignore the definite relationship that exists between the pulsation of the oceans and the raising of mountains by lateral or tangential stress. Periods of positive movement or advance of the seas were times of comparative tranquillity, when tangential pressure was in abeyance. Periods of negative movement and retreat were invariably marked by the operation of great stresses by which the earth's face was ridged and wrinkled in the throes of mountain-birth.

The theory that continuous cooling and shrinkage of the interior of the earth afforded an explanation of mountain ranges and other rugosities on its surface was a legacy from the nebular hypothesis. In spite of the homely simile of a shrivelling apple, this explanation has never received a very enthusiastic welcome from geologists, though, in default of other resources, they had to make use of it. As knowledge has grown the difficulties have become insurmountable to them.

First, there is its inadequacy to explain the vast amount of lateral movement required to account for the greater mountain ranges; their rocks, originally spread over a wider area, having been folded and crushed into a narrower width. The shortening of the earth-crust thus effected has been estimated in the case of the Rocky Mountains at 29 miles, of the Himalayas at 62, the Alps at 76, and the Appalachians at the large figure of 200 miles.

Then there is the periodicity of mountain growth. The great epochs of mountain-building, such as the Caledonian, to which the chief Scottish and Welsh mountains are due, the Hercynian, responsible for the Pennine and South Wales, and the Alpine, which gave us 'the wooded, dim, blue goodness of the Weald,' were associated with vast continental development; and each was separated from the next by a period of relative inactivity lasting dozens of millions of years.

Further, there is the fact that the vigour of mountain-building, of volcanoes, and of other manifestations of unrest, has shown no sign of senility or lack of energy. The geologically recent Alpine-Himalayan range is as great, as lofty, and as complicated in structure, as were any of its precursors. The active volcanoes of Kilauea, Krakatao, or St. Pierre, and those recently extinct in Northern Ireland and the Scottish Isles, were as violent and efficient as any of those of the Palæozoic Era. The earth is 'a lady of a certain age,' but she has contrived to preserve her youth and energy as well as her beauty.

But it was when Lord Kelvin's dictum struck from geology its grandest conception, time, that it became vital to re-examine the position. He had demonstrated that, if the earth had been continuously cooling down at its present rate, its surface must have been too hot for the existence of life upon it a limited number of million years ago. The concept of geological time, indicated by Hutton in his famous saying that in this enquiry 'we find no vestige of a beginning—no prospect of an end,' had been confirmed by data accumulated through the painstaking researches of a host of competent and devoted observers all over the world. To them, familiar with the tremendous changes, organic and inorganic, that the earth had passed through since Cambrian time, it was wholly impossible to compress the life story of the earth, or the history of life upon it, into a paltry 20 or 30 million years. The slow growth and slow decay of mountain range after mountain range, each built out of, and in some cases upon, the ruins of its predecessor ; the chain of slowly evolving organisms, vast in numbers and infinite in variety ; told plainly of long æons of time. And the duration of these aeons can be dimly realised when it is recalled that, within a small fraction of the latest of them, man, with the most primitive of implements and the most rudimentary culture, has succeeded in penetrating to the uttermost corners of the world, and developed his innumerable languages and civilisations.

Huxley, as our representative, took up the challenge in his address to the Geological Society in 1869, and asked the pertinent question ' but is the earth nothing but a cooling mass " like a hot water jar such as is used in carriages " or " a globe of sandstone " ? ' And he was able to point out at least some agencies which might regenerate the earth's heat or delay its loss.

So it is only fitting that the great physicist, who imposed a narrow limit to geological time, should have prepared the way for those who have proved that the earth possesses in its radioactive substances a ' hidden reserve ' capable of supplying a continuous recrudescence of the energy wasted by radiation, thus lengthening out the time required to complete its total loss. These later physicists have given us time without stint ; and, though this time is the merest fraction of that envisaged by cosmogonists and astronomers, we are now so much richer than our original estimates that we are embarrassed by the wealth poured into our hands. So far from the last century's urge to ' hurry up our phenomena,' we are almost at a loss for phenomena enough to fill up the time.

The far-sighted genius of Lord Rutherford and Lord Rayleigh first saw the bearing of the rate of disintegration of radioactive substances in the minerals of rocks on the age of the parts of the earth-crust built of them. The extension and supplementing of this work by Joly, Holmes, and others, has now enabled us to look to the disintegration of uranium, thorium, and potassium, as the most promising of many methods that have been used in the endeavour to ascertain the age of those parts of the earth-crust that are accessible to observation. These methods also promise a means of dating the geological succession of Eras and Periods in terms of millions if not hundreds of thousands of years.

The decline and early death to which Lord Kelvin's dictum had condemned the earth, according so little with the vigour displayed in its geological story, is now transformed into a history of prolonged though not perennial youth. It was for Joly, of whose work the extent, variety, and fruitfulness are hardly yet fully appreciated, to take the next step and see in the release of radioactive energy a mechanism which could drive the pulse that geologists had so long felt, and that Suess had so brilliantly diagnosed. As Darwin found the missing word for Lyell, so Joly in his theory of Thermal Cycles has indicated the direction of search for a mechanism to actuate the rhythm of Suess.

In Joly's conception the running down of the earth's energy, though a continuous process, was, through the intervention of radioactivity, converted into a series of cycles, during each of which relative movements of sea and land must occur; downward movements of the continents, associated with positive encroachments of the sea; upward movements, with retreat of the sea, the formation of wide land masses, and the ridging of strata to form mountain ranges. Thus he forged a link that could unite the continental or epeirogenic movement with orogenic or mountain movement.

The visible parts of mountains and continents, as well as their lower and hidden portions, or 'roots,' are made of comparatively light rocks. In order to stand up as they do their roots must be embedded in denser matter, in which they 'float' like ice-bergs in water. A far larger mass must exist below than is visible above, and the bigger the upstanding part the bigger the submerged root. Over the larger area of the ocean floor, on the other hand, the thickness of material of low density must be very slight, and the denser layer must come close to the surface.

The study of earthquakes, to which the Seismology Committee of the British Association has made outstanding contributions, has yielded, from the times taken in transmission of vibrations through the earth, the best information as to the nature and state of the interior. It has proved that the dense layer is solid at the present time. It is probably no coincidence that the earth is also but just recovering from what is possibly the greatest period of mountain-building, if not the greatest negative movement of ocean retreat, that it has ever experienced.

But solidity cannot be the permanent condition of the substratum. Heat is generated in it by its own radioactivity, but, according to the terms of the hypothesis, cannot escape, in consequence of the higher temperature generated in the continental rocks which cover it. It is therefore retained in the substratum and stored as latent heat of liquefaction, so that, within a period which has been calculated approximately in millions of years, complete melting of the sub-crust must ensue.

The resulting expansion of the liquefied stratum will have at least two effects of great importance to us. In the first place the unexpanded superficial layers will be too small to fit the swelling interior. They will, therefore, suffer tension, greater on the ocean floor than on land, and cracking and rifting will occur, with intrusion and extrusion of molten rock. In the second place the continental masses, now truly floating in a substratum which has become fluid and less dense than before, will sink deeper into it, suffering displacement along the rift cracks or other planes of dislocation. As a result the ocean waters, unchanged in volume, must encroach on the edges of the continents, and spread farther and farther over their surfaces.

Thus we have the mechanism which Suess vainly sought, causing positive movements of the oceans, their waters spreading over wide stretches of what was formerly continental land, and laying down as sediment upon it the marine stratified rocks which are our chief witness of the rhythmic advances of the sea.

This condition, however, cannot be permanent, for by convection of the fluid basic substratum, supplemented by the influence of tides within it, and the slow westward tidal drag of the continental masses towards and over what had been ocean floor, there will now be dissipation of its heat, mainly into the ocean waters, at a rate much faster than it has been or could be accumulated. Resolidification ensues, and again there are two main consequences. First, the stratum embedding their roots having now become more dense, the continental masses rise, and as they do so the ocean waters retreat from their margins and epicontinental seas, leaving bare as new land, made of the recently deposited sediments, the areas previously drowned. Secondly, the expanded crust, left insufficiently supported by the withdrawal of shrunken substratum, will suffer from severe tangential stress, and, on yielding, will wrinkle like the skin of a withering apple. The wrinkles will be mountain ranges, formed along lines of weakness such as those at continental margins ; and they will be piled up and elevated to suffer from the intense erosion due to water action upon their exposed and upraised rocks.

In this, again, we have a mechanism which supplies what was needed by Suess, and one, moreover, which secures the required relationship between continental and mountain movement, between the broader extensions of continental land and the growth of mountains with their volcanoes and earthquakes and the other concomitants of lateral thrust.

Thus a Thermal Cycle may run its full course from the solid substratum, through a period of liquefaction accompanied by crustal tension, back to solidification and an era of lateral stress : and the stage is set for a new cycle.

Professor Arthur Holmes, in checking Joly's calculations, has concluded that the length of the cycles in a basic rock substratum should occupy from 25 to 40 million years, a period much too short to fit the major periods of mountain movement, as determined by him from the radioactivity of minerals contained in the rocks. On this evidence the Alpine movement should date back from 20 to 60 millions of years ago, the Hercynian 200 to 250 millions, and the Caledonian from 350 to 375 million years.

In a preliminary attempt to modify Joly's hypothesis Holmes postulated the occurrence of similar, but longer cycles (Magmatic Cycles) in a denser, ultrabasic layer underlying the basic one, the rhythm of which would be nearer to 150 million years. The shorter cycles due to the basic layer are held in part responsible for periods of minor disturbance, and also to account for the individual variations in effect, duration, and intensity of the larger ones. Each of the later movements has also evidently been limited and conditioned by the results of foregoing ones, and especially by areas of fracture and weakness on the one hand, and by large stable masses composed of rocks intensely consolidated, or already closely packed, on the other.

More recently Holmes has developed the possibility that the loss of heat is mainly due to convection in the liquid substrata, and that convection is the leading cause of the drifting and other movements of the crust, and the disturbances that have occurred in it. He says :—

> 'Although the hypothesis involving sub-crustal convection currents cannot be regarded as established, it is encouraging to find that it is consistent with a wide range of geological and geophysical data. Moreover, it is by no means independent of the best features of the other hypotheses. It requires the local operation of thermal cycles within the crust, and it necessarily involves contraction in regions where crustal cooling takes place. It is sufficiently complex to match the astonishing complexities of geological history, and sufficiently startling to stimulate research in many directions.'

The phenomena are difficult to disentangle as the number of operating causes has been so great and many of them are not fully understood. But, underlying them all there is unquestionably the pulse within pulse which Suess saw and of which Joly pointed the way to explanation.

The view at which we have arrived is neither strictly uniformitarian nor strictly catastrophic, but takes the best from each hypothesis. As Lyell showed, most of the phenomena of geology can be matched somewhere and sometime on the earth of to-day; but it would appear that they have varied in place, intensity, phase, and time. And, as Lyell was driven to accept *evolution* to explain the history of life on the earth, so must we employ the same word to express the life-processes of the earth itself, as was suggested by Huxley in 1869 and strongly advocated by Sollas in 1883.

The contrast in outline and structure between the Atlantic and Pacific Oceans had long been noted when Suess formulated and used the differences as the basis of his classification.

The Pacific is bounded everywhere by steep slopes, rising abruptly from profound ocean depths to lofty lands crowned with mountain ranges, parallel to its shores and surrounding its whole area. On the American side the Coast Range is continued by the Andes. On the Asiatic side chains of mountainous peninsulas and islands, separated from the continent by shallow inland seas, extend in festoons from Kamchatka and Japan to the East Indies, eastern Australia and New Zealand. This mountain ring, as Charles Lapworth said, 'is ablaze with volcanoes and creeping with earthquakes,' testifying that it has been recently formed and is still unfinished.

The Atlantic Ocean, on the other hand, is not bordered with continuous ranges, but breaks across them all: the Scottish and Welsh ranges, the Armorican range, the continuation of the Pyrenees and Atlas; and, on the American side, the uplands of Labrador, Newfoundland and the eastern States, and the hill ranges of Guiana and Brazil. The Atlantic is in disconformity with the grain of the land, while the Pacific conforms with it. The Pacific has the rock-folds of its ranges breaking like ocean waves towards it as though the land were being driven by pressure to advance upon it, while the Atlantic recalls the effects of fracture under tension.

The middle and southern edges of the Atlantic, however, agree to some extent with the Pacific type. The Caribbean Sea, with the Antilles and the rest of its border girdle, recalls the similar structure of the Mediterranean, as it stretches eastwards, with breaks, to the East Indian Archipelago; while the Andes are continued to Antarctica in a sweeping curve of islands. The rest of the Indian Ocean is of Atlantic type, as seen in the shores of eastern Africa and western Australia.

Another feature of the Atlantic is the parallelism of much of its eastern and western coasts, the meaning of which has often attracted the speculations of geologists and geographers. With a little stretch of the imagination, and some ingenuity and elasticity of adjustment, plans or maps of the opposite sides may be fitted fairly closely, particularly if we plot and assemble the real edges of the continents, the steep slopes which divide the 'shelves' on which they stand from the ocean depths. This has suggested the possibility that the two sides may once have been united, and have since broken and drifted apart till they are now separated by the ocean.

This view, outlined by others, has been emphasised by Wegener and dealt with by him in full detail in his work on *The Origin of Continents and Oceans*, and it now plays a leading part in what is known as the Wegener theory of continental drift. The hypothesis is supported by the close resemblances in the rocks and fossils of many ages in western Europe and Britain to those of eastern North America; by community of the structures by which these rocks are affected; and by the strong likeness exhibited by the living animals and plants on the two sides, so that they can only be referred to a single biological and distributional unit, the Palæarctic Region.

The hypothesis, however, did not stop at this; and in the South Atlantic and certain other areas Wegener and his followers have also given good reasons for believing that continental masses, once continuous, have drifted apart.

Broad areas in southern Africa are built of rocks known as the Karroo Formation, of which the lower part, of late Carboniferous age, is characterised especially by species of the strange fern-like fossil plants Glossopteris and Gangamopteris. Associated with them are peculiar groups of fossil shells and fossil amphibia and reptiles. Similar rocks, with similar associations and contents, in Peninsular India have been named the Gondwana Formation. Comparable Formations also occupy large regions in Australia, Tasmania and New Zealand, in Madagascar, in the Falkland Islands and Brazil, and in Antarctica.

The correspondence between these areas is so close that Suess supposed they must at that date have been connected together by lands, now sunk beneath the sea, and he named the continent thus formed Gondwanaland after the Indian occurrences. The break-up of this land can be followed from a study of the rocks, and it was a slow process, its steps occupying much of Mesozoic time. Dr. A. L. du Toit's comparison of South African rocks with those of Brazil and elsewhere in South America favours even a closer union than this between the units now scattered.

One of the most remarkable features shown by these rocks in all the areas mentioned, but to varying extents, is the presence of conglomerates made of far-travelled boulders, scratched like those borne by the modern ice-sheets of Greenland and the Antarctic, associated with other deposits of a glacial nature, and often resting upon typical glaciated surfaces. There is no possible escape from the conclusion that these areas, now situated in or near the tropics, suffered an intense glaciation. This was not a case of mere alpine glaciers, for the land was of low relief and not far removed from sea-level, but of extensive ice-sheets on a far larger scale than the glaciation of the northern parts of the new and old worlds in the Pleistocene Ice Age. I have never seen any geological evidence more impressive or convincing than that displayed at Nooitgedacht, near Kimberley; while the illustrations and other evidence published by David and Howchin from Australia are equally striking.

Du Toit's work on these glacial deposits brings out two remarkable facts; first, that the movement of the ice was southerly, pole-ward and away from the equator, the opposite to what would be expected, and to the direction of the Pleistocene ice-movement; secondly, that the ice in Natal invaded the land from what is now sea to the north-east.

When it is realised that at this period there is no evidence of glacial action in northern Europe or America, but a climate in which grew the vegetation that formed the coal seams of our Coal Measures, it is clear that we are not dealing with any general refrigeration of the globe, even if that would produce such widespread glaciation: we are face to face with a special glaciation of Gondwanaland.

On both sides of the Atlantic these glacial episodes in Carboniferous times were followed by dry and desert climates in Triassic time, and these by violent volcanic outbursts. Nor are the rocks alike only in mode of formation, the structures by which they are traversed correspond; while even in details there is remarkable agreement, as in the peculiar manganese deposits, and the occurrence of diamonds in 'pipes' of igneous rock, both east and west of the Ocean.

Rather than face the difficulties presented by the subsidence of lands connecting the severed portions of Gondwanaland, as pictured by Suess, Wegener has preferred, and in this he is supported by Du Toit and many other geologists, to bring into contact these severed parts, which could be fitted together as nearly as might be expected, considering the dates of severance. Du Toit's map of the period places South America to the west and south of South Africa, Madagascar and India to the east, Antarctica to the south, and Australia farther to the south-east. Such a grouping would form a continent much less wide in extent than that envisaged by Suess, and would offer some explanation of the more remarkable features of the glaciation in the several areas, as well as the problems of the rocks, fossils, and structures involved.

In its application to the geology of Gondwanaland the modified hypothesis of Wegener cuts a Gordian knot; but it still leaves a great climatal difficulty, unless we take his further step and conceive that at this date the terrestrial south pole was situated within Gondwanaland. No shift in the axis on which the earth rotates would, of course, be possible, nor is it postulated: only a drifting at that date of continental land across the pole.

If a hypothesis of drift be admitted for Gondwanaland, it would be illogical to deny its application to other regions, including the north Atlantic. I have already mentioned some facts in its favour.

Others are the resemblances of all sedimentary rocks on the two sides from the Cambrian to the Ordovician, and from the Devonian to the Trias ; the links between the structures of the land, as, for instance, between Ireland and Newfoundland ; and the instance given by Professor Bailey in his address to Section C in 1928. As Bailey then pointed out, the great Caledonian range which crosses Scotland, northern England and Wales from north-east to south-west on its course from Scandinavia is affected and displaced by the east to west Armorican (Hercynian) chain extending across from Brittany to South Wales. 'The crossing of the chains, begun in the British Isles, is completed in New England' ; and from here the Armorican structure continues its westerly course. This is where it should cross if the continent of North America were brought back across the Atlantic and placed in the position which, according to Wegener, it would fit into in the European coast ! Can the Pilgrim Fathers have ever dreamed of such a link between the Old England and the New ?

The hypothesis of continental drift gave rich promise of solving so many difficult problems that it was hailed by many classes of investigators almost as a panacea. Geographers have seen in it an explanation of the forms of continents and the position of peninsulas, islands and mountains ; meteorologists have found it the solution of some of the problems of past climates and their anomalies of distribution over the world ; biologists hope to get help with the intense complexities in the distribution of forms of life and many strange facts in migration, and palæontologists with similar difficulties among the ancient faunas and floras as revealed by their fossil remains ; geodesists have welcomed escape from the rising and sinking of the crust, so difficult to reconcile with the demands of isostatic equilibrium ; and it has been already stated that drift forms a vital factor in Joly's thermal cycles.

But there has been no lack of criticism in all these directions. It has been assailed on the one hand for the detail attempted in its geographical restorations, and on the other hand for its vagueness. Prof. Schuchert quotes Termier as saying that it is 'a beautiful dream, the dream of a great poet. One tries to embrace it, and finds that he has in his arms but a little vapour or smoke : it is at the same time alluring and intangible.' It has been objected that 'no plausible explanation of the mechanics involved has been offered' ; that the continental connexions postulated present by no means so close a match, when fitted together, as has been claimed, in the structure or the nature of either igneous or sedimentary rocks ; that there is good evidence of extensive vertical movements in recent earthquakes, in the accumulation of tremendous thicknesses of sediment indicative of shallow-water from base to summit, and in the growth of coral reefs; that Central America and the Mediterranean are a difficult obstacle; and that the known distribution of the Karroo fossil reptiles is not by any means what the hypothesis demands.

If the idea of drift be accepted it cannot be regarded as a royal road out of all our difficulties, nor can it be the only form of earth-movement to be reckoned with. The late J. W. Gregory, whose life was sacrificed to geological discovery, has studied exhaustively the geological history of the Atlantic and Pacific Oceans, both as revealed by the sedimentary rocks and fossils on their borders, and by the distribution of life to-day. He finds that, according to our present knowledge, in the two oceans, facilities for migration have fluctuated from time to time, periods of great community of organisms alternating with periods of diversity. Again, at some times connexion seems to have been established north of the equator, at others to the south; and we cannot ignore the possibility of migration across polar lands or seas when terrestrial climates have differed from the present. The facts of life distribution are far too complex to be explained by any single period of connexion followed by a definite breaking apart, even if that took place by stages. Mrs. Reid, too, has pointed out that resemblances between the Tertiary floras of America and Europe actually increased at the time when the Atlantic should have been widening. Unless continental drift has been a more complicated process than anyone has yet conceived, it seems impossible to escape from some form of the 'land bridges' of the older naturalists:

> 'Air-roads over islands lost—
> Ages since 'neath Ocean lost—'

We have no right to expect greater simplicity in the life of a planet than in that of an organism.

As the question of drift must in the last appeal be one of fact, it is not unnaturally expected that the real answer will come from measurements of longitude and latitude with greater exactness and over periods longer than has yet been possible. None of the measurements hitherto made has indicated variations greater than the limits of errors of observation. Two things, however, may militate against a definite answer from this source. Many parts of the crust, such as the shield-like masses of Archæan rock, may have completed their movement, or be now moving so slowly that the movement could not be measured. Careful selection of locality is essential, and at present we have little guidance. Also, as the displacement of crust must be dependent on the condition of its substratum, it will be a periodic phenomenon and the rate of movement may vary much in time. According to the theory of thermal cycles the sub-crust is at present solid, and may not permit of drift.

Drift, according to Joly and Holmes, is a cyclical phenomenon; if present-day observations were to give a negative result they would not necessarily disprove it.

The occurrence of recumbent rock-folds, and nearly horizontal slides or 'nappes' in mountain regions, gives positive proof that parts of the upper earth-crust have moved over the lower. In the North-west Highlands of Scotland a sliding of at least ten miles was proved by Peach and Horne, and in Scandinavia it amounts to sixty miles. For mountain packing as a whole the figures already given are far larger, while in Asia Argand has stated that packing of over 2,000 miles has occurred. Thus, when all is said and done, movements on a colossal scale are established facts, and the question of the future is how far we shall accept the scheme of drift due to Wegener, or one or other of the modifications of it. It is for us to watch and test all the data under our own observation, feeling sure that we shall have to adapt to our own case Galileo's words 'e pur si muove.'

Ever since it was realised that the inclination and folding of rocks must be attributed to lateral or tangential stress and not solely to uplift, shrinkage of the interior of the earth from its crust has been accepted as the prime mover, and whichever of the current theories we adopt we cannot deny the efficacy of so powerful a cause.

The general course of events in the formation of a mountain range is fairly well known: the slow sinking of a downfold in the crust during long ages; the filling of this with sediment *pari passu* with the sinking, and associated softening of the sub-crust due to accumulated heat; the oncoming of lateral pressure causing wave-like folds in the sediments and the base on which they rest; the crushing of folds together till, like water waves, they bend over and break by over-driving from above or, it may be, under-driving from below; fracture of the compressed folds and the travelling forward for great distances of slivers or 'nappes' or rock, generally of small relative thickness but of great length and breadth, and sliding upon floors of crushed rock; the outpouring and intrusion of igneous rocks, lubricating contacts and complicating the loading of the sediments; metamorphism of many of the rocks by crystallisation at elevated temperatures and under stress, with the development of a new and elaborate system of planes of re-orientation and movement; and elevation of the whole, either independently or by thickening with compression and piling up to bring about a fresh equilibrium.

Such a course of events would be brought about by lateral pressure developed during the consolidation phase of each of the thermal or magmatic cycles. At each period of their building, mountains have arisen along lines of weakness in the crust, especially coast lines and the steep slopes marking the limits between continents and ocean basins. This is consistent with Joly's theory that the thrust of ocean beds against land margins is the cause.

But the advocates of continental drift point to the siting of ranges across the paths along which the drifting movement is supposed to have occurred, and they consider that the moving masses are responsible ; and indeed that the ridging and packing of the crust has in the end checked and stopped the movement. They note that the great western ranges of America occur in the path of any western drift of that continent, the Himalayas in the course of the postulated movement of India, the East Indies in front of Australia ; and that the Alpine ranges of Europe may be linked with the crushing of Africa towards the north.

The ' nappes ' of rock, cut off from their origin and sliding for dozens of miles, are a constant source of wonder to all who have considered the mechanics of mountain formation. They are so thin as compared with their great length and breadth, that it seems impossible to imagine them moved by any force other than one which would make itself felt throughout their every particle. Such a force is gravitation, and it is of interest that some Alpine geologists and Dr. Harold Jeffreys have used it in explanation of them. Professor Daly has also adopted gravitation on an even greater scale in his theory of continental sliding : and one cannot fail to notice the increasing use of the term ' crust-creep ' by those working on earth-movement.

Is there no other force, comparable in its method of action to gravitation, but capable of producing movement of the earth-crust in a direction other than downhill ? Is it not possible, for instance, that the tidal influence of the moon and sun, which is producing so much distortion of the solid earth that the ocean tides are less than they would be otherwise, and, dragging always in one direction is slowing down the earth's rotation, may exert permanent distorting influence on the solid earth itself ? May it not be that such a stress, if not sufficiently powerful to produce the greater displacements of continental drift and mountain-building, may yet take advantage of structures of weakness produced by other causes, and itself contribute to the formation of nappes and to other movements of a nature at present unexplained ?

Our knowledge of geology has been gained by the survey of the rocks, the study of their structures, and the delineation of both upon maps and sections. This work is being accomplished by geologists all over the world, and this country and its dependencies have contributed their full share. It is therefore opportune to note that there has just been celebrated the Centenary of the Geological Survey of Britain and, with it, the opening of the new Geological Museum at South Kensington.

A century ago H. T. de la Beche, one of the devoted band of pioneer workers then studying the geology of the country, offered to 'affix geological colours to the new maps of Devon and Cornwall' then in course of issue by the Ordnance Survey. His offer was accepted, and, at his own expense and on his own feet, he carried out a geological survey of some 4,000 square miles. In 1835 he was appointed to continue this task, with a small salary and a few assistants. Thus was started the first official geological survey, an example widely followed by other nations and dominions. De la Beche's conception included also a Museum of economic and practical geology, a Library, a Record of Mines, for which he secured support from a strong Committee of the British Association in 1838, and a School of Mines for the scientific and technical education of those to be employed in the survey or exploitation of mineral resources. In these objects, and especially the last, he was warmly supported by the Prince Consort. He lived to see his visions all come true, as he collected round himself that wonderful band of surveyors, investigators, writers, and teachers, which included such men as Playfair, Logan, Ramsay, Aveline, Jukes, Forbes, Percy, Hooker, and Huxley.

Some of the schemes he planned have budded off and grown into large and important entities, rendering conspicuous service to scientific record, education, and research. But the main duties of the Geological Survey remained with it, and have been carried on for a century. These are to map the geology of the country on the largest practicable scale, to describe and interpret the structure of the land, to preserve the evidence on which conclusions have been founded, and to illustrate for students and other workers the geology of the country and its applications to economics and industry. The broad detail of the structure of the whole country is now known, but much new work must be done to keep abreast of or to lead geological thought. For instance, the study of the cloak of 'superficial deposits,' which often cover and conceal the structure of the more solid rocks below, is essential for the proper understanding of soils and agriculture; and a knowledge of the deep-seated geology of the country, which is often widely different from that nearer the surface and thus very difficult to interpret, is vital to the community for the successful location and working of coal and iron, and for tracing supplies of water and oil and other resources at depth.

Evolution of life on the earth has been by no means uniform; there have been periods of waxing and waning which may be attributed to geographical, climatological, and biological influences. The development of large land areas, ranged longitudinally or latitudinally, the invasion of epicontinental seas, the isolation of mediterraneans or inland seas, the splitting of continental areas into archipelagos or the reunion of islands into continuous land, the making of barriers by the rearing of mountain chains or the formation of straits or arms of the sea, the oncoming of desert or glacial climates; all such factors and many others have been of importance in quickening or checking competition, and in accelerating or retarding the evolution of life.

Probably, however, even greater effects have followed the interaction of groups of biological changes on one another. As an instance I might recall Starkie Gardner's estimate of the results following upon the first appearance of grasses in the world. This seems to have been not earlier than Eocene, and probably late Eocene times. By the Oligocene they had made good their hold, peculiarities in their growth and structure enabling them to compete with the other vegetation that then existed; and gradually they spread over huge areas of the earth's surface, formerly occupied by marsh, scrub, and forest. They have, as Ruskin says, 'a very little strength . . . and a few delicate long lines meeting at a point . . . made, as it seems, only to be trodden on to-day, and to-morrow to be cast into the oven'; but, through their easy growth, their disregard of trampling and grazing, and by reason of the nourishment concentrated in their seeds, they provided an ideal and plentiful source of food. On their establishment we find that groups of animals, which had previously browsed on shrubs and trees, adopted them, with consequent alterations and adaptations in their teeth and other bodily structures. To follow their food from over-grazed or sun-scorched regions they required to be able to migrate easily and quickly, and it was essential for them to discard sedentary defence and to flee from threatened danger. Such defence as was possible with heels, teeth, or horns, they retained; but the dominant modifications in their organisation were in the direction of speed as their most vital need.

Side by side with this development, and in answer to increasing numbers, came bigger, stronger, and speedier carnivores, to feed on prey now so much more abundant, but more difficult to catch.

The answer of the grass-feeders, with their specialised hoofs, teeth and bones, better suited to flight than fight, was to seek safety in numbers, and thus develop the herd instinct, with its necessity for leadership and discipline ; but this, in turn, provoked a like rejoinder from some types of their enemies.

When it is remembered how much of the meat and drink and life of mankind is bound up with the grasses, including wheat, maize, millet and other grains, sugar-cane, rice and bamboo, we must realise how close is his link with the development just outlined. Practically his whole food supply is provided by them, either directly by the agriculturist who grows little else but grasses, or indirectly by the herdsman whose domestic animals are fed chiefly on the same food. Nor must we forget that almost every one of our domesticated animals has been derived from the gregarious types just mentioned, which have accepted the leadership of man in place of that of their own species.

It is perhaps not too much to say that the magnificent outburst of energy put out by the earth in the erection of the Alps, Andes, and Himalayas in Tertiary times was trivial in its influence for man's advent and his successful occupation of the earth in comparison with the gentle but insidious growth of 'mere unconquerable grass' and its green carpet of 'wise turf' which in some form clothes by far the greater part of the land of the globe.

The kind of developmental reaction of which this is but a single example must clearly have had influence on bodily features other than bones and horns, teeth and claws, speed and strength ; and one of the most striking has been on intellectual development and the size and shape of brain.

We do not, and perhaps can never, know the quality of the material of which the brains of fossil creatures was made, for we have no instrument to pierce the veil of time as the spectroscope has penetrated the abysm of space. But we are even now learning something about their shapes and convolutions, and more about their mass in its relation to the size of the bodies controlled ; from the time of the earliest Ordovician fishes, through the history of the amphibia, reptiles, birds, and mammals, up to man himself.

The brain of those gigantic if somewhat grotesque reptiles the dinosaurs, the tyrants of Mesozoic time, is relatively tiny. In Diplodocus, 80 feet in length and 20 tons in weight, the brain was about the size of a large hen's egg. It is true that there was a big supplementary sacral ganglion which may have taken chief charge of locomotion and helped to secure co-ordination throughout the hinder part of its huge length and bulk ; but of true brain there was not more than a quarter of an ounce to control each ton of body and limb; and we begin to understand why they lost the lordship of creation.

The proportion of brain to body improved in those reptiles which took to flying, possibly in relation to their acquisition of warm blood, and in the birds evolved from reptiles; but it is only in mammals that a marked advance is seen. Here the brain of Uintatherium, a great rhinoceros-like animal of Eocene date, weighing 2 tons, was about the size of that of a dog. This proportion of half a pound of brain to each ton of body shows how far the mammals had gone, and still had to go.

A 12-stone man of the present day has about $3\frac{1}{2}$ pounds of brain—an amount not far short of half a hundredweight per ton.

Even though we can know nothing of its material, this steadfast growth in the guiding principle, through the millions of centuries that have gone to its development, is surely one of the most remarkable conclusions that we owe to geology. Of all the wonders of the universe of which we have present knowledge, from the electron to the atom, from the virus and bacillus to the oak and the elephant, from the tiniest meteor to the most magnificent nebula, surely there is nothing to surpass the brain of man. An instrument capable of controlling every thought and action of the human body, the most intricate and efficient piece of mechanism ever devised; of piercing the secrets and defining the laws of nature; of recording and recalling every adventure of the individual from his cradle to his grave; of inspiring or of ruling great masses of mankind; of producing all the gems of speech and song, of poetry and art, that adorn the world, all the thoughts of philosophy and all the triumphs of imagination and insight: it is indeed the greatest marvel of all.

And when we contemplate the time and energy, the sacrifice and devotion, that this evolution has cost, we must feel that we are still far from the end of this mighty purpose: that we can confidently look forward to the further advance which alone could justify the design and skill lavished on this great task throughout the golden ages that have gone.

SECTION A.—MATHEMATICAL AND PHYSICAL SCIENCES.

THE STORY OF ISOTOPES

ADDRESS BY

F. W. ASTON, Sc.D., D.Sc., LL.D., F.I.C., F.R.S.

PRESIDENT OF THE SECTION.

This chapter in the history of science contains much to interest the philosopher and offers many illustrations of that interplay of theory and experiment by which advance takes place. Theory is the scaffolding of science, and just as in ordinary building operations, though some parts of it may only be used for a short time before removal, others may function for so long a period that they may well be mistaken for the permanent structure itself. The postulate of Dalton (1803) that atoms of the same element are equal in weight is a good example of very permanent scaffolding. For over a hundred years it was practically undisputed and on it was founded the major part of atomic chemistry.

About ten years later Prout made the more speculative suggestion that all atoms were made up of primordial particles which he thought might be atoms of hydrogen. On this view the weights of all atoms must be expressed as whole numbers, and if, as Dalton postulated, the atoms of any particular element were all equal in weight, the atomic weights and combining ratios of all elements must be whole numbers also. Chemists soon found that this was certainly not in agreement with experiment; the more results they obtained the more impossible it was to express the atomic weights of *all* the elements as whole numbers, and of the two theories Prout's was the one to be abandoned. In this decision they were perfectly justified for, as it cannot be too often emphasised, it is more important for a scientific theory to be simple than for it to be true. Besides it was of little practical importance to chemists if atoms were not equal in weight so long as in all the ordinary operations of chemistry they behaved as though they were.

Crookes, however, thought that he had found evidence that they did not so behave, and in his remarkable Presidential Address to Section B, at Birmingham in 1886, he says: 'I conceive, therefore, that when we say the atomic weight of, for instance, calcium is 40, we really express the fact that, while the majority of calcium atoms have an actual atomic weight of 40, there are not a few which are represented by 39 or 41, a less number by 38 or 42, and so on.' Later, he developed this idea in connection with his pioneer work on the rare earths. He called the components 'meta-elements,' but unfortunately for his reputation as a prophet the experimental results on which his idea was founded were later proved to be fallacious, and Dalton's postulate was reinstated as an article of scientific faith more firmly than ever.

Its overthrow, deferred for another twenty years, was one of the many atastrophic results of the tremendous shock due to the discovery of radio-activity. In the rapid development of this, with which the school of Rutherford is so closely associated, the effects of individual atoms, as opposed to those of vast multitudes, were observed for the first time. Chemists could examine elements in the actual process of the making. In 1906 Boltwood observed that his newly discovered element ionium was so similar to thorium that if, by chance, their salts became mixed it was impossible to separate them by any chemical process. Other chemical identities among the products of radio-activity were soon observed and the most painstaking and delicate methods failed to effect or detect the slightest separation.

Discussing these, Soddy, in 1910, boldly stated: 'These regularities may prove to be the beginning of some embracing generalisation, which will throw light, not only on radio-active processes, but on elements in general and the Periodic Law. . . . Chemical homogeneity is no longer a guarantee that any supposed element is not a mixture of several of different atomic weights, or that any atomic weight is not merely a mean number.' The generalisation underlying his views was the law connecting radio-activity and chemical change, in the discovery and enunciation of which he played so prominent a part. This law asserts that a radio-active element when it loses an alpha particle goes back two places in the periodic table; when it loses a beta particle it goes forward one place. It follows that by the loss of one alpha particle followed by two beta particles, the atom, though weighing four units less, will have regained its nuclear charge and returned to its original place.

Such changes result in bodies to which Soddy applied the following words: 'The same algebraic sum of the positive and negative charges in the nucleus when the arithmetical sum is different gives what I call "isotopes"[1] or "isotopic elements" because they occupy the same place in the periodic table. They are chemically identical, and save only as regards the relatively few physical properties which depend upon atomic mass directly, physically identical also.' It was fortunately possible to put these revolutionary views to an experimental test in the case of one element—lead, the final inactive product of the thorium and uranium transformations. Uranium of atomic weight 238 loses eight alpha particles to become lead of atomic weight 206, while thorium of mass 232 loses six to become lead of atomic weight 208. Soddy maintained that the lead found in uranium minerals should be lighter, and that in thorium minerals heavier than ordinary lead of atomic weight 207·2.

The complete chemical inseparability of the heavy isotopes formed in radio-active processes passed the most stringent tests and was soon accepted. It was later put to a most ingenious and elegant use by Paneth and Hevesy, who, by adding to an inactive element a small quantity of its radio-active isotope, gave it, so to speak, an indelible label by which its movements and reactions could be followed by the almost infinitely

[1] Of recent years the word 'isotope' has changed its meaning, and is now used, for lack of another, to designate any atomic species. In the same way the meaning of the word 'mass-spectograph' applied by me to one special type of instrument has now been extended to any form capable of analysing mass-rays. Such changes, though troublesome, are inevitable for the language of science is a living rather than a dead one.—F. W. A.

delicate methods of radio-activity. These 'radio-active indicators' have been applied to problems of chemistry, otherwise unapproachable, such as the rates of molecular diffusion in the liquid state and the movements of compounds of heavy elements in the sap of living organisms.

The application of the theory of isotopes to elements generally was another matter. The idea that ordinary elements could consist of atoms of different mass received great opposition, for it appeared quite incompatible with such facts as the constancy of chemical atomic weight, the apparently perfect homogeneity of elementary gases, and the almost incredible invariability of such accurately measurable constants as the electrical conductivity of mercury independent of its source. This reluctance of orthodox science to accept the theory was, I think, a perfectly natural and healthy reaction. Criticism very seldom destroys enthusiasm and is usually the best stimulant to further research, whereas too immediate a welcome of a new and sensational idea, the outstanding fault of the lay press in dealing with science, may lead to waste of effort. It appears to me a very regrettable thing that, of recent years, it has been repeatedly necessary for experienced research workers to waste their time on the thankless task of disproving the claims of well-meaning victims of self-deception, of whom Blondlot, with his N-rays, is the classical example.

The only satisfactory criterion, a method of comparing the masses of individual atoms, was at the time in process of development. This was Sir J. J. Thomson's 'parabola' method of positive ray analysis, and here at first all the results seemed to support Dalton's postulate, indeed the appearance on a sensitive screen of a clear-cut parabolic streak, caused by the impact of the atoms of hydrogen, was the first experimental proof that it was in any sense true of any element, previously it had been purely an article of scientific faith. Hydrogen, carbon, nitrogen, and oxygen, present either as atoms or molecules, gave parabolas in the positions expected, and it was only when the rare gas neon was examined that an anomaly was observed. Neon, however pure, always gave two parabolas, a strong one at 20 and a weak one at 22. Referring to the latter in January 1913, Sir J. J. Thomson said: 'The origin of this line presents many points of interest; there are no known gaseous compounds of any of the recognised elements which have this molecular weight. Again, if we accept Mendeléef's Periodic Law, there is no room for a new element with this atomic weight. . . . There is, however, the possibility that we may be interpreting Mendeléef's law too rigidly, and that in the neighbourhood of the atomic weight of neon there may be a group of two or more elements with similar properties, just as in another part of the table we have the group iron, nickel and cobalt.'

It was my privilege to be associated with him in this work, and as his attention was fully occupied with the investigation of a parabola of mass 3 —now known to be triatomic hydrogen—it fell to my lot to search for a proof that neon was not homogenious. This I endeavoured to do by partial separation of its hypothetical constituents, using as a test its density measured by a quartz micro-balance specially designed for the purpose. The first method, that of fractional distillation from charcoal cooled with liquid air, failed, as we now know was inevitable. The second, diffusion through pipeclay, though extremely tedious, had more success and I was able to announce at the meeting of the Association at Birmingham in 1913 that, after thousands of operations, a definite change of density, amounting to about 0·7 per cent., had been achieved. Further data from positive rays was obtained, and, when the War stopped work, there were several lines of reasoning indicating that neon consisted of two bodies of different mass, and that the behaviour of these was exactly that predicted by Soddy for isotopes, but none of these was sufficiently strong to carry conviction on so important a conclusion.

During the War Soddy's prediction concerning the atomic weights of leads from uranium and thorium minerals had been triumphantly vindicated by some of his most severe critics, the experts in chemical atomic weights, and when work was started again, although I continued for a time to experiment on separation by diffusion by means of an automatic apparatus, I realised that the most satisfactory proof of the existence of isotopes among the elements in general was only to be obtained by much more accurate analysis of positive rays. This was done by means of a sequence of electric and magnetic fields which gave focussed images of fine collimating slits, thus forming a spectrum dependent upon mass alone. This I called a 'mass-spectrograph' (*see* footnote 1). It had a resolving power of about 1 in 130 and an accuracy of mass measurement of 1 in 1,000. This was ample to prove in 1919 that neon consisted, beyond doubt, of isotopes 20 and 22, and that its atomic weight 20·2 was the result of these being present in the ratio of about 9 to 1. Chlorine was found to contain 35 and 37, and bromine, of atomic weight almost exactly 80, and hence expected to be simple, gave two equally intense lines 79 and 81. Other elements were shown to be much more complex. Krypton, the first of these, had six isotopes, 78, 80, 82, 83, 84, 86; xenon and tin even more. Of the greatest theoretical importance was the fact that the weights of the atoms of all the elements measured, with the exception of hydrogen, were whole numbers to the accuracy of measurement. This 'whole number rule' enabled the simple view to be taken that atoms were built of two units, protons and electrons, all the former and about half the latter being bound together to form the nucleus.

Although the interpretation of mass-spectra was often far from simple owing to the difficulty of distinguishing between lines due to compound molecules and those representing true atomic mass-numbers the analysis of the more suitable elements advanced rapidly. Dempster at Chicago discovered the isotopes of magnesium, calcium, and zinc by means of an instrument of his own design with semi-circular magnetic focussing. By 1925, when I replaced my first mass-spectograph, now in the Science Museum, South Kensington, with one of higher resolving power, information on the isotopic constitution of more than half the elements had already been obtained. The new instrument was designed primarily for measuring the minute variations of the masses of atoms from the whole number rule, and had a resolving power ample for the heaviest elements. By its means the search for isotopes has been carried on until a few months ago.

The difficulty of obtaining the necessary rays for analysis varies enormously from element to element. Two main devices are employed:

the ordinary gas discharge which requires the element to be volatile or form suitable volatile compounds; and the anode ray discharge, in which the halide or other compound of the element is treated as the anode in a discharge at low pressure. The inert gases are particularly suitable to the first method, the alkali metals to the second, other groups of elements being intermediate. Our knowledge of the mechanism of the discharge in both methods is far from complete, so that working with them is still rather an art than a science. The element of luck has played an important part in cases where the properties of the materials are unfamiliar and unfavourable to the conditions of the discharge.

The analysis of the recently discovered element rhenium offers a good example. The only available volatile compound was the heptoxide, a sample of which has been kindly provided by the discoverer Noddack. The vapour of this crystalline solid was first admitted to the discharge bulb, but without success. The solid was then introduced into the bulb itself, and, although its vaporisation was so copious that a visible layer was formed on the walls, still no lines were obtained. At this stage the element was abandoned as quite hopeless and preparations were made to go on to another. Purely by chance, this happened to be gold, which it was intended to attack by means of its slightly volatile chloride. This compound gives off chlorine gas when heated, and, as previously it had been noticed that the presence of a halogen gas often stimulated the appearance of lines otherwise faint, it was considered just worth while to make one trial with it *before* the rhenium oxide deposit had been cleaned off the walls. This was successful beyond all hopes. No lines of gold were found but the rhenium doublet appeared in great strength giving convincing evidence that it consisted of two isotopes, 185 and 187.

The technique of anode rays is, if anything, even more capricious but, when successful, yields spectra almost free from the lines of compounds and is for this reason particularly suitable for the identification of new isotopes. This method has been recently applied to the large group of the rare earth elements yielding some thirty new isotopes.

From the point of view of the identification of the more abundant isotopes our knowledge is nearly complete. A year ago only four elements, palladium, iridium, platinum, and gold, remained without mass-spectograph data. Dempster has since developed an entirely new method of obtaining suitable rays by using a very intense spark discharge, and I have just heard from him that he has already identified five isotopes of platinum and one of gold. It seems very probable that the last two elements will have yielded before this address is delivered.

In all some 253 stable isotopes are known of which seven were discovered by observations on optical spectra, and have since been confirmed by the mass-spectograph. This large assembly shows many emprical laws, of which perhaps the more remarkable is that no odd numbered element, with the possible extremely rare exception the isotope of hydrogen of mass 3, has more than two isotopes. Even elements are not so limited. The most complex element so far observed is tin, with eleven isotopes ranging in mass number from 112 to 124. One of the most astonishing results is that, for practically every natural number up to 210, a stable elementary atom is known, many are filled twice over and a few three times with 'isobares,' that is atoms of the same weight but different chemical properties. Schemes of tabulation of all the known species have led to the prediction of isotopes and to theories of nuclear structure to account for their occurrence.

Study of the relative abundance of isotopes in the mixture we still call, for convenience, an element, is of interest from two entirely different points of view. In the first place since it appears to be perfectly invariable in nature, not only in terrestrial but also in meteoric matter, there was a slight hope that a systematic measurement of abundance ratios might disclose some simple relations bearing on the great problem of how the nuclei of atoms were evolved. The relative abundance of isotopes can be estimated by several methods but that of the most general application is the photometry of mass-spectra. A technique of this was worked out in 1929, and a number of elements examined, but the ratios, obtained in numbers large enough for statistical treatment, showed no groupings other than would have been expected from pure chance. These measurements have a second important practical value. If we know the masses of the isotopes of an element and their relative abundance it is easy to calculate their mean weight. This, with proper corrections, can be used to check the chemical atomic weight. During the past six years nearly every atomic weight has been determined by this purely physical method, which has the great advantage of being, in general, independent of purity, and requiring an almost infinitesimal quantity of material.

Instead of the original view that the nuclei of atoms consisted of protons and electrons, it is now considered more likely that they are built of protons and neutrons. In either case the binding forces holding the particles together must represent loss of energy, that is, loss of mass. Hence it is that the atom of hydrogen has abnormally high mass, and that the accurate determinations of divergences from the whole number rule are of such profound theoretical importance. As I have stated, my second mass-spectograph was designed for this and found capable of an accuracy, in favourable cases, of 1 in 10,000. The atom of oxygen 16 was chosen as standard and the percentage divergences expressed in parts per 10,000, called 'packing fractions,' were determined for a large number of elements. These, when plotted against mass number were found to lie roughly on a hyperbolic curve. This drops rapidly from hydrogen, passes through a minimum of about — 10 in the region of iron and nickel, and then rises gradually, crossing the zero line in the region of mercury. Our knowledge in this field has been notably increased by the brilliant work of Bainbridge, who set up at Swarthmore a powerful mass-spectograph of an original design which made use of a velocity selector and semicircular focussing. With this instrument he discovered new isotopes of tellurium, rectified results on zinc and germanium, and has made many of the most accurate comparisons of mass so far known.

Fortunately for these comparisons, and particularly so for the extension of an accurate scale of mass to the heavy elements, particles occur in the discharge which carry more than one positive charge. A particle with two charges will give a line corresponding to half its mass, one with three charges will have an apparent mass of one third, and so on. These lines are called lines of the second, third and higher orders. The complex element mercury seems specially provided by nature to help in the work. Not only do its nine isotopes provide a most valuable scale of abundance but it usually occurs in the discharge, to which its presence is advantageous from the point of view of smooth running, and it is unique in its property of forming multiply charged ions. Mercury lines up to the fifth and sixth orders can be detected so that it provides a perfect natural scale, a link between light and heavy atoms absolutely necessary to extend accurate measurements to the latter. The packing fraction of mercury, which is practically zero, was determined by means of its third order line $^{198}Hg^{+++}$.

Of the recent episodes in the story I relate certainly the most sensational is the discovery of deuterium, the heavy isotope of hydrogen. The events leading up to this and following it form a most remarkable sequence. In them the elements of nature seem to have joined in an impish, but fortunately benign, conspiracy to delude the observer and to turn his most sober researches into a sort of blind man's buff.

The first comparison of the masses, now termed 'isotopic weights,' of the atoms ^{1}H, ^{12}C, ^{14}N, and ^{16}O to a high degree of accuracy were made with my second mass-spectrograph and published in 1927. Various methods were used which cannot be given in detail here, but since the comparison of H with O could only be done through the intermediate ^{4}He, and even then the ratios measured were very large, little reliance could have been placed on the figure for H unless it could be checked in some quite independent manner. It was possible to do this by means of the close doublet O—CH_4, and, when measurements of this appeared to support my values for C and H, I had no reason to doubt their substantial accuracy. In this I have been justified to some extent for the figures have stood for seven years, and a direct determination of the He,H ratio, made later by Bainbridge agreed exactly with mine. A further support was afforded by the fact that the figures for the four elements, all then supposed to be simple, agreed within 1 or 2 parts in 10,000 with the accepted chemical atomic weights.

This satisfactory agreement was completely upset in 1929 by the startling discovery of the heavy isotopes of oxygen 17 and 18 which, present in small quantity, had naturally been overlooked on mass-spectra of that element owing to the technical difficulty of ensuring the absence of the isobaric compound lines OH and OH_2. The discovery was made by Giauque and Johnson by observations on band spectra, which are free from this confusing disability, and the careful quantitative work of Mecke, made later, showed that, owing to the presence of these isotopes, the chemical standard of atomic weight $O = 16$ was about 2 parts in 10,000 heavier than the physical one $^{16}O = 16$. Examination of compounds of carbon and of nitrogen by the same method showed not only that these elements also contained heavy isotopes ^{13}C and ^{15}N but that their apparent abundance, by a most incredible coincidence, was just about enough to bring their mean weights into line with that of oxygen.

Birge pointed out that to satisfy my low estimate of ^{1}H hydrogen must also contain at least one heavy isotope. Urey took up the problem and, happily unaware of the real uncertainty in the figures concerned, with the collaboration of Brickwedde and Murphy fractionated liquid hydrogen and proved by examination of the Balmer lines that ^{2}H was present.

Washburn showed that its heavier atoms could be concentrated by the electrolysis of water. This method was developed so rapidly and brilliantly by Lewis that, soon after its discovery, pure heavy water had been obtained in appreciable quantity. The isotope of hydrogen of mass 2 cannot be treated as a normal isotope. Its exceptional difference in mass enables it to be separated with comparative ease in a pure state. It has been given the name deuterium, symbol D, and heavy water D_2O is now obtainable in quantity at reasonable prices, one of the most surprising reagents in the history of science and certainly one which would have dismayed the founders of the C.G.S. system of units.

Now comes the interesting sequel. Deuterium and its triatomic molecule supply two links, missing before, of the three forming a closed chain of masses by which H can be directly connected with O, given a mass-spectrograph of sufficient resolving power. These links are the doublets D—H_2, at mass 2, C^{++}—D, at mass 6, and O—CH_4 at mass 16. By means of an improved collimator I have recently increased the resolving power of my mass-spectrograph to that necessary to achieve at least a partial separation of the extremely close doublet D—H_2, and to make a much more accurate estimate of the doublet O—CH_4. The latter has disclosed the disturbing fact that this is really wider than I had taken it to be and so no longer confirms the early value of C and H. Provisional work on the wide doublet C^{++}—D_3 makes it reasonably certain that my original value for H is 2 or 3 parts in 10,000 too low, as is also suggested by nuclear transformation experiments. Here we have the pretty paradox of the element discovered providing the means to remove that very discrepancy which seemed to point the way so clearly to its discovery. In view of its valuable results I am not likely to regret my mistake, however serious it turns out to be. The only moral to be drawn from this seems to be that you should make more, more and yet more measurements. Even a bad one *may* be of service, but, fortunately, it will be essential for you to make a considerable number of good ones first, or no notice will be taken of it.

In the field of isotopes, as in so many fields of physical and chemical research to-day, the objective we now aim at is the next decimal place, an elusive object which always appears to be running away from the observer, like a distant spiral nebula. The need for isotopic weights of the highest accuracy is urgent. In artificial radio-activity and transmutation we see the real beginnings of a great new subject, the nuclear chemistry of the future. Its equations can only be founded securely upon direct determinations of masses by the mass-spectrograph, and the nuclear chemist already demands these to an accuracy of 1 in 100,000. I have little doubt we shall be able to provide him with these in the course of a year or two. Armed with reliable equations, and thereby with more and more definite knowledge of nuclear construction, he will transmute and synthesise atoms as his elder brother has done molecules, with results to be wondered at and possibly even misused by his fellow creatures. I foresee a time, not immeasurably far distant, when it will be possible for us to synthesise any element whatever, wherever and whenever we please; alchemy indeed in the service of man.

SECTION B.—CHEMISTRY.

THE MOLECULAR STRUCTURE OF CARBOHYDRATES

ADDRESS BY

PROF. W. N. HAWORTH, F.R.S.,

PRESIDENT OF THE SECTION.

In his *Testament of Beauty* the late Poet Laureate, Robert Bridges, speaks of:

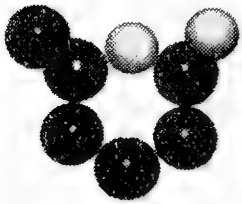
' those many organic substances which, tho' to sense
wholly dissimilar and incomparable in kind,
are yet all combinations of the same simples,
and even in like proportions differently disposed ;
so that whether it be starch, oil, sugar or alcohol
'tis ever our old customers, carbon and hydrogen,
pirouetting with oxygen in their morris antics ;
the chemist booketh them all as CHO, ...'

In my Presidential Address I shall endeavour to expand this estimate of the relations of starch and sugars and portray something of the symmetry and the rhythm of the motions which differentiate these from cellulose and glycogen and the wealth of other substances which, ' in like proportions differently disposed,' constitute the organic group of the carbohydrates. The oil and wine I propose to leave with the poet.

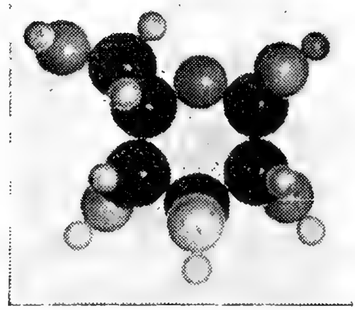
It would, however, be impossible in the time at my disposal to give more than a brief survey of the molecular structure of carbohydrates. Many have contributed to the advances in this subject. A number have been associated with me closely in my own work in this field, and if in this rapid summary I do not find it possible to mention the names of present and past colleagues, it must be recognised that I acknowledge and appreciate more than I can say the services they have rendered to this branch of chemistry.

Ten years have elapsed since a structural model of glucose was first presented as a six-atom ring form, an observation I communicated to

Nature in 1925. The experimental work of the succeeding two years made it possible, with the aid of colleagues and pupils, to establish the broad generalisation that all normal sugars higher in the series than tetroses are constructed on the basis of the six-atom skeleton model which can



Skeleton Model of Glucose.



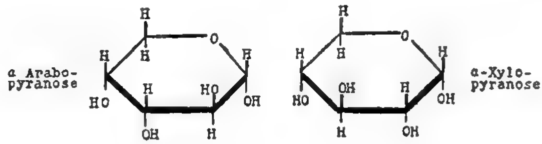
Model of β-Glucose.

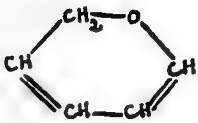
be regarded now as the unit of the complex carbohydrates such as cellulose, starch, and many others. This simple model assumes the character of a sugar as soon as it is clothed with hydrogen atoms and hydroxyl groups.

This generalisation, published in 1927, had presented itself as a strong probability from the moment it was seen that the representative sugar occurring in nature, glucose, conformed to this structural type. The experimental basis for the whole of the preliminary work was strengthened and supported by the systematic study of the sugar lactones carried out between the years 1924 and 1927. In the latter year there appeared a paper on the formulation of normal and γ-sugars as derivatives of pyran and furan, and the suggestion of a new nomenclature. The normal sugar types can all be given a standard structure recognisable under the name of a pyranose. The labile or γ-sugars, which had hitherto been but little investigated, were shown to be ascribable to the parent form of furan and therefore recognisable under a nomenclature describing them as a furanose type. The developments of this nomenclature were thereafter simple, inasmuch as the spatial arrangement of hydroxyl groups and hydrogen atoms, which characterised structurally identical forms, could be made abundantly clear by the addition of the characteristic prefix defining the kind of configuration which differentiates one sugar of any class. This nomenclature has been generally adopted and with the advantageous result that much confusion has been banished from the literature. Thus arabinose assumes two structural forms represented by the terms arabopyranose and arabofuranose and, similarly for the other pentoses, xylose, ribose and lyxose. The corresponding forms for glucose are represented by the expressions glucopyranose, glucofuranose and similarly mannopyranose and mannofuranose, and so on for all aldohexoses and also for the keto forms fructopyranose and fructofuranose. This scheme of nomenclature would only have academic interest if it concerned merely the crystalline sugars of the hexose and pentose series which are ordinarily accessible as free isolated substances. The simple sugars

Pyranose Forms of Pentose and Hexose.

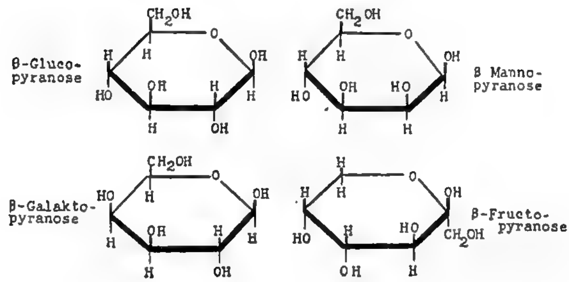
Normal Pentoses



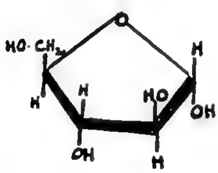


Pyran.

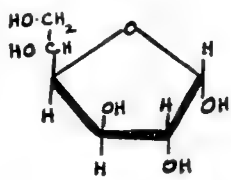
Normal Hexoses



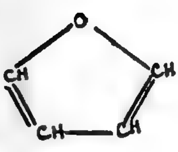
Furanose Forms of Pentose and Hexose.



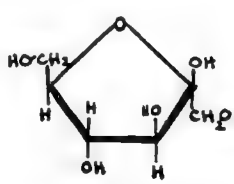
α-Arabofuranose.



α-Glucofuranose.



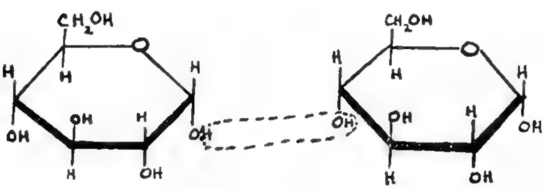
Furan.



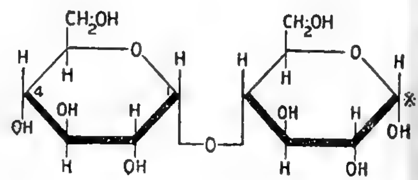
β-Fructofuranose.

acquire their wider significance when regarded as the building-stones assembled as the constituent parts of those complex natural products comprised in the carbohydrate group. It is in such circumstances that the allocation of structural forms held in combination whether as a di-, tri- or polysaccharide assumes importance, and the allocation of the precise form constituting these complex carbohydrates is a fascinating experimental problem. Let us pass to consider the kind of atom model which must be ascribed to maltose, cellobiose, sucrose, and the relationship which these structural types bear to such important carbohydrates as starch, cellulose, and inulin.

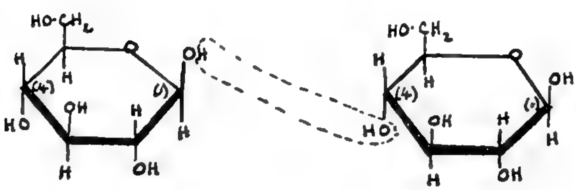
There are several ways in which two glucose units may be united through the intermediary of a common oxygen atom. Experimental work during the past twenty years has enabled us to proceed beyond the speculations of Fischer and to arrive at a precise picture for each of the disaccharides. The expressions $C_6H_{12}O_6 + C_6H_{12}O_6 = C_{12}H_{22}O_{11} + H_2O$ merely indicate the union of two hexose residues with loss of water to give a biose. Of the several hydroxyl positions available for providing the point of union of two glucose residues it was found that it is those groups at the first carbon atom in one residue and the fourth carbon atom in a second residue which furnish the oxygen bond uniting two glucopyranose units in both maltose and cellobiose.



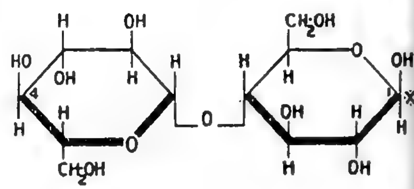
Union of two α-Glucopyranose molecules.



α-Maltose.

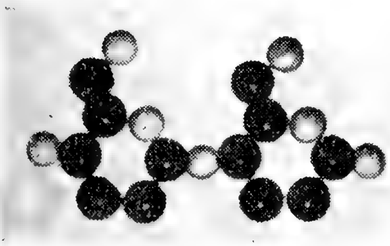


Union of two β-Glucopyranose molecules.

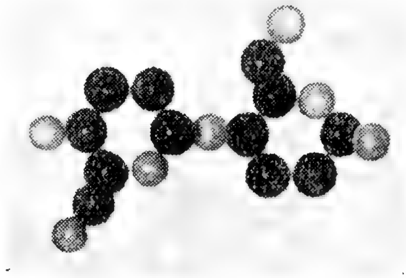


β-Cellobiose.

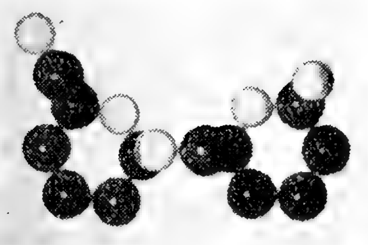
It will be observed that in the latter formulations two β-glucoses are shown united through two OH groups which are spatially above and below the planes of the pyranose rings. To bring the final cellobiose formula into alignment one of these rings is now inverted. It is of the highest importance to observe that although the units participating in the union of maltose are structurally identical with those assembled in cellobiose, yet these products are widely different in kind. The difference is entirely in the spatial arrangement of the left-hand components, indicated as α- or β-forms of glucose. It is this simple distinction which provides the reason for the different identities of starch, which is formulated on the maltose model, and cellulose, which is based on the formulation of cellobiose. There exist other polysaccharides in which the linking is different. This type may be illustrated by the assembly of two glucose molecules united through the hydroxyl positions at 1 and 6, which is found to occur in gentiobiose. Still another mode of union is exemplified



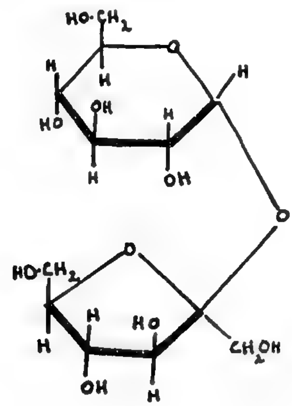
Maltose skeleton.



Cellobiose skeleton.



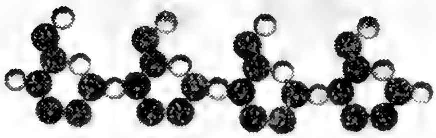
Gentiobiose skeleton.



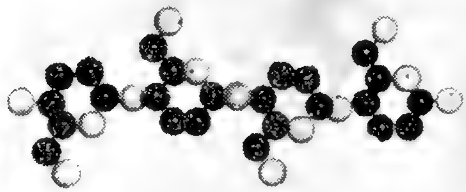
Sucrose.

by the formula which applies to sucrose. Here two different hexose units are involved, namely, glucose and fructose which are assembled as a pair through sharing a common oxygen atom or glucosidic link situated at the first carbon atom in each hexose, and it will be observed that whilst α-glucose is present as the pyranose form the β-fructose on the other hand occurs in sucrose as the furanose. It may here be added that this structural type established for the occurrence of the fructose residue in sucrose occurs also in the polysaccharides inulin and the levan from grass. It may well be the case that other furanose sugars occur more widely than we have suspected in complex polysaccharides. Recently one such residue has been found to be present as a terminal group in xylan, or wood gum. It appears to be the case that the arabofuranose we have found in xylan constitutes also a large part of the molecule of arabic acid, which is the modified polysaccharide in gum arabic.

Returning from this rapid review of these structural forms, and of the modes of assembly of pairs of sugar units in a biose, let me now present a picture illustrating similar experimental conclusions as to how more than two such sugar units are united in the various forms of carbohydrates. Without giving the intimate experimental basis for these conclusions, I may here show how two molecules of cellobiose are united in a continuous chain of such units in cellulose, and how maltose units are assembled in starch. Let us envisage this process, repeated by



Two maltose units assembled as in starch.

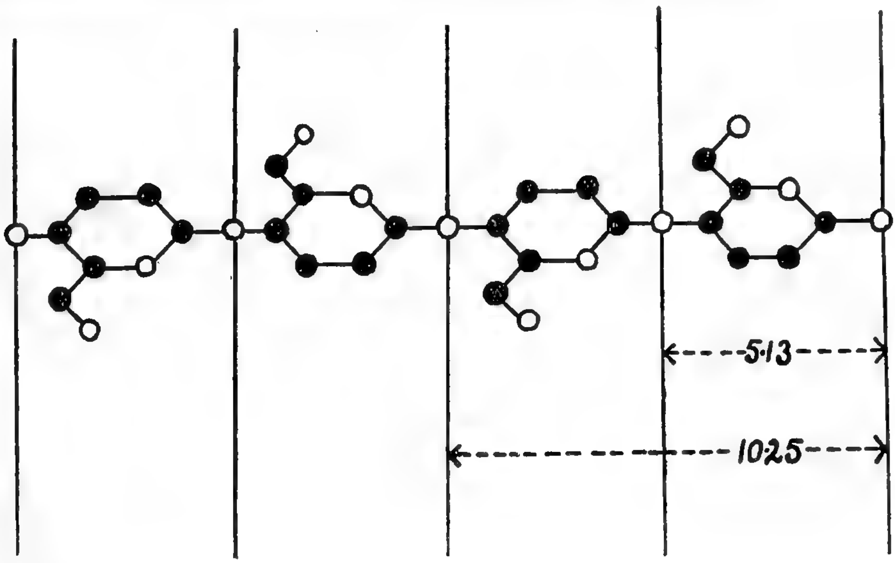


Two cellobiose units assembled as in cellulose.

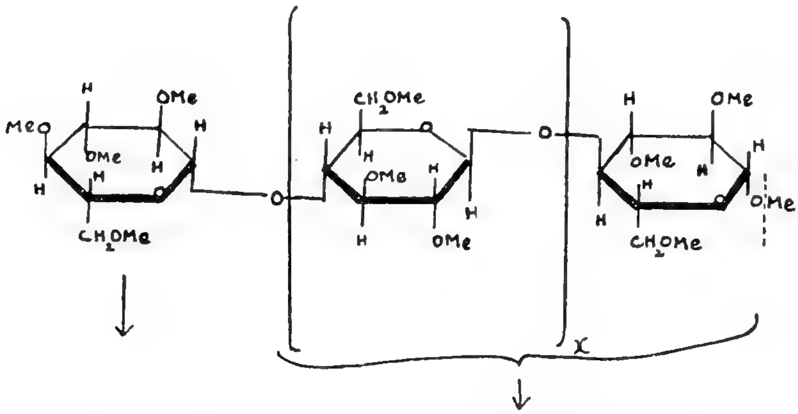
adding still more maltose units or cellobiose units to our lengthening chain and we approach to the constitutional picture representing starch and cellulose. Striking as the statement may appear, it is nevertheless the case that these two models are structurally identical. They owe their differences to the varied stereochemical forms of the same glucopyranose units which are found to be those of α-glucose in maltose and β-glucose in cellobiose. Arranged as a continuous chain, it will be found that the models present a perfectly symmetrical picture in the case of cellobiose, showing the sixth carbon atom or side chain of each hexose residue alternately above and below in the picture, whereas, in the case of continuous units of maltose assembled in a chain, this sixth carbon atom occurs entirely on one side : a representation less symmetrical than that of cellobiose. Moreover, the continued repetition of α-glucopyranose units in the starch complex, represented by assembling numerous maltose residues, provides a model which departs markedly, in zig-zag or spiral fashion, from the more or less straight line which is furnished by the continuing units of cellobiose in cellulose. And so, as Milton puts it :

‘ with many a winding bout
Of linked sweetness long drawn out,’

we picture the sinuous track of glucose units assembled in the continuous chain of the starch molecule. This circumstance appears to account for the difficulty of obtaining a regular pattern for starch which marks the X-ray diagram obtained for native cellulose. It will be seen that not only does the cellobiose picture, as determined by the classical constitutional methods of organic chemistry, fit perfectly into the size of cell demanded by the X-ray diagram, but this diagram fulfils every particular dimension of the repeating pattern of the cellobiose formula :



This mental picture of the constitution of cellulose will remain incomplete if we can gain no knowledge of the number of β-glucose units constituting the chain length of cellulose. Here an endeavour has been made to reach an approximation of the size of the chemical molecule by a gravimetric assay of the end group of methylated cellulose. A specimen of the latter material, prepared under very carefully controlled conditions to avoid chemical rupture, enables us to gain an insight into this problem by investigation of its products of hydrolysis. An estimation of the weight of tetramethyl glucose obtained from these hydrolysis products has yielded under proper technique a value for the average length of the cellulose chain, which is thus found to consist approximately of 200 glucose units. In this connection, and especially when we come to consider the same problem in reference to starch, it must be recognised that native cellulose is most probably a molecular aggregate consisting of a much larger physical molecule than is here represented. A molecular aggregate of such chains, joined by physical links or by co-ordination end to end, is calculated to give a much enhanced value for the determination of molecular weight by viscosity methods as interpreted by the Staudinger constants. Similarly a determination of particle size by the sedimentation method of the ultra-centrifuge is now found to give a much higher value than that of 200 glucose units. Here again the physical molecule or molecular aggregate may be expected to take account not only of an aggregation which increases the length of the chain but also of the forces which affect molecular aggregation laterally between adjacent chains. I think these factors must be recognised in any comparison of the molecular weights of cellulose determined by physical and chemical methods. It may well be that in the formation of cellulose in the plant a limited chain length of the chemical molecule is imposed by thermo-

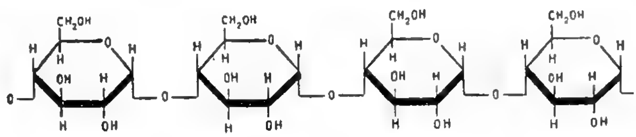


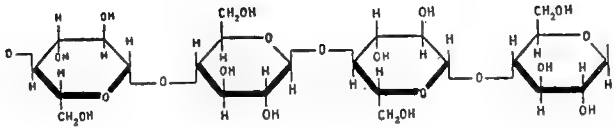
Tetramethyl glucose. Trimethyl glucose + methyl alcohol.

Methylated Cellulose ($x = 200$).

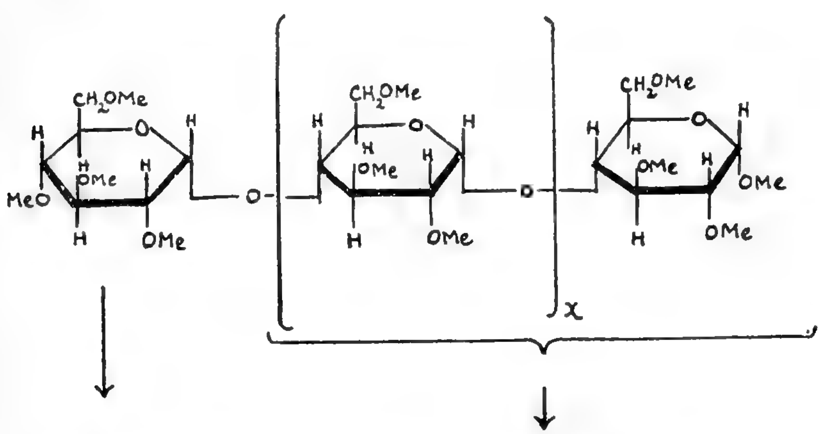
dynamic considerations. We shall see, however, in the case of starch that molecular aggregation of the chemical molecule occurs freely *in vitro*, and is promoted by a choice of chemical reagents. Similarly, it has been found possible to effect the reverse change of disaggregation in the case of starch. Doubtless many of the common reactions to which cellulose is subjected in the laboratory and in industry are unconsciously directed to a disaggregation of the physical unit in order to promote more facile chemical change in the preparation of derivatives. There is no doubt, as shown by our recent experiments, that progressive chemical breakdown occurs the more drastic are the reagents used. Hydrocellulose has been found by the method of chemical assay to correspond to a chain length of rather less than half that of cellulose and is evidently degraded cellulose. Again, the use of oxidising agents promoting the formation of oxycellulose is accompanied by a more profound breakdown with the formation of portions of very short modified chains, and also invariably a residual portion for the most part consisting of a chain of 60–80 glucose units. Both hydrocellulose and oxycellulose are frequently formed in processes to which cotton is subjected. These products may also accompany the use of chemical reagents which are empirically employed for the preliminary disaggregation of cellulose in the manufacture of the newer textiles. But these shortened cellulose chains represent the more soluble portions and may be removed by solution.

An insight into the difficult problem of starch is slowly being gained. We have shown that the mode of linking of a large portion of the starch complex is represented by continuous units of α-glucopyranose linked through the positions 1 and 4. Here side by side there are given in perspective formulæ parts of the continuing chains of starch and of cellulose. It is well known that the starches contain combined phosphorus and silica, but the quantities present of these so-called extraneous materials seem to have no easily recognisable stoicheiometric relation to the unit chemical molecule.





Methylated starches of different origins have now been examined by the method of gravimetric assay of the end group, particularly the starches from potato and maize, and also a less common variety known as waxy maize starch. Investigated by these methods and prepared in a variety of ways, all three methylated starches from these sources show a remarkable uniformity in the chain-length of the chemical unit. This corresponds to a molecular weight for starch of about 5,000, or 25 glucose residues.



Tetramethyl glucose. Trimethyl glucose.

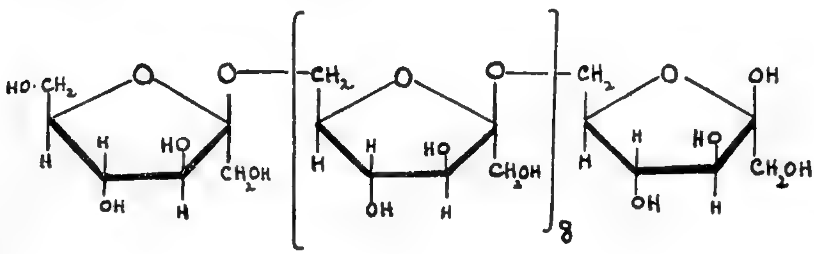
Methylated amylose and amylopectin ($x = 25$).
Methylated glycogen ($x = 12 - 18$).

Despite this fact the many different samples we have prepared of methylated starches exhibit viscosities which, by the use of the Staudinger constant, would seem to indicate a chain length of 5, 10, or 20 times that just given. The same may also be said of the starch acetates. The amylopectin or α-amylose portion, representing the less soluble part of starch, shows a much greater molecular size as compared with that of amylose (or β-amylose). In spite of this, however, the end group method of determination yields invariably one and the same value for all specimens. Moreover, it is possible by keeping amylose for some time to observe its molecular aggregation to amylopectin, exhibiting enhanced viscosities both for the acetates and for the methylated derivatives. Recently we have been able to bring these factors into line and have succeeded in preparing, after surface etching of the starch grains with ethyl alcohol containing small quantities of hydrogen chloride, a disaggregated starch which, in the form of its acetate and its methylated derivatives, furnishes the same value for molecular weight both by viscosity methods and by the gravimetric assay of the end group. This simplified disaggregated variety of starch is not degraded. We believe that it represents the chemical unit of starch, and by keeping it for a short time it reverts by re-aggregation to physical assemblages of increasingly high viscosity corresponding to the original amylose or amylopectin of the starch grains. We shall have occasion to inquire into the factors controlling this change. In my view, however, there can be no doubt that the chemical unit of starch is of limited size, having an average molecular weight of about 5,000 and that these units undergo aggregation to physical units of much larger dimensions.

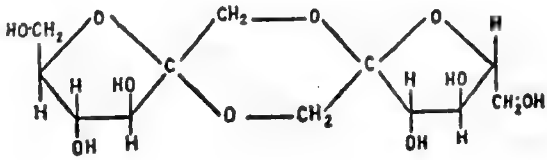
In Birmingham we have now prepared a considerable number of break-down products of starch representing the starch dextrins of varying chain-length. The study of these products has yielded results of interest and value from many points of view. Their gravimetric assay has furnished progressively different values for the end group, and this graded diminution in value corresponds exactly to their properties, such as solubility of the dextrin and its acetates and the capacity to undergo re-aggregation. This convinced us that we were dealing with a terminated chain of glucose units and not a closed loop. If the latter model were adopted and a closed loop of glucose units, represented as a flat ring, were assumed to be the picture of starch, then, in interpreting results of the end-group assay method, we should have to envisage side chains of glucose extended at regular or irregular intervals from different parts of this loop and to consider that these side chains were responsible for the tetramethyl glucose isolated in the end-group assay of methylated starch. In such an event we should expect to find, in dealing with the break-down products of starch, no very regular and progressive value for the 'end-group,' and indeed it would be possible to isolate a starch dextrin which gave the same 'end-group' value as the undegraded methylated starch. This has never been found to be the case. Starch dextrins corresponding to 17, 12, 9, 7, and 5 glucose units have been prepared. The α-amylodextrin obtained by the action of barley diastase on starch shows an end-group value corresponding to 17 glucose units. This product is significant in that it contains in its diminished chain-length almost all the phosphorus which was originally present in starch. Whether for this or other reasons this dextrin exhibits a remarkable capacity towards molecular aggregation and in this respect differs markedly from samples of glycogen which have similarly been examined. The factors which underlie this tendency are of absorbing interest and are under close investigation. These glycogen specimens have chain lengths of 12 and 18 glucose units, but they display little or no tendency towards molecular aggregation. It may possibly be promoted by the interlocking of adjacent chains by forces corresponding to those which bring about co-ordination, and by the so-called extraneous materials such as combined phosphate or silica.

What seems clear is that starch polysaccharides of comparatively short chain-lengths of 10 or so glucose units are devoid of this property.

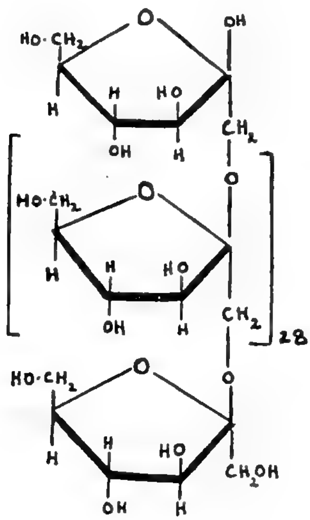
The occurrence of cellulose and starch in the green leaf of the growing plant has long been recognised, and so also has the occurrence of a very different polysaccharide inulin in the root organ of the *Compositæ* and related families, where it replaces the starch found in other types of plant. The recent discovery of the presence of a water soluble polysaccharide in the leaf of certain grasses has shed new light on the rôle of fructose and its synthetic operations in the plant. This polysaccharide is a levan and is composed of repeating units of fructofuranose united through the positions 2 and 6, thus displaying a different mode of combination of its fructose members from that which obtains in inulin. The formula of this levan is given below and its chain length is almost certainly that of 10 such members of fructofuranose :

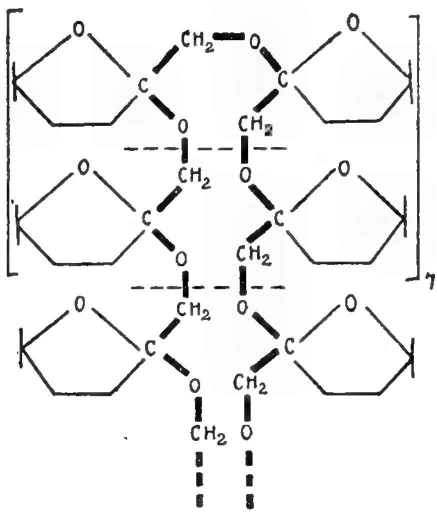


Very different, although related to this, is the type of combination which characterises the mode of union of successive fructofuranose members comprised in inulin. The break-down of inulin is easily accomplished with the mildest acid reagents, giving rise to and indeed providing the best source of fructose. What has not been recognised until recently is that inulin may under the most unforeseen circumstances also give rise to a biose anhydride. An analogy may therefore be drawn between the break-down of this carbohydrate to a biose derivative and the break-down of starch and glycogen to maltose and that of cellulose to cellobiose. So sensitive is inulin in this respect that some of the dextro-rotatory products given in the literature as substituted inulins are really to be formulated as the 1 : 2-difructofuranose anhydride :



The tendency for inulin to undergo this change is best understood from writing the complete constitution of this carbohydrate in the following way. In no case can the constitution of inulin be represented as a flat model, inasmuch as the stereochemical arrangement necessitated by the 1 : 2 junctions demands that the model should be spaced in either of the following ways :

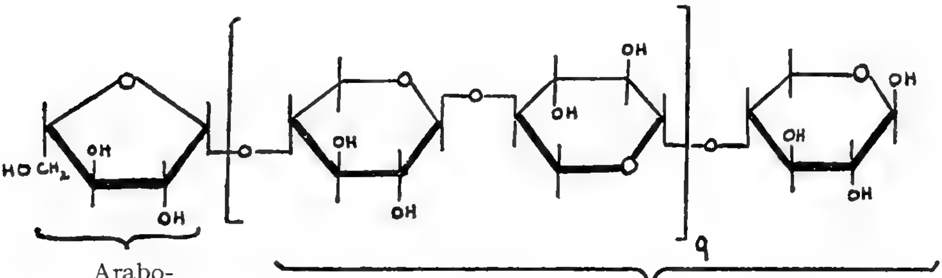




In the second of these formulæ for inulin, which are really identical constitutions differing only in the draughtsmanship employed to represent them, it will be seen that a simple cleavage along the dotted lines in a hydrolysing medium will liberate pairs of fructo-furanose units which can readily combine as the difructofuranose anhydride shown above. From what has been said of the stereochemical arrangement of inulin, and the difficulty of compressing the model within a linear chain, it is perhaps not surprising to learn that acetyl inulin and methylated inulin give altogether fallacious results for molecular size by the viscosity method and the Staudinger formula, from which it would appear that the molecular weight is of the order of 1,300. The end group method of assay of methylated inulin shows the molecular weight to be about 5,000 and the chemical molecule to be composed of 30 fructose units. Alternative methods of measurement of molecular weight confirm this value. The ebullioscopic method gives indeed an identical value and it has recently been found that the osmotic pressure exhibited by inulin derivatives fully confirms this figure. I have invited Dr. S. R. Carter to give some account of the experimental equipment and the choice of membranes which have already been of service in the case of one or two other polysaccharides in determining the molecular weight of high polymers. These constitutional models for inulin and levan illustrate how wide a disparity there is between the several carbohydrates which may occur in one and the same plant. It must be conceded that in no other natural products does the factor of stereochemistry enter so largely as in the carbohydrate group. Here one has to deal with configurational or spatial arrangement and no one model can be selected as typical for the whole group. The classical methods of organic chemistry will always be given first place among those available for the elucidation of constitution in this as in other series of compounds. A great many other factors must, however, enter into the discussion and interpretation of these results. Among the more important are the considerations which apply to the observations of optical rotatory power. It would be difficult to exaggerate the value this property possesses for the more intimate explorations of the carbohydrates. Occasionally too much has been claimed for the significance of optical rotatory power in the sugar group and numerous empirical rules designed to correlate structure with this property are valid only within narrow limits. During the subsequent discussion, Dr. E. L. Hirst, F.R.S., will speak on this subject, so that I need not pursue it further in this address.

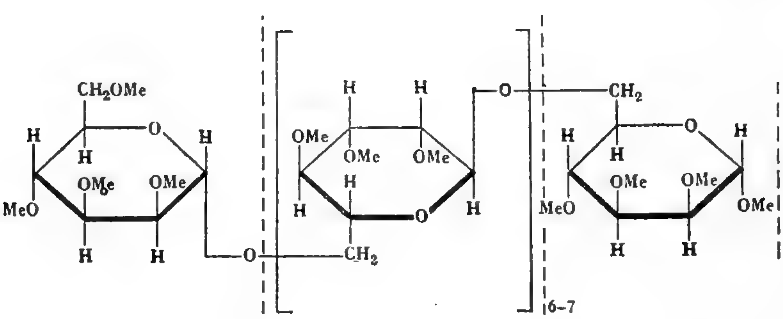
Other problems of the spatial arrangement which carbohydrates assume are bound up with such considerations as the conformation of the pyranose ring. In this the atoms may be all co-planar, in which case strain will be introduced by deflexion of valency direction or the various atoms constituting the ring may be staggered, in which event the structure will be strainless. This question of the different modes of packing the atomic assemblages may find some solution by the application of X-ray methods, which have already rendered great service in the carbohydrate field. Mr. E. Gordon Cox will deal with some experimental results which have followed from this line of inquiry.

In the cell wall of many lichens occurs the polysaccharide lichenin, which resembles cellulose except in its property of being water-soluble. Recently its investigation has been resumed and many of its properties show that it is closely allied in structure to cellulose. Its chain-length is, however, considerably shorter, corresponding to about 80 glucose units. A pentosan constituent of certain grasses such as esparto, and also of wood, is recognised as the polysaccharide xylan. Its recent investigation has shown that, although 93 per cent. of xylose may be isolated from its hydrolysis products, yet it is by no means the case that the whole of this polysaccharide is constituted on the basis of xylose. It is found that the deficiency of 7 per cent. is entirely made up by the presence of this exact percentage of arabofuranose residues which occur as terminal groups in the xylan chain. This observation is a sufficient commentary on the need of an inquiry into the finer structure of carbohydrates. That the xylose residues are linked as pyranose units through the 1 : 4 positions as in cellulose has been made clear. The chemical molecule of xylan consists of 18 or 19 xylopyranose residues united in this way and terminated at one end by an arabofuranose unit. It is probably aggregated with two or three other such chains by co-ordination at the reducing terminal group. The progressive break-down of xylan gives rise to a shortened chain consisting only of xylopyranose residues and these xylodextrins are invariably terminated by a xylopyranose group isolated as trimethyl xylopyranose after the loss of the arabofuranose residue. This is confirmatory evidence of the occurrence of xylose units in the body of the chain in the pyranose form. It is believable that of the numerous and varied types of polysaccharides which Nature doubtless provides, chemists have only succeeded in isolating and characterising a comparatively small



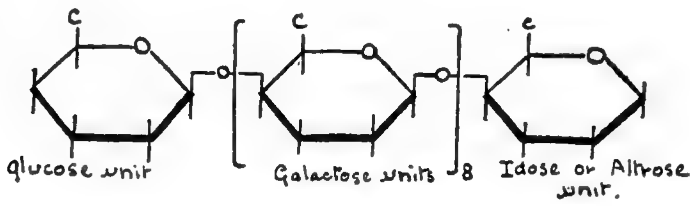
Arabo-furanose unit. Xylopyranose units.

number. A great many of which we have at present no knowledge will doubtless be isolated from natural sources by the application of the more modern methods of investigation. It seems evident from the work of Raistrick and others, who have prepared complex polysaccharides *in vitro* by the action of moulds on nutrient solutions containing glucose and other sugars, that many similar synthetic processes must go on in the plant. The detailed investigation of several of these polysaccharides, obtained by the agency of micro-organisms, has served to increase our knowledge of the type and variety of modes of assembly of sugar units in the more complex carbohydrates. It was altogether unexpected, for example, that the growth of *P. Charlesii* on glucose would produce two polysaccharides, one composed only of mannose residues and the other only of galactose residues. The detailed structure of the former has now been investigated and the polysaccharide prepared in this way and known as mannocarolose has been shown in our recent work to have a chain length of 9–10 mannopyranose units united through the 1 : 6 positions as indicated here.



Yields 2 : 3 : 4 : 6-tetramethylmannose (III). Yields 2 : 3 : 4-trimethylmannose (II) and methyl alcohol.

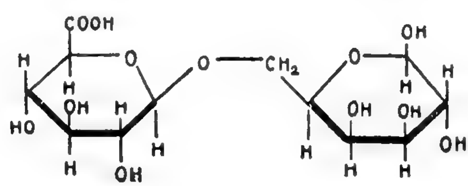
Still more striking is the polysaccharide varianose obtained in a similar manner by the growth of *P. varians* in glucose which gives rise to a complex polysaccharide containing three different kinds of hexose residues. The constitution and chain length have been investigated and the following model is presented for this interesting type :



These examples serve only to illustrate the manifold character of the polysaccharides which are capable of existence and suggest that we are at the beginning of our knowledge not only of the structure of this group, but also of the functions which such polysaccharides serve in Nature.

Nothing could be more important than the development of the more recent discoveries of polysaccharides possessing immunological functions. Several of these have been recognised as antigens, and a knowledge of their composition, properties, and intimate structure must obviously be of immense service. The properties of the specific polysaccharide of type III pneumococcus may be imitated by a degraded fragment of arabic acid derived from gum arabic (gum acacia). In our general investigation of gums, experiments have proceeded a considerable distance in the direction of unravelling the complex structure of arabic acid. This is composed of arabinose, rhamnose, galactose and glucuronic acid residues, and the mode of assembly of these different sugars will, it is expected, soon become clear. The glucuronic acid residues are intimately associated with a galactose chain and the union occurs through position 6 of the latter sugar. The pentose units appear not to be vitally concerned with this nuclear portion of the molecule and are capable of removal by scission without disturbance of this essential nucleus.

The carbohydrates of immunological interest are not simple in structure and probably have a molecular weight much above 2,000. The most characteristic, though by no means the only repeating unit, is represented by a bionic acid which in the case of the degraded arabic acid contains a glucuronic acid residue linked through the sixth position of galactose, a mode of union which resembles that which occurs in gentiobiose :



It is already evident that wider knowledge of the constitution of these polysaccharides will lead to great advances in medicine on the side of immunology. In order that this branch of the subject may be developed here in greater detail, Dr. W. T. J. Morgan has consented to give an outline of the broad general results obtained in this field. In concluding this review I thank most warmly those of my helpers who by their devotion and skill have contributed to this scientific advance.

SECTION C.—GEOLOGY.

SOME GEOLOGICAL ASPECTS OF RECENT RESEARCH ON COAL

ADDRESS BY

PROF. H. G. A. HICKLING,

PRESIDENT OF THE SECTION.

TRADITION almost demands that a Sectional President shall embark on that salutary though often painful process known in the outer world as stocktaking; and in my own case the historic succession seems to point with no uncertain finger to the department of the geological store where the accounting is to be done. My predecessor at Leicester led us to the Carboniferous rocks; at Aberdeen we reviewed the investigation of the plants which they contain; and so it falls to my lot at this meeting to take stock of our knowledge of the rock which the plants themselves have formed.

I shall attempt this the more willingly because I believe that this rock is not only in itself worthy of more attention at the hands of the geologist than it has been generally accorded, but is likely to repay that attention by shedding light on some of the major problems of the science. Later in the address I shall revert to the conception of coal as a metamorphic rock. The idea is ancient, but the data necessary for its establishment and more precise definition have been lacking. Perhaps they are now to hand. If that be so, we have in this familiar rock an indicator of crustal conditions far more delicate than any of the index minerals of the metamorphic petrologist; so delicate indeed, that should it come within range of even the lowest grade of metamorphism, as usually understood, it is completely shrivelled up and leaves only a trace of graphite as witness of its former self.

But before this aspect of the matter can be seriously discussed, it is necessary to know the nature of the rock itself; or, rather, rocks, since there are many kinds of coal. And this is where our knowledge has been most deficient. Any text-book will furnish a body of more or less convincing circumstantial evidence concerning the conditions under which certain deposits of coal have been formed. It may discuss at length the question whether the deposits have been formed by the growth of vegetation *in situ* or out of 'drifted' plant material; but as to the rock itself, the most we are likely to learn is that it contains recognisable fragments of plant tissue and, frequently, plant-spores. As to the nature and condition of the general mass of the rock, we shall probably learn nothing.

This is, in fact, a fair indication of the state of knowledge regarding the structure of coals in general, up to some thirty years ago. Enough was known from such investigations as those, for example, of Grand' Eury on the coals of St. Étienne, to indicate that different coals might have been formed from substantially different materials, but far too little information was available to enable anyone to determine just how far the conspicuous differences in composition between the coals were due to that cause. There was complete uncertainty whether even the major differences were determined during the accumulation of the deposit, by the kind of plant materials concerned and by their state of decay; or whether the chief factor was the effect of physical forces brought to bear on the deposit after its burial in the crust. During the past thirty years the state of knowledge in this matter has undergone a complete change; but the investigators responsible for the change have, for the most part, been palæobotanists and fuel technologists rather than pure geologists. The results of their work have not for the most part appeared in the ordinary geological journals, and their geological implications have consequently not received general attention.

Early Microscopic Studies.—The earlier uncertainty regarding the structure of coal was due to the extreme difficulty of preparing slices sufficiently thin to be in any degree translucent, and so to permit of microscopic examination. Nevertheless, so far back as 1831, Henry Witham had prepared sections in which he had seen plant structure, and in January 1833, a paper was read before the Geological Society of London, by William Hutton, based on the examination of a considerable collection of thin sections. This was, unfortunately, published in brief abstract only, but the original manuscript, at present in my possession, shows that he had observed most of the features which were noted by later observers until very recent times. The paper is accompanied by nine illustrations in colour, which greatly assist in the interpretation of his descriptions. He notes three types of coal in the Newcastle district, each with a characteristic structure. The first and most abundant is (to quote his words), the 'fine caking coal,' which consists of 'a mahogany-brown coloured substance, compact and uniform; mixed and entangled in this are to be seen portions retaining the fine reticulations of the original plants.' From its 'more or less perfect rhomboidal fracture, when broken' it is 'seen to be a crystalline compound; the parts composing it must have been in a state of solution. . . .' 'Along with this there are generally a number of curious elongate cells, filled with a light wine-yellow coloured substance . . .' which is 'undoubtedly a bituminous compound . . . and may be volatilised by a gentle heat so as to leave the cells empty without the surrounding coal being altered' [a remarkable observation]. These cells are, of course, the spores, and in the light of subsequent discussion, it is interesting to note that the material of which they consist is later described as yellow resin. The second variety, or 'slate coal,' is described as largely made up of these 'elongate cells' and consists also 'of a congeries of other smaller cells . . . similarly filled with yellow resin' [the microspores]. The third variety is the Cannel, Splint or Parrot coal, which is 'totally devoid of crystalline structure' and displays an 'almost uniform series of these smaller cells.' He notes the frequent interbanding of these different types of coal, and acutely observes that since they occur together (sometimes in bands 'as fine as a hair') their differences must be original, and cannot be due to any changes subsequent to their entombment. He notes especially, the occurrence of 'charcoal' intimately mixed with 'the most splendent' coal as evidence of the fact that the former must have been in the condition of charcoal at the time of its enclosure. The observation that the coating of some of the larger fossil plants enclosed among the shales is 'converted into the finest and most crystalline coal' is noted as evidence that entombment among other plant material is not necessary for its conversion into this type of coal. His final conclusion is 'that every variety of coal is of vegetable origin,' and 'the difference of the nature of these varieties has most probably arisen from an original difference in the nature of the vegetables of which they were composed.'

Hutton had clearly recognised that bright coal consists almost entirely of translucent and apparently homogeneous material in which plant structures are discernible here and there; that some dull coal is largely composed of megaspores and microspores (the true nature of which he could not know); and that these types of coal are often finely interbanded, together with layers of mineral charcoal. This was the first serious attempt to determine the structures of the different kinds of coal, and little advance was made in this matter for over half a century.

During this long period, advance was due to the slow accumulation of isolated observations rather than to any sustained effort to study coal itself as a major problem. The difficulty of preparing satisfactory sections obviously discouraged most workers from serious attempts in that direction, while those who made such attempts lacked some of the knowledge to interpret what they saw. By the use of bleaching and macerating agents many observers were able to show that such minute details of plant-structure as the fine pittings on the walls of wood-fibres were perfectly preserved, spores and cuticles were isolated from the coal, and even traces of the softer tissues of the plants were found. But it would seem that almost all workers throughout this period looked upon the fragmentary plant remains merely as interesting indications of the material out of which the coal had been made. It appears to have been usually taken for granted that such remains were merely items in the mass of the coal, a great part of which was assumed to be structureless. It was not *expected* that most of the plant material would have retained any trace of its original organisation. The surprise, therefore, of the modern work, is the discovery that in the more common types of coal, at least, nearly every portion of the mass can be seen to retain evidence of its orginal organic structure.

Recent Work.—The modern period of coal petrology is clearly the offspring of the palæobotanical research on petrified coal which culminated at the close of the nineteenth century. This work gave us a precise knowledge of the structure of the plants which formed the Carboniferous coals, and a clear picture of the condition of some of the coal peats at the time of their deposition. It was inevitable that this should be followed by more determined attempts to see these structures in the coal itself, and was equally natural that such attempts should be made quite independently by a number of workers.

With renewed interest in the subject, advances in the technique of microscopic examination were rapid. The first development was E. C. Jeffrey's combination of maceration with section-cutting. He treated very small blocks of coal for long periods with hydrofluoric acid, thereby removing the mineral matter and so far softening the substance that it could be sectioned on the microtome like a modern plant. By this method sections may be prepared which show much detail with surprising clearness. Its limitations are the small size of the blocks which can be successfully treated, the liability to tearing of the more delicate portions of the coal by even the smoothest razor, and a doubt whether the finer structures are not in some degree obliterated by the maceration. While its results were a very great advance on the earlier efforts at direct section-making by grinding, they are not equal to some of the more recent products of the latter method.

Direct cutting was developed to a high degree of efficiency by Reinhardt Thiessen in America and by the late Mr. James Lomax in this country. The former aimed, in the first instance, at getting sections of moderate size, but of such extreme thinness that the finest details could be studied with the highest magnifications. The latter was the pioneer in the preparation of large sections, which made possible the examination of an entire coal-seam in a moderate number of slices. In the early stages these large sections were naturally made with some sacrifice of thinness and uniformity, but increasing experience has made possible the attainment of these features in even the largest sections.

Simultaneously with the foregoing developments an entirely new method of examination was introduced in Germany by H. Winter—namely, the examination by reflected light of polished and etched surfaces of coal. This method has been developed with conspicuous success in this country by Mr. C. A. Seyler, and is extensively used by many workers on the Continent. The vividness with which many fine details of plant structure in the coal are revealed by this method can only be described as startling; and one of its advantages is that, by variation of the methods of polishing or etching, different features can to some extent be revealed at will. The size of surface which can be examined is, of course, almost unlimited, and a few minutes is sufficient for its preparation. For the examination of the complete section of a seam it has obviously great advantages. At the same time it must be observed that the character of a good deal of the coal substance remains obscure, and the interpretation of the structures actually seen can be securely attempted only by close comparison of the etched picture with actual thin sections. Used in conjunction, the two methods of examination afford a means by which the whole story of a coal seam may be deciphered with accuracy and comparative rapidity.

What have been the results of all the attempts to study the microscopic structure of coal?

The 'Uniform Brown Substance.'—Before the time of Witham and Hutton coal was often regarded as a deposit from 'solution' in water—as a kind of vegetable 'extract,' which might consequently be expected to possess a distinctive composition, independently of the materials from which it was derived. The earlier microscopic observations at once limited this idea by demonstrating the presence of plant remains which retained their organised structure; but the 'uniform brown substance,' which Hutton had observed to form so much of the coal, clearly appealed to many observers as the essential feature, and many references to the 'coal substance' seem to be more or less clearly identified with it. The foremost question in coal petrology has been, in fact, the nature of this brown substance—in particular, as to whether it is, in more modern phrase, a colloidal precipitate, or whether it represents actual fragments of plant material. Since it forms probably quite 75 per cent. of all our common coal, this question is of the first importance. As Hutton observed, it is this substance which forms the general mass of the 'bright coal.

All recent workers have drawn attention largely to this dominating material. E. C. Jeffrey named it 'lignitoid material.' He regards it as representing pieces of plant tissue, largely woody, in which all trace of the original organisation has been destroyed by decay. Thiessen, who approached the study of the structure of bituminous coals by way of an extensive examination of lignites, in which the structure is more easily seen, differed from Jeffrey chiefly in his belief that the structure of the original plant material is rarely quite obliterated, and that it can nearly always be detected if the sections and the microscopic technique be sufficiently good. He named the material 'anthraxylon.'

The recent trend of work and discussion on this important part of the coal has been much influenced by the writings of Dr. Marie Stopes. In 1919 she essayed a classification of the types of coal substance which can be distinguished by eye in an ordinary bituminous seam, and gave some account of the constitution of each type as determined by microscopic examination. She emphasised again the laminated character of the seam, and the fact that the laminæ consist of different types of coal which can be separated for examination. While earlier writers had usually been content to describe the coal as divisible into 'bright' and 'dull' layers, together with occasional bands of 'mineral charcoal' or 'mother of coal,' she directed attention to the additional fact that the 'bright' coal might be separated into two portions. The general mass of the bright substance has a just perceptible fine lamination which gives it a silky sheen; but interbanded with it are many thin layers which at once strike the eye by the mirror-like reflection from their perfect cleavage surfaces. The same observation was undoubtedly made many times before, but failed to attract notice, in the same way that the whole matter of the distinctive character of the various laminæ which make up the seam received only casual attention from time to time. Dr. Stopes was the first to apply distinctive *names* to the different types of laminæ. She adopted the French *fusain* to replace the questionable English term 'mineral charcoal,' and devised corresponding terms for the other types of coal: *durain* for the true dull bands; *clarain* for the ordinary silky bright coal; and *vitrain* for the brilliant glassy-looking substance.

Not all the weight of Shakespeare's authority can alter the fact that names are most potent things, especially if they are apt. These names directed attention sharply to the facts that common coal is a complex mass of different materials, and that *some* of the chief components (vitrain and fusain) or characteristic mixtures of components (clarain and durain) can be picked out of the coal and subjected to separate examination. They focused that attention and have thereby stimulated a very large volume of work on the nature and constitution of these components; and it is no adverse comment to say that this work has necessitated some modification of their original definition.

We can now revert to the 'uniform brown substance.' Dr. Stopes observed that the clarain bands were mainly composed of this translucent material, finely interspersed with other ingredients, and often showing its original plant structure. Vitrain consisted entirely of similar translucent material, free from admixture with other substances, but seemed to show no trace of structure.

The development of technique during the past decade has shown, however, that this latter distinction was due largely to the physical properties of the vitrain. The pure unmixed substance of these bands is excessively brittle and most difficult to section effectively; but it is now abundantly shown that a very large proportion of the vitrain, at least, retains the structure of the tissue from which it has, in fact, been formed, no less clearly than the smaller fragments of translucent material which enter into the composition of the clarain bands. In a recent classification of coal ingredients (January 1935), Dr. Stopes has indicated clearly that the chief part of the substance of the clarain bands appears to be identical with that which forms vitrain. In direct proportion as the methods of preparing thin sections or of etching coal surfaces have been improved, an ever-increasing proportion of the 'uniform brown substance' of the bright coal has been shown to retain the structure of the plants of which it is composed. While it is true that some small portion of the mass generally remains apparently structureless, the conviction becomes increasingly strong that this is a matter of appearance only. This conclusion is made more insistent by the observation that even when the structure is most faint and difficult to detect, this is due, not to any lack of perfection in the minutest details, but merely to want of contrast between the colour of the cell-walls and the material within the cells.

The relation between vitrain and clarain, which has been the subject of very extensive discussion and much confusion, may be regarded as now cleared up. Subject to a qualification to be mentioned immediately, each separate band or lenticle of vitrain represents a single fragment of wood or bark or other piece of plant tissue. Its distinctness and its homogeneous character result directly from this fact. In other words, each plant fragment of sufficient size to be clearly visible on the coal surface constitutes a vitrain lenticle. Clarain, on the other hand, consists largely of similar plant fragments, which are individually too small to be distinguished without the microscope, and are moreover mixed with more minute plant debris such as spores, isolated cuticles and other matter. It is the minutely heterogeneous character of the mass which results in a lower surface lustre.

Two views regarding the nature of the 'uniform brown substance.'—Thus the 'uniform brown substance' for the most part, at least, represents portions of plant tissue with their organised structures exquisitely preserved. But the reservation in the preceding paragraph was necessitated by the fact that with any technique yet devised, it has been impossible to demonstrate that *all* this material possesses structure; and this fact is frequently seized upon in discussions of the two views which are held regarding the essential nature of the brown substance as a whole. There are those who regard it as made up entirely of plant fragments, each of which now consists only of the remains of the organic substance of which that particular plant fragment was originally composed. The alternative view is that a large part of the substance of the original vegetation was reduced by early decay to the condition of a true fluid, some of which was absorbed into those plant fragments which retained their organisation, while other portions of the fluid may have solidified as a truly structureless gel, and acted as a cement to the whole mass. The latter view is almost universally held among Continental workers, and these accordingly are disposed to interpret the 'structureless' material as evidence of such a gel. Whatever may be the amount of truth in this latter hypothesis—and there is considerable evidence that it applies in some cases—it is absolutely unquestionable that the plant remains which now form this translucent coal substance have been rendered jelly-like, whether by their own decay or by absorption of extraneous material. In nearly all cases cell-walls which were clearly rigid have been flattened and folded without rupture. Often the entire tissue has been contorted into the most fantastic forms, but still remains unbroken.

So far as appearance is any guide to composition—and there is good ground for the belief that it does give some indication—there is little reason to suppose that the essential nature of this substance is very different whether the plant-structure be discernible or not. Differences we must expect to find when sufficiently detailed chemical examination is applied, and it will be of the greatest interest to discover how far they are affected by the nature of the original plant material. But for the present, all our evidence points to a remarkable general uniformity. The discussion of this question is obviously a matter for the chemist, but reference to only two of the distinctive qualities of this substance may be made, as sufficiently significant. If the purest substance, as represented by vitrain, be examined, the ash-content is always found to be amazingly low. Not only is it a mere fraction of that present in the rest of the coal substance, but it is much below that in any average aggregate of modern plant materials. There is no reason to suppose that the vegetation of the coal-forests was abnormal in its content of inorganic matter, so we must presume either that the inorganic content of this part of the coal has been reduced, by leaching out, or that there has been a very large addition of pure organic substance. Secondly, this material shows extremely little variation in its organic composition, as compared with the other constituents of the coal. While the hydrogen content, for example, in the different ingredients of a single block of bituminous coal may be found to range from $3\frac{1}{2}$ to 8 per cent., the variation among samples of vitrain from the same block will rarely exceed a twentieth of that amount. It is because most coals consist mainly of this substance that they differ so little from one another. Prof. Wheeler and his colleagues have shown that it is mainly composed of ulmin compounds.

If, now, I have seemed to dwell unduly on this 'uniform brown substance,' which we see practically pure in the bands of vitrain and somewhat adulterated in clarain, I must repeat that it is by far the most important constituent of coal. If anything deserves the name of 'coal substance' it is this, though there are countless reasons why such a designation would be most undesirable. But it is none the less unfortunate, in the interests of clarity, that we have no universally accepted term by which to denote it. It is the 'anthraxylon' of Thiessen and the 'lignitoid' of Jeffrey. Both these terms offend the more scrupulous by their implication that 'wood' is the only parent substance; which is far from being the case. Some workers have suggested the restriction of those terms to such examples as can be shown microscopically to have been formed from wood, coupled with the introduction of such terms as 'suberitoid' for examples in which 'bark' can be shown to be the parent material, and so on for other cases. There is grave danger of confusion and misunderstanding of much valuable work in a welter of conflicting terminology. Dr. Stopes has recently tried to cut the Gordian knot by devising a set of co-ordinated terms which will cover all the possible cases. But the prime need of the moment is clear recognition of the general similarity of this substance irrespective of the plant tissue out of which or in which it has been formed. A term is required which has no botanical implications. In the vitrain bands we see the substance in its most tangible form. But the term vitrain cannot well be applied to the substance itself, since it is also the major component of the clarain bands. The term *vitrinite*, however, suggested by Dr. Stopes, offers an escape from this difficulty, while recalling the fact that in vitrain we have the substance in its purest form. I shall therefore use this term in the sequel.

The other Components of Coal.—We must now take stock of the other materials which go to the make-up of an ordinary coal seam. Though they are subsidiary in amount to the vitrinite in most portions of the seam, it is the character and varying quantity of these other materials which primarily differentiate the quality of the coals.

Most conspicuous and familiar is the 'mineral charcoal' or fusain. This illustrates at once the fact that in some cases the mode of preservation of the plant-substance may be of greater import than its original nature. The fusain is usually woody tissue, clearly identical originally with much of that which has been converted into vitrinite. But how different in its present form! Devoid of any organic substance in its cell-cavities; every cell-wall so brittle as to break at a touch; always extremely low in its content of hydrogen and oxygen, and correspondingly high in carbon. Physically and chemically it stands in the strongest possible contrast. On account of its porous nature it has commonly formed the receptacle for much of the mineral matter which has been deposited from solution in the coal, and is consequently a great carrier of ash. Quite moderate variation in the amount of fusain in the coal has important effects on its utility for various purposes. Practically as well as theoretically it is therefore important to notice that the amount of fusain in a seam cannot be estimated by the quantity existing in separate fragments or layers of sufficient size to be visible to the eye. Its most conspicuous quality is its friability, and it is consequently but natural to find much of this material in the form of microscopic fragments in the dull coal or durain, and even to some extent among the clarain.

The next group of coal components may for the purpose of this review be designated the 'high-hydrogen' group—the outer coatings of stems, leaves and spores which are characterised by an accumulation of waxes, fats, resins and allied substances. Leaving to the chemists the difficult problem of determining the precise nature of the materials forming these various plant-coatings, and degree of alteration to which they have been subjected in the coal, it is enough for us to note the characteristic fact that these components of the coal have a relatively high hydrogen content, and that they differ so strikingly in chemical properties from the rest of the coal that by the roughest chemical treatment the remainder of the coal can be broken down while the spore-coats and cuticles are left little altered. On this account Dr. Wheeler speaks of these components as the 'resistant plant remains.' Extracted from the coal, these coatings are seen under the microscope to differ in structure little, if at all, from their condition in a living plant. Their obvious relative indestructibility has resulted in their accumulation in the coal in quantities much in excess of their natural proportion—in extreme cases, even to the total exclusion of other materials. How greatly their presence may affect the composition of the coal is indicated by recent work in which such material has been mechanically separated from the coal and found to have a hydrogen content of nearly 8 per cent.

Associated with the cuticles and spores in respect of chemical peculiarities and durability, but differing somewhat in the manner of distribution in the coal, are the resinous secretions of the plants. Since the resins were originally contained in the wood or bark, they are found largely in the vitrinite of the coal. On the other hand, they are often found in local aggregations among the more disintegrated plant debris, in such a manner as to suggest that the aggregates may represent the resinous content of a tissue which has, for the rest been almost entirely destroyed.

There is one other distinctive ingredient in most ordinary coal seams characterised by its minute state of fragmentation. It forms a kind of paste, made up of particles of 1 or 2 microns or less in diameter. Careful examination of the rest of the coal substance has shown, as might be expected, that it consists of plant-fragments of every size from pieces of several inches down to the size of single plant cells. But below that size (say 20 to 60 microns) there is an unmistakable jump to the immensely more fine paste just mentioned. Obviously it represents quite a distinct stage in the degradation of the plant material; and there is some indication that it has distinctive chemical peculiarities. It is of very dense colour, and is consequently opaque except in the thinnest sections. It is essentially characteristic of the dull coals. So far it lacks a generally recognised title and has been merely described as the 'residuum.' Dr. Stopes would christen it 'micronite.'

'Sapropelic' Coals.—In the foregoing account of the components of coal I have dealt with those to be found in our normal bituminous coals of Carboniferous age. So far as my knowledge extends, the account does not require material modification in reference to the coals or lignites of other ages, except in so far as results from the minor structural differences (such as the greater proportion of true wood) in the more recent vegetation, and from some difference in the physical character of the materials in the lignitic condition. But there are other types of coal, particularly the cannels and bogheads, which have a widely different structure and at least one very different component material. There is much evidence to support Potonié's view that these latter coals are essentially water-deposited accumulations of fine plant-residues (sapropels), while the 'normal' coals are essentially peat ('humic') deposits. One of the essential characters of a cannel is certainly the fine state of division of all its materials. But the feature of most pertinent interest is the occurrence in these sapropelic deposits, and in no others, of microscopic oil-bearing algæ. It is well known that these were described long ago by Bertrand and Renault; and also that their algal nature has been over and over again denied. None of the criticism did justice to Bertrand's original work, but in the last few years these organisms have been carefully re-examined by Zalessky, by Thiessen, by P. Bertrand, and by my own colleague Dr. Temperley, who have not only demonstrated their structure in greater detail, but have established their essential similarity (and possible identity) with the living oil-alga *Botryococcus braunii.* This constituent of the cannels affords the most striking of all examples of the effect of original materials on the composition of the coals. There are cannels entirely devoid of algæ, and others in which they are present in all proportions up to that in the best bogheads, of which they may form 90 per cent. As the algal content increases, so the percentage of hydrogen in the coal rises, from about 6·0 per cent. in those without algæ up to more than 12 per cent. in the purest algal bogheads.

Types of Coal Aggregate.—I believe these are all the constituent materials which have so far been recognised in ordinary coals. It remains to consider how they are distributed among the various types of coal aggregate. With a considerable number of components it might be expected that a great variety of aggregates would be formed. It so happens, however, that the most important constituents are distinguished by widely different average size of the fragments in which they occur; and in coal, as in other fragmental rocks, size is the great sorting factor. The dominating component, vitrinite, exists for the most part in fragments much larger than those of any other component except fusain. It follows that as the average size of the particles in any coal aggregate decreases, so the proportion of vitrinite usually becomes less, while that of spores, cuticles, resins, fragmented fusain and residuum become greater. This introduces an important element of order where there might have been almost complete chaos. It is a further fortunate circumstance that the physical character of the vitrinite—the brilliant cleavage surfaces with which it fractures when in fragments of sufficient size—affords a means by which the proportion of this material in the aggregate can at once be roughly assessed. The more vitrinite, the brighter the coal, is a rule which is seldom broken. Ever since coal was used the different qualities of 'bright' and 'dull,' or 'softs' and 'hards' have been recognised; and it is the large or small proportion of vitrinite which is mainly in question.

Complete gradation from the brightest coals, consisting entirely of large fragments of vitrinised tissue—that is, of vitrain lenticles only—through every stage of decreasing particle size, decreasing vitrinite content and decreasing lustre, to the most finely granular dull aggregate is to be expected and is easily found. But experience readily shows that in most seams there is a small proportion of bands which are unmistakably quite without lustre, and that these are sharply separated from the 'bright' coal, even though the lustre of the bright bands may vary widely. The distinction of the two types of aggregate clearly corresponds to some difference in the mode of accumulation. The really dull bands are usually (though not necessarily) characterised by a very much higher content of ash than the bright coal, and this excess always consists of a very fine clay which must have been water-borne. It is clearly desirable to distinguish this true dull coal from the rest of the seam, and hence the term durain applied to it is much to be preferred to the merely relative 'dull coal,' which is in fact often applied to some of the vitrinite-rich coal which is merely less lustrous than the rest. Durain and clarain are the two main types of coal in an ordinary bituminous seam. Both are of variable composition, and the one may shade into the other though they are commonly somewhat sharply separated. The clarain, however, with its dominating vitrinite constituent, tends to comparative uniformity of composition, while the durain may be far more varied. A rich content of spores, cuticles or resins may make the durain conspicuously rich in hydrogen; while a dominance of residuum, or a high content of fragmented fusain, may have the opposite result. It is the variable part of the coal.

The Rank of Coals.—We have now reviewed what microscopic examination has disclosed concerning the nature of the various ingredients which make up the coal deposits, and have glanced slightly at the various *types* of coal aggregate which these ingredients may form. It has always been more or less clearly recognised, however, that coals differ not only in the type of aggregate of which they may have been compounded, but in the degree to which the original composition of this aggregate has been altered. This degree of alteration constitutes what we speak of as the *rank* of the coal, we must now consider the respective shares of type and rank in determining the final composition of the coal.

Ever since Rogers drew attention to the gradual change in the quality of the coals as one proceeds towards the Allegheny axis or away from it, debate has continued on the question as to how far the quality of the coals has been determined by the geological conditions to which they have been subjected, and how far it is due to the original plant composition, conditions of deposition and the manner of organic decay. No one has ever seriously contended that either set of circumstances has not been responsible for *some* share in producing differences in quality; but there has been the most extreme divergence of opinion as regards the relative importance to be assigned to each. From the geological standpoint the greatest contribution which is made by the microscope to the study of coal is, that it enables us to determine definitely whether the difference in quality of two coals can or cannot be attributed to original difference of composition. If they can be seen to consist of entirely similar plant materials in a similar state of preservation, then any considerable difference in quality must be attributed to some other factor. Conversely, we may compare the quality of coals which are visibly composed of different materials, and find what are the constant differences between them.

Composition of the several Components.—In common with most vegetable substances, coals consist mainly of carbon, hydrogen and oxygen, and as the first step in the discussion of this problem we may enquire how the proportions of these constituents vary among the different plant materials which may be isolated from any single piece of coal. All the vitrinite is found to be of very uniform composition. The group of cuticles, spores and resins is notably high in hydrogen, but is not exceptional in the ratio of carbon and oxygen. Any fusain present will be very deficient in both hydrogen and oxygen. In a coal in which the general percentage of oxygen is 15, that of the fusain may be as low as 5. The chemical composition of the residuum needs further investigation; the indications are that it is usually a little deficient in hydrogen and oxygen, but not to such an extent as in the case of fusain. The outstanding fact is that the different components vary strikingly in their hydrogen content (from about 3·5 per cent. in fusain to 8·0 per cent. in some spores), while only in the case of fusain is there any notable variation in the oxygen.

Composition of the Aggregate.—How does this variation in the composition of the individual plant materials compare with the observed range of the bulk composition of different coals? If we take a very large number of representative analyses of lignites and bituminous coals (but exclude for the moment anthracites and cannels) we shall find the limits of variation of the chief constituents to be approximately as follows: Hydrogen, 4·5 to 6·0 per cent.; carbon, 65 to 90 per cent.; oxygen (varying in almost exactly complementary proportion to the carbon) 30 to 5 per cent. We see clearly that the whole variation of hydrogen content is well within the range observed among the different plant constituents in a single piece of coal. There is consequently no reason to suppose that among *this* group of coals the hydrogen content has been appreciably varied except by the character of the original materials. Variation in the type of coal shows itself in the chemical analysis chiefly in differences of hydrogen content, and it might account for the whole of those differences.

But the answer is emphatically reversed when we turn to the carbon : oxygen proportions. A great increase in the proportion of *fusain* in the seam is the only change among the plant materials which could affect the general oxygen content of the coal very considerably; but so much as 10 per cent. of this material would be an exceptionally high quantity in any seam, and this amount might reduce the general oxygen content of the coal by about 1 per cent. The observed range of oxygen content in different coals is therefore many times greater than could be produced by any known variations of the plant constitution. This observation, taken in conjunction with the fact that the microscope fails to reveal any general difference of plant constitution between coals with high oxygen content and those with little, leaves no doubt that this aspect of the chemical history of the coal is determined by something other than the type of plant aggregate. It is this difference of oxygen content which chiefly denotes the *rank* of the coal, distinguishing the lignites, bituminous coals and anthracites.

A very significant feature of this variation in rank is the fact that it is *continuous* throughout its long range. If any very large number of analyses of lignites, coals and anthracites be plotted, they will be found to form on the graph a very long and narrow belt which is unmistakably continuous. The significance of this continuity is emphasized in an interesting way by the work of Prof. Bone and his colleagues, who have shown that the proportions of the different types of organic compounds present in the coal vary progressively throughout the series.

Cannels and Anthracites.—Cannel coals were excluded from the foregoing remarks on chemical composition merely because they form an extreme and relatively uncommon type. But just for this reason they afford the most striking illustration of the dependence of type on mode of origin and plant constitution, as also of the fact that in ultimate composition it is the hydrogen which is most affected by these differences. Its increase in proportion to the number of algæ in the mass is unmistakable, and the figure of 12 per cent. reached in the pure algal cannels is sufficiently remarkable to ensure that no one will overlook its significance.

Anthracites were omitted because in these very high-rank coals the rule that hydrogen content is independent of rank breaks down. In these coals the oxygen content has been reduced almost to the lowest possible limits, and as alteration proceeds further the hydrogen begins to be eliminated, and may be reduced to 2 per cent., or even 1 per cent. The last stage is graphite. That this hydrogen reduction is the result of a late stage of alteration is sufficiently proved by the fact that it is found *only* in those coals in which oxygen is reduced to 5 per cent. or less. Since a good deal of the discussion about the significance of rank in coal has centred round the anthracites, this fact that hydrogen elimination occurs only in the last stages has often been overlooked. For example, the use of the carbon : hydrogen ratio as a measure of rank is clearly permissible only in these high-rank coals ; but it has often been applied also to those of lower rank, in which, as we have seen, the hydrogen variation is expressive of the plant constitution of the aggregate rather than of ' metamorphic ' changes.

The Significance of Rank.—The thesis towards which all my remarks have been preparatory is that the rank of a coal is the measure of the alteration in composition which the deposit has suffered in consequence of the rise of temperature and increase of pressure resulting from its burial in the crust. I have been at some pains to distinguish between the differences in composition which denote rank and those due to the varying type of the deposit, since this thesis can only be fully established when this is done.

What do we know of the relation between the rank of coals and their distribution in the rocks ?

The oft-quoted fact that Tertiary coals are mostly of low rank (lignites) and the Carboniferous ones mostly of high rank (bituminous or anthracitic) may be dismissed with the comment that it is in fairly obvious agreement with the fact that the former are for the most part contained in relatively thin deposits and the latter in much thicker accumulations ; while the formation of Tertiary anthracites under appropriate conditions sufficiently disposes of any suggestion that the mere lapse of time is a necessary factor.

An association of high rank with areas of intense folding is well established, but is open to more than one interpretation. David White's observation that the area of highest rank in the Pennsylvanian and Virginian fields does not lie on the Allegheny axis, but to one side of it, agrees with the distribution in South Wales and elsewhere. It may be held at least to show that the direct effect of movement on the coal substance is not a prime factor. The true relation between folding and rank is more likely to be found in the relation of both to geosynclines.

The fact which appears to me to establish most clearly that change of rank must be caused by some geological factors is its areal distribution. In every coalfield where substantial variation of rank has been noted and examined, the rank of any given seam is found to change *progressively* as it is followed across the field. If the variation be plotted on a map by means of lines representing volatile content, carbon content, or any suitable measure of rank, these lines are found to be arranged in an orderly pattern and—this is the important point—the same pattern is repeated by each seam within the area. Wherever the rank of one seam is increased, there also is that of the others. Whatever cause has affected one has affected all.

An attempt has been made to meet this fact without introducing ' metamorphic ' effects by the assumption that the patterns revealed may reflect the form of the original basin of deposit, it being further assumed that the character of the coal-peat varied progressively from the margin towards the centre of the basin. There are many reasons why it is difficult to accept this interpretation. Apart from the fact that I do not believe that any geologist familiar with all the circumstances could accept the actual patterns as related to shore-lines in this way, especially in view of the difficulty that the same pattern has to be repeated through a great thickness of deposits, there is the complete absence of any shred of evidence from the coals themselves that the character of the deposit did change in this manner, coupled with much positive evidence that it did not.

Valuable light is shed on this matter by the detailed information concerning the composition of many of our own coal seams and their variation which is being accumulated by the National Fuel Survey. Many of the seams examined, particularly in Northumberland and Durham, show large changes in rank as they are followed across the coalfields. Some of the seams are notably ' bright ' coals, with a relatively high hydrogen content; others contain a larger proportion of durain and (commonly) a lower percentage of hydrogen. A careful comparison of the analyses shows clearly that the seams which are high in hydrogen retain that peculiarity regardless of change in rank, while those which are low remain low. In this way the chemical evidence supports that provided by the detailed examination of the physical peculiarities of the seams, which shows them to have, on the whole, a very constant character throughout their range. Still further proof of the same fact is provided by the work of Dr. Raistrick and others on the very distinctive spore-content of the various seams, which again shows a notable constancy and is quite unaffected by the changes in rank. The cumulative evidence leaves no room for doubt that in these instances the change of rank is quite independent of the original constitution of the seams.

Hilt's Law.—The simplest and most familiar evidence of a relation between rank and geological conditions is Hilt's law: that, in any single vertical section, the deeper seams are of higher rank than the upper seams. In spite of frequent denials, there seems little doubt of the general applicability of this rule. Apparent failure of the rule in some cases is doubtless due to the fact that original differences between seams may affect their present composition to a greater extent than small differences of depth. But when the differences of depth are substantial, exceptions are rare. Another cause of doubt would appear to be a not infrequent misunderstanding as to the nature of the law itself, which becomes rather easily misconstrued into a statement that the (stratigraphically) lower seams are of higher rank than the upper seams. Consequently the fact that a stratigraphically lower seam in one place is actually of lower rank than an upper seam elsewhere is mistakenly accepted as evidence against the rule.

The value of Hilt's law lies, first, in the fact that it is unambiguous in its significance, and, secondly, in the fact that since we know something of the increments of temperature and pressure which correspond to given differences of depth, and can compare these with the changes of rank produced, it gives us the data necessary to reverse the process, and to consider the rank of coals as an indication of the temperatures and pressures to which they have been subjected. The temperature increments are clearly so small that most geologists have been inclined to attribute the effects mainly to pressure. It is impossible to discuss this matter within the limits of this address, so it must suffice merely to refer to the experimental work, which has shown how readily coal, even in its present condition, yields volatile products at very moderate temperatures, and to the fact that in the effects of igneous intrusions we have a series of beautiful natural experiments in the alteration of rank of coals by heat alone. In some of these natural experiments the resultant effects on the coal appear to be in every respect analogous with the ordinary changes of rank; in others they are obviously different. In the latter instances it is not difficult to see that the results are due to the rapid application of somewhat considerable increments of temperature. There appears to me to be quite good evidence to show, on the contrary, that in those cases, in which considerable changes of rank of the normal type have been produced, the total increments of temperature have been quite small.

If it be true that the rank of coals has been determined mainly by the depths to which they have been buried, then it is natural to look for some relation between the varying rank of any seam and its present depth below the surface, or to relate it to axes of folding. Much has been written on this subject, and completely contradictory conclusions reached. But this is to be expected. The coal can only indicate the *maximum* temperature or pressure to which it has been subjected, since change of rank is almost certainly an irreversible process ; decrease of temperature and pressure will not restore it to its former level. Now a little reflection will show that, after the completion of the coal-bearing series, the most general result of subsequent folding will be elevation and denudation, leading to a decrease rather than an increase of load. In so far as this is true, the folding will not be reflected by any variation of rank ; while, on the contrary, any circumstance which does lead to a further increment of temperature will leave its mark. Later burial of the whole series below an unconformable cover may lead to a change of rank in the deeper parts of the seams, while leaving the upper portions untouched. The time factor, moreover, can by no means be left out of account. Geo-isotherms creep with exceeding slowness, even in terms of the rate of sedimentation and denudation. The duration of burial as well as its depth is therefore material. In fact, the whole sequence of events which have determined the maximum temperature and pressure reached at any point must have been much too complicated to be readily decipherable from the present disposition of the rocks.

In all these complications, however, one cardinal principle remains. At any given place, both temperature and pressure must always have increased downwards—apart, of course, from the influence of igneous intrusions. And so, while the interpretation of the lateral variation of rank is involved in many complicating factors, Hilt's law remains as a simple and significant sign. Even in this case the significance is liable to be obscured by the variation of the original coal substance of the different seams ; but the technique of the microscopic study of coal has now reached the point at which, I believe, the effect of this factor can be almost completely assessed and eliminated. If this be so, then we are in a position to use coal as a geological thermometer—or, perhaps, combined thermometer and barometer—and we may set about calibrating it by means of a thorough study of Hilt's law and of the effects of igneous intrusions. But we must never forget that the thermometer has one peculiarity—it is a maximum thermometer only.

SECTION D.—ZOOLOGY.

THE SPECIES PROBLEM

ADDRESS BY

PROF. F. BALFOUR-BROWNE, M.A., F.R.S.E., F.Z.S., F.R.E.S., P.R.M.S.

PRESIDENT OF THE SECTION.

A PREDECESSOR in this Chair [1] called the attention of the Section to the fact that Alfred Russell Wallace, in referring to 'the curious correspondence both in mind and in environment' by which Darwin and he reached the theory of Natural Selection, accounted for it in the first place by the fact that both Darwin and he commenced by collecting beetles and thus acquired 'that intense interest in the mere variety of living things which led them to speculate upon the "why" and the "how" of this overwhelming and at first sight purposeless wealth of specific forms among the very humblest forms of life.'

It is, therefore, with excellent backing that I confess that my main interest as a naturalist has always been in this same Order of insects but, whereas in the case of these two great men, the study led them to the origin of species by means of Natural Selection, I come here hoping that absolute faith in that theory is no longer the only hall-mark of a balanced mind, because a long experience of the habits and structure of water-beetles has led me slowly but surely to the belief that Natural Selection plays a much smaller part in the origin of species than has been claimed for it.

I propose to deal mainly with two groups of water-beetles to which most of my time has been given, the Carnivorous group or Hydradephaga, and the so-called Vegetarian group, the Hydrophilidæ. From the fact that they inhabit water other than salt water, they occupy isolated areas, and these can be roughly grouped as ponds, lakes and rivers, and the beetles occupying any one pond, lake or river may be described as a community. An intensive study of any such habitat produces a list of species forming the community in that particular habitat, and I have spent hours working out the percentages of occurrence of the species in

[1] W. T. Calman, *The Taxonomic Outlook in Zoology*, Bristol, 1930.

these communities. Such work certainly justifies the recognition of associated species, a pond community differing in its composition from that of a lake or river, and a further study of ponds, lakes and rivers shows that they also can be classified into types, in each of which the community of water-beetles differs in species-composition from the others. A silt-pond, for instance, in clay or marl, gravel or sand, has a community differing markedly from a detritus pond, where decaying vegetation has produced a muddy bottom and somewhat turbid water. Again, a brackish pond provides the collector with species not to be found in the previously mentioned types, and the peat pond produces other species. The silt pond is by far the richest in species and, out of about 250 in the British list, from forty to sixty species occur in it and may even be taken in one pond at the same time.

It is, however, obvious that this classification of types of ponds, etc., is only a rough one, because the silt pond gradually changes to the detritus pond and all ponds are slowly changing their character to pass through a swampy marsh stage to dry land. The lake, around its edges, acquires pond conditions and the evolution of the lake follows that of the pond. Rivers are slowly changing, the less rapid parts tending to silt up and produce pond conditions so that, although, as I have said, the intensive study of water-beetles justifies the recognition of groups of species associated with types of habitat, the same spot visited throughout a series of years will provide an ever-changing habitat and an ever-changing community of water-beetles.

Now the obvious explanation of this community grouping of species is that some are less well adapted to a particular type of habitat and are, therefore, excluded from it by better adapted species, but is this the whole explanation ? That there is a struggle for existence is beyond dispute, but is it as severe and determinate as is usually supposed ? Among vegetarian insects there is often a range of food plants, upon any of which they may be found. In most cases there is no evidence that the different plants carry monophagous races, in fact it is normal for such insects to remain healthy and to complete their life-histories when changed from one to another of the plants. In the case of some insects, either monophagous or oligophagous, other plants are resorted to under some circumstances, indicating that the normal food plants are the 'choice'[2] of these insects and that other plants are food reserves. The Small Eggar Moth[3] has a variety of food plants, but I have reared it successfully upon laurel, birch, elm, and some other plants which are not included in its normal menu. Among the bark-beetles, the majority commonly breed in dying or fallen trees or in trees which, owing to fire or other cause, have been weakened. These beetles are, therefore, in the nature of scavengers, clearing away dying trees ; but at times when great damage has been done to the forest by wind, fire or snow, they increase greatly in numbers and then attack not only healthy trees of their normal food

[2] It will be understood that I am using the term 'choice' in the same sense as a scientific man uses the term 'free will,' knowing that every action is an effect following a cause.

[3] *Eriogaster lanestris*, L.

species but other species as well. In the French vineyards a bug [4] attacks the vines, but the damage is done mostly after a clean up which entails the destruction of a weed,[5] which is the preferred food. 'At Dartford in Kent, where henbane and belladonna are grown on a large scale for the sake of their alkaloid bases, it has been found that, whereas in some years as much as 80 per cent. of damage is done to the former crop by the maggot (of a fly) the latter remains unaffected, although in close proximity. . . . When henbane is absent, belladonna proves quite attractive.' This was Cameron's observation upon the Belladonna Leaf-miner.[6] The Cotton Boll-worm, the caterpillar of a moth,[7] a pest of various crops, including maize, cotton, tobacco, lucerne, etc., which is a very general feeder in many countries, shows a definite preference in some for maize over cotton, and one of the methods of control in the cotton-fields is to interpose rows of maize, upon which the moths lay their eggs in preference to ovipositing upon the cotton.

In all the above examples, and they could be multiplied many times, it is evident that choice plays a part in determining the food of the insect, and I think it is possible to show that choice also plays its part in connection with the habitat occupied by the water-beetles. In the first place, the carnivorous water-beetles are not restricted to any type of habitat by the nature of the food, since both adults and larvæ will consume any living organism they can catch and which can be penetrated by their mandibles, and the adults will also eat any dead material of a similar soft nature. I have kept in captivity many species in both these stages and have never had any difficulty in feeding them. In the second place they are not restricted by soil conditions or by the nature of the vegetation, since they can be kept in captivity under conditions very different from those in which they are normally found. Peat pool species live quite well in my cement-lined aquaria in hard water and even breed there. A brackish pond species [8] rarely found inland has bred in one of these aquaria for three years. I have kept for some years one of the small running-water species [9] in tumblers in which the water was never changed.

All these examples, and many others could be given, indicate that neither soil nor plant environment have a direct effect upon the water-beetle communities, so that, if the struggle for existence is what segregates the species, the active factor must be the internecine strife of the animal population. There is undoubtedly a large amount of preying of one organism upon another, but unless some species of water-beetles are more palatable than others or unless the life-history of different species differs to such an extent that the larvæ of one species are killed off at a time

[4] *Nysius senecionis*, Schill. (Lygæidæ).

[5] *Diplotaxis erucöides.*

[6] A. E. Cameron, 'A Contribution to a knowledge of the Belladonna Leaf-miner, *Pegomyia hyoscyami*, Panz., its Life-history and Biology,' *Ann. Appl. Biol.*, vol. i, 1914, pp. 43–76.

[7] *Heliothis obsoleta.*

[8] *Hygrotus parallelogrammus*, Ahr.

[9] *Bidessus minutissimus*, Germ.

when another species is safe from attack, it is not reasonable to explain these more or less constant communities in that way. Moreover, unless we assume that the 'purity' of a community is maintained by the immediate destruction of all emigrants, the struggle for existence cannot account for the fact that at no time of the year is there a general mix up of communities, even when the new generation, overcrowding its birthplace, is migrating elsewhere, indicating that the emigrants *choose* their new homes and do not go to the first water they may find. Ponds in areas liable to flooding may contain river species after the flood has subsided, but such species will be rare or absent after a period free from flood. Neighbouring ponds in an area where ponds are numerous, such as brick pits, often provide certain species in certain ponds, even for periods of two or more seasons, although the general fauna of all the ponds may be otherwise similar. In many places in Scotland the roads in the moorland districts are repaired by digging the boulder clay along the sides and using this material as ballast. These holes quickly fill with water and form typical silt ponds. In the course of time, sphagnum and other vegetation fills them and they become peat pools. In Lewis and Harris, in 1914, I paid special attention to these ballast ponds. Of the 23 examined, 15 were either free from any weed or contained water-grass (*Glyceria*) with, at most, traces of sphagnum ; that is, they were recently dug holes. In the 15 ponds 30 species occurred, out of the 52 taken by me in the island. Of these 30 species, 13 occurred proportionately [10] more often in these ponds than elsewhere, indicating that these species, or at least some of them, sought out these silt ponds in preference to the much more numerous bog pools. In one of my aquaria, about 12 ft. long and 2 ft. wide, there is a bank of stones and earth dividing it into two ponds. One of these is preferred by some of these species of water-beetles and they always migrate to it when placed in the other. The one they prefer is also preferred by the water-shrimp (*Gammarus*) which is always more abundant in it than in the other.

All these examples show that choice plays a part in the composition of these communities, but, just as water-beetles are grouped into communities associated with types of habitat, so also can they be allocated to groups according to their distribution. In the British Islands these groups have been recognised, not only for the water-beetles but for the whole fauna and flora. H. C. Watson,[11] in 1832, divided the country into provinces based upon the groupings of the plants, and in 1846, Edward Forbes [12] showed that similar groupings could be made of the animals. Forbes was the first to offer an explanation and he regarded

[10] The method of determining the proportional occurrence of these species is as follows : *Hydroporus nigrita*, Fab. occurred in 4 of these 15 ponds and in 14 of the other 115 collections. Fifteen is about one-eighth of 130, so that, if the species were generally dispersed, it should have occurred in 28 of the other collections. Actually it only occurred in 18, so that, proportionately, it was more common in silt ponds than elsewhere.

[11] *Outlines of the Geographical Distribution of British Plants*, Edinburgh, 1832, and *The Geographical Distribution of British Plants*, London, 1843.

[12] 'The Geological Relations of the Fauna and Flora of the British Islands, etc.,' *Mem. Geol. Survey*, vol. i, 1846.

the groups as indicating elements composing the fauna and flora which had arrived at different times. Further, by comparing the European distribution of the British species, he suggested the directions from which those different elements had arrived and the relative times of their arrival. He recognised three preglacial groups, the 'Lusitanian' in the west of Ireland, which he believed came from the Spanish peninsula, the 'Gallican,' in south-east Ireland and south-west England, from the Mediterranean region, the 'Kentish,' from the same source, but later, the 'Scandinavian,' which came with the Ice-age from Northern Europe and occupies north-west Scotland and northern and western Wales, and the 'Germanic' element, the great post-glacial invasion occupying a large part of Ireland, southern and eastern Scotland and north, middle and east England. Forbes regarded each succeeding invasion as having driven the earlier inhabitants from the territories previously occupied by them, the whole theory being based upon the struggle for existence, species better adapted to the changed conditions pushing out the less well adapted. But, as in the case of the communities in their habitats, is this the whole story? Experiment shows that at least some species can be reared in districts far beyond their normal range. Two of the southern and south-eastern species lived in my tubs in north-east Ireland and I had succeeding generations each year. One of Forbes's Scandinavian species, with a British distribution limited to northern and western Scotland and north-west Ireland, lived and bred freely in my tubs in north-west Ireland and later in Cambridge. Someone will say 'Yes, but these beetles were protected in the tubs.' Protected from what? I imagine that they were chiefly protected from moving elsewhere, from exercising choice. If the struggle for existence were the whole explanation of the grouping, how can we account for the fact that some species in our islands do not occur under similar conditions to those under which they are found on the Continent? To take, for example, one of the north European species [13] which should belong to Forbes's Scandinavian type; until the last few years it has only been found in south-east England and East Anglia, except for a record for a single specimen taken in the Isle of Man in 1910,[14] but in 1930 it was found in Durham,[15] and in 1933 in Forfarshire in a place which was thoroughly worked in 1908 and where the beetle certainly did not occur.[16] Another Scandinavian species, common in many of the Scottish lochs, flourishes in a lake in Berkshire, and certain other 'northern' species occur in the New Forest and in Devonshire, apparently perfectly adapted to the very different climatic and organic conditions. Thus it is not only internecine strife or lack of adaptability which has caused the changes in the fauna but also movements of the insects stimulated by choice, an attribute of

[13] *Ilybius subæneus*, Er.

[14] F. Balfour-Browne, 'The Aquatic Coleoptera of the Isle of Man, etc.' *Naturalist*, 1911.

[15] Joyce Omer Cooper, 'Some Notes on Dytiscidæ collected in Northumberland and Durham in 1930,' *The Vasculum*, vol. xvii, 1931.

[16] F. Balfour-Browne, 'The Aquatic Coleoptera of the County of Angus, etc.' *Scottish Naturalist*, 1934.

the lower as well as of the higher forms of animal life, a point in which animals differ from plants and a point which has usually been overlooked in discussing the relationship of animals to their environment.

What I have called choice appears to play an even more important part than in mere localisation and distribution of species, and this is brought out in the observations that have been made upon biological races. Most of the work which has been done in this connection has been upon vegetarian species, but such races are probably much more widely spread than has been recognised. Where a vegetarian species has several food plants, it has been found possible, in some cases, to induce a preference for one of these by keeping a number of generations on that plant so that, ultimately, a race is formed which restricts itself to that food plant. Although in most cases known in nature, no morphological changes have occurred, in a few cases changes of habit have appeared and, in a very few, certain other changes have been recorded. Thus, the 'Railroad fly,' [17] an apple pest of North America, has a larger race on apple and a smaller one on blueberry. Cameron [6] noted a colour variety of the Belladonna Leaf-mining fly, known as 'var. betæ,' definitely associated with the race found on chenopodiaceous plants and absent from the solanaceous race. Again, Nuttall,[18] who showed that the head and body lice of man are biological races of one species, stated that, although identical in all essential points of structure, they differ in habit, in feeding habit, in size and in the thickness and length of antennæ and length of legs, and he explained these differences as due to darkness (inducing longer and finer antennæ and longer legs in the body form), feeding habit (inducing a larger size in the body form, which takes large meals at intervals, the head form feeding frequently). Thus he associated the changes with physiological influences and, as the two races are on the same host, their origin must have been connected with choice on the part of individuals.

Physiological effects are far-reaching and, although we have as yet no good evidence from these biological races that new species have arisen in this way, we have abundant evidence of the effects of function upon structure. Both Darwin and Wallace stressed the importance of use-inheritance, that is, the inheritance of functionally-produced modifications, so that it seems possible that physiological change, induced by surrounding conditions, may have had far-reaching effects.

A study of any group shows that species differ in their relationships to one another; some form clusters and are difficult to distinguish, while others stand apart. So far as the water-beetles are concerned, the clustered species are not usually members of the same community or sometimes even of the same district. Although there is no evidence that they are recently separated species, the fact that they occupy different habitats, and that the differences are small, at least suggests that they may have originated from biological races. In this country we have many examples of these clusters. The two species *Agabus affinis* and *unguicularis*

[17] *Rhagoletis pomonella*, Walsh.

[18] 'The Systematic Position and Iconography of *Pediculus humanus* and *Phthirus*,' *Parasitology*, 1919.

are frequently mixed in collections because of their general likeness. They differ slightly in general outline and *unguicularis* is very slightly more brassy in colour than *affinis*, but otherwise only the male secondary sexual characters will separate the species. The males differ in the shape of the tooth on the inner front claw, in the shape of the ædeagus and in the form of the stridulatory file on the under side of the abdomen. *Affinis* is a peat bog species, although in areas where it does not occur, it may be replaced by *unguicularis*, the two not usually occurring together. *Agabus nebulosus* and *conspersus* are also found mixed in collections, as they closely resemble one another in general appearance. The former inhabits freshwater ponds and the latter brackish pools, but either can live in fresh or brackish water. *Nebulosus* is usually identified by inexperienced amateurs by two black spots on the pronotum, but in brackish water these spots are absent. The secondary sexual characters are again the best means of distinguishing the species. In both Grand Canary and Madeira, *nebulosus* occurs and, even under microscope examination, it is impossible to find any difference between these ' Atlantic ' specimens and those from Europe and North Africa. In the Azores, however, is *A. godmanni*, which is barely distinguishable from *conspersus*. *Agabus bipustulatus* is a species widely spread over Europe and North Africa and is one of the commonest British water-beetles. In the mountains of Scotland and on the Continent there is a narrow form of it which was given specific rank under the name *solieri*, but which differs in no way except shape and size from the type. In Madeira is an *Agabus* which in general appearance is a large *bipustulatus* and was so named by Wollaston. Sharp, however, recognised small distinctions which definitely give it specific rank, *wollastoni*, but it is difficult to believe that it has not originated from *bipustulatus*. *Agabus guttatus* and *biguttatus* form another pair of closely related species, scarcely distinguishable except by the fact that the male *biguttatus* has a toothed claw on the front feet while *guttatus* has not. Both occur in Britain but *guttatus* extends over Scotland, while *biguttatus* only reaches northern England. In Europe, *guttatus* is more northern and *biguttatus* more southern and extends to the Canaries where it is rather larger than elsewhere. In Madeira there is a small species, *maderensis*, which appears to be a modified *biguttatus*, the tooth on the male claw showing various stages of disappearance. In Majorca *biguttatus* is represented by a form which has been given specific rank under the name *binotatus*, but the relationship with *biguttatus* is exceedingly close. *Ilybius fuliginosus*, a common European species, is overlapped in the south and in the Mediterranean islands by *meridionalis*, but here again the differences seem to be too slight to justify specific separation.

In all these examples, and there are others in the Dytiscidæ and more in the Hydrophilidæ, there seems to be no interbreeding between the related forms, although in many of them opportunities for crossing must occur ; but no intermediates have been recognised. There are, however, some of these species clusters which, if they could be satisfactorily explained, might prove to be intermediates between biological races and species. These are cases of which I have elsewhere called ' composite species,'[19] a term which does not commit one to an interpretation of the phenomenon. I have been studying one of these complexes for some years and it consists of a series, at one end of which is what Fabricius named (*Deronectes*) *depressus*, while at the other end is what Panzer named (*Deronectes*) *elegans*. Both extremes undoubtedly have as distinct specific characters as any of the previously mentioned pairs. The general shape differs; although the type of marking and colouring is the same in both, *elegans* is distinctly brighter than *depressus*. The anterior claws of the male *depressus* are large, somewhat straight and sharply hooked towards the apex, while in *elegans* male they are more delicate and more evenly curved from base to apex. Further, the ædeagus is broad with a bluntly rounded apex in *depressus* and narrow and tapering to a point in *elegans*. But between the two extremes of each of these characters there are intermediate stages and one can form a complete series from one end to the other. A distribution map, based upon the width of the ædeagus, making six intermediate stages, shows that *depressus* is more northern and western and *elegans* more southern and eastern, and *depressus* is definitely more a peat form than *elegans*. The question arises: Is this a variable species controlled by climatic or edaphic conditions? Is it two biological races in process of formation or are these two species which interbreed? At the present time I am trying to solve this problem in the only way I can think of, by keeping *depressus* in my aquaria in Somerset under conditions in which previously *elegans* has lived and bred, and I am wondering whether, in the course of several generations, I shall find that they have become *elegans*.

Now it must be admitted that, although my studies of these water-beetles have led me towards the view that new species may arise by the means I have suggested, proof is still lacking and the view that acquired characters are inherited is still a pious hope rather than a proved fact. But in connection with the gap in the evidence on this subject, in the case of the water-beetle clusters referred to, it must be pointed out that we have no evidence that the species-characters distinguishing the pairs are really heritable and not merely the effect of the environment upon each succeeding generation. There is evidence from other groups of animals that acquired characters may not disappear directly after the stimulus which caused them has been removed. Therefore, it may well be that, in these water-beetles it would take a number of generations before any change would appear in the characters by which they are recognised. But, besides the possibility of these species having arisen in this way, there is another, based upon the work on Drosophila and Oenothera, where it has been shown that new characters may arise from changes in the chromosomes of the germ-cells, so that we can still ask the question, did the ancestors of water-beetles go into the water by choice and then develop adaptive characters, or did changes in form and structure create the choice by reason of which these beetles took to an aquatic life?

[19] 'The Aquatic Coleoptera of the Scilly Islands, with some remarks upon the Genus *Philhydrus* and upon "Composite Species,"' *E.M.M.*, vol. 68, 1932.

Someone is certain to challenge my statement that these species-characters are, for the most part, non-vital but, as a fact, comparatively few of the characters upon which we rely for classifying the water-beetles can be recognised as vital for the survival of their possessors. In the general characters there is a uniformity everywhere among water-beetles because the obvious features are, first those common to all Coleoptera, secondly those which belong to their land-relations, and thirdly those which place the species in one or other of these two groups, Hydradephaga or Hydrophilidæ. These latter characters are such that we recognise them as eminently suited to the habits of their owners and we call them 'adaptive.' The form of the adult is more or less streamlined, and in almost all the Hydradephaga the body is smooth and free from projecting hairs. The Hydrophilidæ are also smooth except for a felting of hairs on parts of the underside. The hind legs of both groups are adapted for swimming and, in both groups, an air-reservoir exists which enables the beetles to remain under water for long periods. The larvæ also show certain adaptive characters.

If we now analyse these characters we find that, although in some cases it appears that there have been special modifications of structure to enable the insect to live in the water, in other cases a change of function explains the adaptation. The modification of the hind legs into oars may be regarded as a modification of structure, since it is almost inconceivable that such legs could be of much use out of water. Moreover, the Hydradephaga include four families which, according to current opinion, have not had a common origin and yet all four have developed swimming legs in varying degrees, three of them on much the same lines. The enlargement of the basal segment or coxa of the hind leg is to be found in various land insects, but the special form of the postcoxæ and their fusion to the body has developed independently in three of these families. In one, the Pelobiidæ, which Sharp regarded as having only recently taken to the water, the changes in this structure have not advanced far, but, in the other two, the coxæ are greatly enlarged at the expense of the ventral body plate, the metasternum, and in almost all the Dytiscidæ the two parts form a perfectly smooth surface and present the minimum resistance in the water.

The Hydrophilidæ possess clubbed antennæ which are of use in connection with respiration. These beetles carry their reserve of air not only under the wing-cases, like the Hydradephaga, but also on the felting of hairs on the under side of the body and, when renewal of air is necessary, the beetle comes to the surface and breaks the surface film by pushing up one of the antennæ. This brings the ventral air-film into communication with the atmospheric air and a renewal of the air-supply takes place, not only in the two communicating reservoirs but also in the main air tubes or trachea which open into these reservoirs. Now the clubbed antenna is a structure which occurs in a number of families of beetles, at one time all regarded as having had a common origin and classed together as the 'Clavicornia,' but now recognised as belonging to different groups, indicating that the clubbed antenna has appeared more than once in the

Coleoptera. Whether or not it has a special function in other families, we can only say that it may have arisen in the Hydrophilidæ in response to physiological activities.

If we now concentrate our attention upon the Dytiscidæ and examine the characters upon which the subdivisions are based, we find that the majority of those upon which the tribes, genera and species are separated, show different stages of development and, since each stage is obviously a survival stage, the progress in evolution can scarcely have been due to natural selection or the elimination of the unfit. The Dytiscidæ include about 1,700 species grouped in about 80 genera and the modern classification is based upon that published by Sharp [20] in 1882 in his classical volume on the family. First there are two series known as the *Fragmentati* and the *Complicati*, distinguished by the fact that in the former the metathoracic episternum is cut off from the mid-coxal cavity by the mesothoracic epimeron, whereas in the *Complicati* the latter sclerite or plate does not intervene. The *Fragmentati* are divided into two on the shape of the post-coxæ which are more like those of the land relations in the *Noterinæ* and more like those of the *Complicati* in the *Laccophilinæ*, we find that the latter are, so to speak, approaching the boundary line between the *Fragmentati* and the *Complicati*.

In the *Complicati* there are three tribes: *Hydroporinæ*, *Colymbetinæ*, and *Dytiscinæ*, the first being separated from the others because the prosternal process, which projects backwards between the bases of the front legs and is a definite feature of the whole family, is bent and does not lie in the same plane as the rest of the prosternum, whereas in the other two this structure is flat. The *Colymbetinæ* are separated from the *Dytiscinæ* because the eye is notched in the former and smoothly rounded in the latter.

These are characters upon which the main divisions of the Dytiscidæ are based and our classification is founded upon what we believe to be relationships. The ancestral Dytiscid gave rise two to forms, *fragmentatus* and *complicatus*; the former again divided and produced the *Noterine* and *Laccophiline* ancestors, while *complicatus* first gave off the *Hydroporine* and then split to form the *Colymbetine* and the *Dytiscine*. But examination shows that, very frequently, the tendency to vary in the same direction exists on both sides of a division. As already mentioned, the *Laccophilinæ* tend to become *Complicati* and, in the *Hydroporinæ*, there are variations in the bend of the prosternal process, some having the structure almost as flat as it is in the *Colymbetinæ* and *Dytiscinæ*.

Within the *Hydroporinæ*, the largest group of the family, with about 34 genera and 870 species, another interesting tendency is recognisable. In all other Dytiscids we find that the ventral plates of the middle and posterior thoracic segments (meso- and meta-sterna) are connected in the mid-ventral line. In most of the *Hydroporinæ*, however, this is not the case, these parts being separated. In the genus *Hydroporus*, usually

[20] 'The Aquatic Carnivorous Coleoptera or Dytischidæ,' *Trans. Roy. Dublin Soc.*, vol. ii, series 2, 1882.

regarded as the highest genus in the group, connection is complete, whereas in *Deronectes*, separated from it only on this distinction, the distance between the parts differs in different species and suggests that the genus is developing along the same lines as *Hydroporus* and will ultimately join up with it. In the genus *Hygrotus*, also, one species (*decoratus*) has reached the stage seen in *Hydroporus* although, as Sharp points out, 'the contact is of the most minute and imperfect character.'

In the land relations of the Dytiscids and in the majority of the members of this family, the anterior foot is composed of five easily recognisable segments. In the *Hydroporinæ*, however, only one section of about twenty species (*Methlini*) possess five normal segments, all others having the fourth either reduced in size or absent, and although this tendency to reduction has not appeared elsewhere in the family, it occurs in other families of the beetles.

The *Colymbetinæ* are separated from the *Dytiscinæ* by the shape of the eye, a small projection of the fronto-epicranial plate having grown out upon one side and so indented the outline. This character is common to the *Hydroporinæ* and *Colymbetinæ*, but in the *Dytiscinæ* the projection passes outside the eye, which is smoothly rounded. We thus see that, although the *Hydroporinæ* and *Colymbetinæ* agree as to eye condition, the *Dytiscinæ* having, as it were, advanced farther, in the prosternal character the *Colymbetinæ* are in advance of the *Hydroporinæ*.

An examination of the upper side of the abdomen of the Dytiscid shows eight pairs of abdominal spiracles, of which the first pair are elongated transversely. The second pair are often somewhat enlarged but the next five pairs are more or less alike in size, the last or eighth pair being usually somewhat smaller, and all, except the first, are circular. In the *Dytiscini*, a small group including *Dytiscus* and one other genus, about thirty-two species in all, the last two pairs are greatly enlarged transversely and thus this small group differs from all other Dytiscids. But a careful examination of other *Dytiscinæ* shows a tendency to transverseness in the hind pairs of spiracles, suggesting that the change is going to spread through the whole tribe. The spiracles are, of course, the respiratory openings by which air is taken in and expelled from the body, so a change in relative size of spiracles probably indicates a change in air intake and expulsion.

The wing-cases of the Dytiscidæ are so constructed as to cover the upper surface of the abdomen and they are perfectly fitted over the hard edges of the abdominal segments. Beneath them is the large air-reservoir which, of course, exists in the land beetles but assumes a special function in the sub-aquatic beetles. In the *Hydroporinæ* these wing-cases are usually punctate, as is the rest of the upper surface, whereas in the *Colymbetinæ* and the *Dytiscinæ* punctate elytra are much less common, ornamentation usually taking the form of reticulations or modifications of these. The punctures are small pits, often with a short projecting hair. They may be thickly or sparsely scattered over the wing-cases, and they are either all of one size or there may be two sizes, producing what is called 'double punctuation.' This latter type occurs in a number of

Hydroporine genera, but it is remarkable that in the higher genera it only appears in sections, suggesting that it is a characteristic of the lower forms and is disappearing in the higher ones. Further, in a number of the Hydroporines, even in those with double punctuation, there are frequently other markings, and these are often similar to those found in the higher Dytiscids, suggesting that, if the higher forms have lost their punctuation and developed reticulation, so the lower ones are, so to speak, preparing to follow along the same line.

Among the secondary sexual characters displayed by the Dytiscidæ is a widening in the males of the anterior and sometimes also of the middle pair of feet, and this occurs in varying degrees throughout the family. The sexual importance of these structures is in connection with cöitus when the front feet rest upon the pronotum of the female while the middle feet lie along her wing-cases towards the apex.

The under side of each of the three basal segments of the foot is covered with a brush of hairs of two kinds, simple hairs tapering to a point and sucker-hairs, open at the apex and capable of being applied to a smooth surface and of adhering to it. These sucker-hairs occur in every species of Dytiscid I have examined, from the Noterines upwards, but they show considerable variety, from what appears to be a mere widening tube with an open end to a pedicel carrying a very highly-developed sucker-disc; but the sucker-hairs are, apparently, definite in number and position in each genus and, certainly in the higher forms, in each species. Here we have a structure which performs a definite function and which Chataney [21] has shown has evolved from a simple hair, and whose stages of growing complexity can be traced through the Dytiscidæ from the lowest, in which they are simple wide tubes and few in number, to the highest, in which elaborate and often very numerous suckers are to be found. Moreover, not only can this gradually improving structure be traced as described, but in the *Colymbetinæ*, with about twenty-seven genera and 560 species, each stage can again be recognised, suggesting that the evolution of sucker-hairs, which appeared in the *Hydroporinæ*, appeared again independently in the *Colymbetinæ*. With regard to the Dytiscinæ, there seem to be no early or intermediate stages, all the forms possessing highly complex structures but, within the group, a further variation has taken place. All the *Hydroporinæ* and *Colymbetinæ* have the apex of the sucker elongate and parallel-sided, not rounded, but in only one group of the *Dytiscinæ*, the *Cybistrini*, containing about one hundred species, does this type occur, all the other sections, with about two hundred species, having circular suckers. Chataney, who has studied these suckers, has shown that in the *Cybistrini* every species can be identified by the arrangement of the suckers and, if this is not strictly true for other groups, there is very little overlapping from one species to another.

In all this wonderful evolution no change whatever has taken place in the female pronotum and wing-cases which, apparently, have been equally

[21] 'Sur le Tarse des Dytiscides,' *Ann. Soc. Ent. France*, vol. lxxix, 1910.

suitable for the simple feet of the lower forms and for the elaborate suckers of the higher ones, but there is one point which may be urged as showing the necessity for the evolution of a more prehensile foot and that is the increased size of individuals in the higher groups. A size census of the Dytiscids shows that the *Hydroporinæ* include the smallest species, the *Colymbetinæ*, those of intermediate size and *Dytiscinæ* the largest, each group overlapping its neighbour. Therefore those who regard this evolution as the result of natural selection will suggest that the inefficient individuals have been constantly weeded out and that the more efficient have bred more efficient, and so on. When we remember that both in *Colymbetinæ* and *Dytiscinæ* species with a more simple and a more complex arrangement of suckers are to be found side by side, each stage of complexity being entirely efficient for its purpose, we may be justified in wondering where any elimination of the unfit takes place.

Another character of the male feet, to which it seems impossible to attach any vital importance, is the form of the claws at the apex, which are usually two in number. The claws of the front feet may be alike, fine, gently curved and tapering to a point, or they may be sharply curved at the base or they may differ from one another. The males of neighbouring species may be distinguishable by them, as we have seen, and the differences in these claws seem to be unrelated to other characters. In the *Hydroporinæ*, the inner or anterior claw of certain species has an extension on the inner face, which might be described as a tooth, but only odd species possess it and not all the species in a genus or section of a genus. In *Hydroporus*, for instance, seven out of the thirty-six British species show this ' tooth,' but they are distributed in four sections of the genus. In *Agabus* again, the distribution of species with a toothed claw follows no recognised relationship. Sharp made twenty-three sections in this genus and of these, so far as I can find, only six or seven contain tooth-clawed species ; in some sections all the species having a tooth, in others only odd species.

In practically all female Dytiscids the anterior and middle feet claws retain the normal curve and tapering form and suggest usefulness, but it is difficult to ascribe any utility to the modified claws of many males. The toothed claws are definitely prevented from performing any function of gripping, while in other cases the shape or size also makes impossible any such function, and yet in some genera the form of these male claws can be used for systematic purposes.

The claws of the hind feet, on the other hand, show a definite line of evolution, as did the tarsal suckers of the male forefeet. In the *Noterinæ* the hind legs end in a pair of delicate, gently-curved and pointed claws, but in the *Laccophilinæ* reduction has taken place and although a number of authors have described two claws, in *Laccophilus* at least, only one exists. In the *Complicati* the arrangement seems to be constant for most of the genera, but each seems to have had its own idea as to these claws. The genera can be grouped as they have two equal or two unequal claws, but although those genera usually recognised as lower in the scale all come into the ' equal ' group and most of the higher genera into the other, *Dytiscus*, one of the highest, has two equal or subequal claws. Only in *Cybister* has one claw disappeared, and in the related genus, *Megadytus*, the male has two equal claws, although the outer is greatly reduced in thickness, while in the female the outer is not only reduced in solidity but also in length. All through *Agabus*, one of the lower genera, the claws are similar in both male and female, but in *Ilybius*, with unequal claws, the male outer one is more or less triangular and blunted, while in the female it still retains the normal curved and pointed appearance. Thus while in *Ilybius* the male seems to be in advance of the female, in *Megadytes* the female is nearer to the one-claw stage.

The foregut of the Dytiscid ends posteriorly in a structure known as the proventriculus, which is usually very muscular and armed with spines and hairs on its inner wall. Its functions are to crush solid particles of food and to filter fluids passing forward from the mid-gut. It is tubular and consists of eight lobes, four of which, the primary lobes, alternating with the others, project farther into the lumen and overlap the secondaries. On making a comparative examination of this structure about a year ago, I was struck by the fact that the four most conspicuous lobes in a number of species were oval in shape, while in others they were triangular, and an examination of more than a hundred species showed that, except in one genus, the same type of proventriculus was constant throughout every genus. Further, it showed that, whereas all the *Hydroporinæ* came into the ' round ' group with the *Noterinæ*, the *Laccophilinæ* were in the ' triangular ' group with the *Dytiscinæ*, the *Colymbetinæ* being in both groups, the single genus *Copelatus* having one subgenus in one and the other subgenus in the other. This proventricular character, therefore, seemed to be inexplicable on any theory, until I discovered that the round lobes so prominent in the one group are the secondary lobes, not the primaries, as I had described them,[22] so that the change which has taken place has not been from round to triangular but has been a development of the secondaries so as to squeeze out the primaries which have been greatly reduced. Moreover, whereas the prominent primaries were very obviously crushers, the improved secondaries are much less crushers and more efficient filters, and this fits in with the thesis I have already put forward with regard to various external characters that definite evolutionary lines run through the family, always from a more simple to a more complex stage. But here again it is difficult to recognise any part played by a struggle for existence or elimination of less efficient types, seeing that a whole series of these exists.

One other character to which considerable importance is attached by systematists is the male and, to a less extent, the female sexual armature, the apical part of the male armature consists of a median ædeagus and a pair of lateral lobes or parameres, the organ of intromission being the ædeagus. These three parts are frequently of extreme importance in separating species, but they also retain a constancy of type in each genus.

[22] ' The Proventriculus in the Dytiscidæ as a Taxonomic Character,' *Stylops*, vol. iii, 1934.

The parameres are unequal in size in the *Fragmentati*, but otherwise they are alike throughout the family. In most genera the parameres are free from one another except at the base, whereas in some they are united along one side, the one to the other. But the shape and chætotaxy of the parameres varies in different genera and different species, as does also the form and size of the ædeagus. It is most probable that the variations that occur would in no way affect cöitus between many species in any one genus and, similarly, in many cases cöitus between species of different genera would be possible, so that, although the idea underlying the systematic value of the armature is the mechanical isolation of the species, it seems as if the modifications are mostly evolutionary and of no vital importance.

The function of the parameres is presumably as claspers during cöitus and, if so, appearance suggests that there is a varying degree of efficiency ; but in this connection it is interesting to notice that in three genera—I have so far discovered no more—what appear to be sucker-hairs have appeared on these structures. These are of a simple form and may not be very efficient, but they suggest a developing line of evolution. In the genus *Ilybius*, all the seven British species possess these hairs, which are rather more rudimentary in one or two species—*e.g.*, *I. ater* and *obscurus*. In *Rhantus*, out of thirteen species examined, only three possess them and in one, *adspersus*, they are so concealed among the simple hairs of the apical brush that it is impossible to imagine that they can function at all. Out of twenty-two species of *Agabus* examined, only one, *chalconatus*, possesses the suckers, which, in this case, form a very efficient-looking tuft near the apex.

I have selected some of the main characters upon which the classification of the Dytiscidæ is based and I have endeavoured to show that, in at least many of them, a progressive development can be recognised. These characters are not vital to their possessors, since various stages in their development exist side by side, so that natural selection can have had nothing to do with their progress. Such lines of increasing complexity are recognisable throughout the world of living things. In plants, for instance, the gradual reduction of the gametophyte and the evolution of the sporophyte is a progression through many families. The tendency to cluster flowers into heads, brought to perfection in the *Compositæ*, runs through a number of families, as does also the opposite tendency to isolation and specialisation of the individual flower. In animals, increase in size, repetition of form, development of horns and innumerable other tendencies, all appear to be of the same order as the progressive lines in the Dytiscidæ.

The discoveries in connection with chromosome control of characters suggest that the orthogenetic tendencies may be the outcome of mutations, under control of mathematical laws and caused by external stimuli, although some authors look upon directional evolution as an inherent property of the organism like growth and reproduction. On the other hand, it seems possible that if function can cause variation in structure, these evolutionary lines may be responses to physiological activities, assuming that acquired characters are inherited. The inheritance of acquired characters must also depend upon the ultimate effect upon the germ-cell-chromosomes of changes in habit, physiological activity and in structure in individuals, so that the only centre which can be responsible for the origin of new species is the one which is responsible for maintaining orthodoxy and the chief struggle for existence seems to be in the chromosomes, which are perpetually endeavouring to maintain their normal constitution and relationship against agencies endeavouring to change them.

SECTION E.—GEOGRAPHY.

SOME ASPECTS OF THE POLAR REGIONS

ADDRESS BY

PROF. F. DEBENHAM,

PRESIDENT OF THE SECTION.

We are accustomed to the saying that the world is becoming smaller every year, yet it is still the privilege of very few to visit personally all the major regions of the world. We do say, and say wisely, that it is the duty of geographers, if possible, to visit the lands of which they read and write; but we know all the time that this is a counsel of perfection so rarely attained that it may almost be left out of practical consideration. We are, in fact, in the mass, still immobile on this world of ours, and we still have to take our impressions of regions other than our own from picture and narrative. Nevertheless, with so many travellers apt at descriptive writing, with such a world-wide Press, and, perhaps even more vitally, with so much broadcasting, we can, if we care to try, summon a very clear picture of the main natural regions of the world. It is not, for instance, difficult for the normal reader to imagine the green hell of the Amazonian forest, the parched solitudes of the great desert belts, or the towering magnificence of the Himalaya.

Each of us, according to the extent of our reading and the vigour of our imagination, carries a picture in our minds of these major regions, and no doubt all of you have a fairly vivid picture of the polar regions in your minds. What is not so easy to come by, however, is an appreciation of that picture in terms of its value to mankind. I propose, therefore, to guide your facility for correlation by briefly sketching, not the polar regions themselves, of which you already have an idea, but the influence those regions may have, and perhaps should have, on both the material and the ethical progress of mankind.

There is now a vast literature of the polar regions, both north and south, but the proportion of those books and papers which deal with the subject on a broad basis is very small, and is certainly not easily accessible. In many of these books we are invited to conjure up the sensations of the polar explorer, to feel his frost-bites, to savour his pemmican, to glory in his pack-ice and his glaciers, even to die his death. Not the least part of our interest in polar work is due to these invitations so graphically offered to us in text and illustration.

Much more rare is it to find a polar explorer viewing his territory as a whole, and trying to fit it into the scheme of the world in general. In a word, we are rather encouraged to regard the polar regions as places apart, extraneous to the real comity of the world.

It is perhaps a natural but nevertheless a lamentable fact that immediately one speaks of values the listener interprets it in pounds, shillings and pence, and indeed many will never get farther than that, and can hardly conceive of a value that cannot be stated in the terms of the economist. We will therefore first consider the kind of value of the polar regions which appeals most quickly to the public.

There is little need to sketch the history of man's attempts to achieve economic gain from the polar regions. From the days when Martin Frobisher attempted to find a quick route westwards to the Spice Islands *via* the North-West, and Barents a similar route eastward, down to more recent times when, though the routes had lost value, the products of hunting, fishing and mining attracted venturers with similar motives, the chief aim of promoters of polar expeditions has been one of ultimate gain. It is true that many of the leaders of the expeditions had little care for the commercial side, but the money that sent them forth was, in the greater number of cases, put out in the time-honoured hope of all ages that it would bring in interest in some form or another.

There is certainly such a thing as the romance of commerce in the North, for most of its industries have something peculiar and unusual about them. We may instance the cryolite mines of Ivigtut in Greenland,—a strange mineral found in quantity nowhere else in the world, which however is almost essential to the large-scale production of aluminium. Again, until recently a large proportion of the ivory for use in northern China did not come from the present-day elephants of the rain forest belt of Asia, but from the mammoths of primeval times whose tusks lay for many thousands of years buried in the mud of the great Siberian rivers flowing into the Arctic Ocean.

Romantic or not, the story of Arctic trade has a grim and melancholy side, in that several of its most promising ventures have died a slow and painful death by reason of the cupidity of man and his unwillingness to co-operate either to preserve life or even to preserve it sufficiently for his own benefit. The history of the whaling industry in the Arctic is an instance of this incapacity of man to co-operate in taking the most common-sense measures to cherish a valuable industry. There is every reason to hope that the day of non-co-operation has passed and that a similar fate to whaling in the Antarctic will not take place, for it is probably common knowledge that many bodies, in which we may include the League of Nations, the Norwegian whalers themselves and the Discovery Committee of the British Government, are at work in their various spheres to prevent any extermination of the southern whales, and at the same time to regularise an industry which, even in these days of synthetic materials, still has its vital uses to man. How large that industry now is may be gathered from the fact that the annual catch of whales in the southern seas is about 20,000: how mindful it now is of its own future may be seen from the fact that whereas the average whale used to provide only 60 or 70 barrels of oil it is now made to yield nearly 120 barrels of oil besides other products.

The fur trade in the Arctic has never suffered quite such staggering blows as the whaling industry, yet it is not so very many years since nothing less than international complications were a strong enough threat to ensure that the fur-bearing seals should not be exterminated as a species. That is precisely what did happen in the Antarctic in the early years of last century, when in less than a decade all but a few hundred of this kind of seal were slaughtered.

These products of hunting, fishing and mining were the natural resources of the North and were the first to be exploited, but quite recently a new factor in the commercial aspect of the North has come to the forefront. With the progress of long-distance aviation and the simple application of the principle of great-circle navigation, the idea of using these northern latitudes for passenger and even freight routes in the air has become not only prominent but almost insistent.

Owing to the misleading projections on which most of our maps are constructed it is not usually recognised that the most direct route between, say, Berlin and Montreal or Glasgow and Winnipeg is over Greenland, but it is so. It seems to be only a matter of time and the inevitable improvement of aeroplanes before some use is made of a route which was first investigated as to conditions by the Watkins Expedition of 1930.

All these economic aspects of the polar regions necessarily have a political bearing. Though it was not until the present century that the great Powers began to take a close interest in the idea of possessing polar territories, there has been in recent years a degree of keenness in this respect which is not dissimilar to that which prompted the partition of Africa in the latter part of last century. In the eyes of the historian of the future it is probable that the more or less forcible partition of Africa will be regarded with condemnation, since in that case there were peoples whose rights had to be ignored, and a degree of envy and jealousy between participating nations which was far from being creditable. In the polar regions the case is different, in that those lands which had a native population were taken under protection at an early date by Russia, the United States, Canada, and Denmark. Though there has been, since the great war, a rush for the remaining unclaimed land areas of the north this was, however, carried out with a reasonable lack of animosity between the nations concerned. In the north there are now no tracts of land which are not either settled in part or specifically claimed by one of the Powers. The recent adjudication of rights over East Greenland by the International Court at The Hague in favour of Denmark has settled what might have been a standing cause for bickering.

In the Antarctic regions, which are far less known than the Arctic, the political aspect has come forward of recent years almost entirely on account of the whaling industry which, though now largely carried out at sea, had at first to depend upon land stations for its full operation. It cannot be said, even by the British nation, which claims the greater part of the Antarctic continent, that the matter is settled in a satisfactory way as yet. It seems that none of the usual precedents of international law can be made to apply to the land mass of Antarctica, for not only is occupation, in the proper sense of the word, more or less impossible, but not even the most sanguine company-promoter could say that the land, as such, has a value. The wealth of the Antarctic to man lies in the seas around it, which are free to all, and such claims as there have been for land sectors have been based variously on the protection of whales, the pursuit of whaling, the juxtaposition of civilised land and possibly, but not certainly, the assertion of land claims merely as a gesture. Naturally these claims are apt to be inconsistent.

It is difficult, if not dangerous, for the layman to step in where only the diplomat is accustomed to tread, but one is forced to wonder whether the various Foreign Offices concerned in claims to territory in the Antarctic have been fully and wisely informed as to what is the real value of some of the zones or sectors which have been the subject of negotiation in recent years. A claim to land which is almost entirely covered by ice, which has no harbours and can rarely even be approached by a ship is surely a shadowy if not a useless one, and invites the suspicion that an aggressive and capricious spirit lies behind the claim.

None of the nations concerned is quite free from blame in this respect, and no special nation is referred to in particular.

It is probably too late for any alternative arrangement to be adopted, but had there been a League of Nations in existence at the beginning of this century, before any claims had been laid in the Antarctic, the protection and administration of this last and least useful continent would have been a most appropriate subject for League administration as an 'international park' of vast proportions which should be open to all nations who would respect its amenities.

Political might-have-beens, however, are no more useful than social ones, and claims to territory, which can do little beyond giving a large splash of colour on the map, are bound to continue.

One point, however, must be made clear as a matter of common justice to possible claimants, and that is that territory claimed should at least be investigated, and we can well imagine that it is for the purpose of carrying out this obvious duty that the British Government has felt kindly towards recent Antarctic exploration by its nationals.

Summing up this economic aspect of the polar regions, the warning may be given that even now, as in the past, there is a tendency to ascribe potential wealth merely on account of the existence of land masses. Indeed, even explorers, who should have known better, have been heard to speak glibly of the untapped mineral resources of the polar lands, neglecting to tell their public that though these resources undoubtedly exist, they are for the most part covered by thick ice sheets or rendered inaccessible by topography, or climate, or both. Quite a brief calculation, for instance, would show that the proportion of the Antarctic continent available to the prospector and miner is to the total land mass in somewhat the same proportion as the area of the city of Norwich is to the whole of England.

Although the land can have little value in the Antarctic there is, strangely enough, a natural resource in the air which, however fantastic it may appear to us, may yet have a substantial interest for our descendants. It is a truism of science that we draw practically all our sources of power from the sun, either indirectly in the form of coal and oil, or directly in the form of water power, in which the sun by evaporation has raised water to a height from which gravity, suitably used, returns power to us. Now, although water is one of the things of which there is a great scarcity in the polar regions, and the movement of ice masses can hardly be handled by engineers, yet meteorological processes are doing the same thing for air, raising masses of air in one area which sink down in another, and so provide a source of power less tangible but just as real as that of water in a highland lake. The persistence, the strength and the frequency of the Antarctic blizzards compels anyone who has experienced them to feel that here is a vast source of power as yet untapped. May we be permitted to forecast that some day the miseries of the storm-bound parties of Mawson's expedition, when for a whole year the wind averaged gale force, may be atoned for by our descendants making use of this power when coal is scarce and oil exhausted, while all the water power in the temperate regions is fully harnessed ?

It would be unwise and inappropriate to burden a presidential address with statistics of wind in the Antarctic, but I do invite you to compare in your mind the power in the well-known falls of Niagara, about 6,000 tons of water falling per second, with the power in the little known Adélie Land, where an air river of at least 50 miles in width and probably some hundreds of feet in depth is moving outwards from the plateau at an average velocity of 50 miles per hour or about 70 ft. per second for most of the year.

I will not further anticipate some H. G. Wells of the future who will ring the Antarctic with windmills producing power to be sent by wireless to the southern hemisphere, but merely assure my audience that the winds of the Antarctic have to be felt to be believed, and that nothing is quite impossible to physicists and engineers.

We will not refer in detail here to the well-known efforts of the Canadians in particular, guided by the enthusiasm of Mr. Stefansson, towards increasing the pastoral value of the Canadian Arctic by the introduction and preservation of reindeer and other animals. This must go on ; but in spite of Mr. Stefansson's arguments one is forced to believe that if we limit these efforts to the truly Arctic lands the net effect on the world production of meat will be slight.

We pass now from the economic aspect of our subject to some others which have less appeal to the man in the street, but which must never be omitted in any consideration of a region by a geographer.

If we ask ourselves why so many people have gone to the polar regions in the past for other than economic reasons, the answer is perfectly plain. To say they have gone because they wanted to is too bald a way of putting the answer. Their motive in going is because the polar regions have offered them something which they cannot get elsewhere. One of these things is solitude and relief from the company of too many of their fellow men. One must be careful in dealing with such an abstract part of the subject to define that love of solitude or, as the journalist would call it, ' the lure of the wide open spaces.' To begin with, it affects only a very small proportion of men and, I venture to suggest, very few women.

It also is usually of a temporary nature, and the man who considers himself most content in the heart of the Sahara, or on the plateau of Greenland, is very often so content because he knows that at the end of a certain term of residence in such a place he has Paris or Piccadilly to return to for contrast. When he does return, however, he is likely to be bothered and fussed with the apparently seething mass of his fellow creatures, to be bustled out of his contentment by a world of telephones and postmen and the daily press, and to consider very quickly that the lives and aims of men in the mass are sordid and small compared to the simple life of the lands from whence he has returned. We may smile at these psychological effects, and we may consider that the explorer type, who is restless in civilisation, is a person apart, to be given his way but not to be pampered.

On the other hand, we must not forget that not only are holidays necessary to man, but that, with increasing rapidity and ease of transport, the holidays of civilised peoples will tend to be taken farther afield. Even before the War there were such things as pleasure cruises to the North; but what is just as feasible and has not yet come, is the extension of these cruises into summer holidays on land in the Arctic. Nor is it too wild a forecast to say that in time to come there may be a Brighton of Spitzbergen, a resurrection, in fact, of the Smeerenberg of two centuries ago, when each summer a large township established itself on Spitzbergen for the whaling. The township will be a city of rest and holiday instead of a city of greasiness and blubber; but the means of establishing such a centre come closer to hand with every new invention.

It is true that the Antarctic can never be considered a playground for the southern hemisphere, except for those who are willing to undergo an uncomfortable, if not a risky, sea voyage or a rather long aerial journey. It is true also that in the North, under present circumstances, the amount of territory available for holiday purposes is practically confined to Spitzbergen, now known as Svalbard. The accessible parts of Greenland, for instance, belong to the Greenlander under the careful guardianship of Denmark, and must not be looked upon as a holiday resort. The Franz Josef Archipelago is not always accessible, and the more distant Nova Zemlya, as well as the Canadian Arctic islands, will be for a long time to come too far from the main centres of population in Europe and America.

This consideration of the polar regions as a holiday resort for the citizens of crowded lands, leads us naturally to a far greater value which has as yet hardly been considered by civilisation, a value which indeed may yet prove to be more worthy of study than all those we have so far mentioned. It is reasonable to suppose that when some far-travelled medical man comes to write a book on the geography of diseases we shall be able to come by a clear idea of where health is best to be sought. The ordinary geographer would, however, even now be able to make something of an essay on the distribution of healthiness over the world. Leaving out cities as unnatural, or at least unhealthy aggregations of humans, he would at once say that on the whole the most unhealthy parts of the world were in the Tropics, though he would have to have a special category for tropical and oceanic islands, which as a rule are decidedly healthy. He would, if he were wise, consider that the Steppe deserts were healthy zones; but probably he would decide that the temperate zone as a whole, provided it is not too far from the sea, is the healthiest belt of the world for man. It is almost certain that he would entirely forget that the polar regions are definitely the most healthy segments of the earth's surface, for the simple reason that the ordinary disease-bearers, whether they be rodents or insects or minute bacilli, find the conditions either impossible for existence or inhibitive.

But we are not concerned here so much with the healthiness of the zone as with its value from a remedial point of view, for we are certainly not going to migrate in millions to the Arctic just because we cannot there contract the diseases of our own lands. But what we may well pay attention to is the corollary to that healthiness, namely that many, though not all, of the diseases contracted in temperate climates can be cured by residence in the polar regions.

I am aware that it is more than dangerous, indeed provocative in the highest degree, for anyone outside the medical faculty to say how far special diseases are curable by residence in a pure air and a cold one. It seems, however, from the experience of sanatoria in the Alps, etc., that it is the sufferers from pulmonary diseases who are most likely to get benefit from such residence. The question will at once be asked as to what the polar regions can supply which is not already obtainable, say, in the Alps. For an answer to this question we must look to the doctors; but it does seem likely that residence in a vast territory free from germs or the conditions for their transport must, *prima facie*, be better than residence in an alpine region which is surrounded by, and is merely above, zones teeming with possibilities of disease. If this thesis is correct, and it is one which a small period of research could easily confirm or refute, then surely we are neglecting an aspect of the polar regions which is of major importance to mankind, more valuable than all the industries they will ever support.

If it be true, as I believe, that the greatest gifts of science to mankind lie in the realms of preventive and remedial medicine, then surely here is an investigation which should not be left as merely a pious hope in a presidential address, but deserves promulgation and action.

To test the value of the suggestion there is needed some research and experiment, most appropriately to be carried out under the auspices of one of those international bodies such as the Rockefeller Foundation, which has already done so much for remedial medicine. For assistance in carrying out this research there is needed the sympathy of governments, especially that of Norway, in whose care is the most promising territory in the Arctic for that purpose, namely, Svalbard or Spitzbergen.

Let us remember too, before we allow hands of horror to be raised at the expense of such research, that in the past sums of money have been spent in Spitzbergen itself for the erection of an airship hangar and provision of the airship itself for a few hours' flight to the Pole, which would be sufficient to erect a hospital and run it for many years in an experiment which might be of permanent value to the world. We must be properly cautious as to results, but at the same time let us preserve our sense of proportion in the value to man of how we spend money in the polar regions. It is almost lamentable to consider the sums of money which have been spent in what you will all understand by the term of 'stunt expeditions' and place those sums in contrast to the difficulty in raising money for such an object as this.

I am aware that in thus inviting consideration of the possibility of establishing sanatoria in the polar regions I shall be incurring the displeasure of explorers, both of the past and of the present; but my answer to such would be that the end is worthy of the means, and that just as an Alpine hotel, full of youth and health, can now be found one hundred yards from a sanatorium filled with the ailing, there is room in the polar regions both for sanatoria and for expeditions.

We may now turn to yet another aspect of the polar regions, and one which possibly has a more direct appeal to this Association of scientists than those which have so far occupied our attention, namely, the value to the scientist, both pure and applied, of the phenomena which are peculiar to these regions—phenomena whose existence is well known but whose study is still in its early stages.

No doubt each science will claim the chief value of these phenomena for itself, but it is without any particular bias to one or the other that I should venture to place in the first rank the subject of meteorology as likely in the future to gain most by a prolonged and more intensive study in high latitudes.

We have spoken of the more or less permanent blizzards on parts of the Antarctic continent, and we ourselves live under the intermittent threat of depressions over Iceland. We can therefore, without much imagination, see that even if our weather is not actually manufactured at the polar ends of the world, it is profoundly affected by them. Meteorologists themselves have long been aware of this, and in two successive onslaughts, namely, in 1882 and in 1932, a determined effort was made to collect data simultaneously and widely within the precincts of the Arctic. The conclusions which have been drawn from these results are, as yet, hardly in full circulation, but you will meet few meteorologists who do not sigh for more and more data from the polar regions.

The phenomena of magnetism and aurora, which are somewhat akin to those of meteorology in that they occur in the atmosphere, are also best studied in high latitudes, where, too, the most promising investigations of the ionosphere seem to be likely.

When we come to the more earthly sciences, the immediate value to mankind is perhaps less evident. In the science of geology, for instance, especially in its branch of tectonics, we cannot afford to do without close investigation of two segments of the earth comprising together nearly one-tenth of the surface of the globe, and indeed the structure of the earth must become the more interesting the nearer one gets to its axis of rotation. The geologist has a hard task in lands where the rocks are usually buried beneath ice-caps, and has to be more than usually ready with the inspired guess than in other parts of the world.

In the Antarctic in particular, the highest of all continents and the most closely hidden, there are obviously to be found keys to some of the major problems of earth structure. We may instance only one which, no doubt, is occupying the attention of the geologists of the British Graham Land Expedition at the present moment, an expedition which hopes to press far to the south of the Archipelago where they are wintering, and to determine why and where the folded ranges of South America and Graham Land merge into or butt against the faulted escarpments of the Australian sector of the Antarctic.

It is in these larger problems of geology that the polar geologist can give most assistance to science. It is not long since the papers, in America at all events, were full of the discovery of coal beds by Admiral Byrd's geologist within 300 miles of the South Pole, and it was interesting to see that this discovery, which however was originally made by the Shackleton party in 1908, moved the press public to exclamations of wonder that such things could be. Nevertheless the great controversies of whether the Poles have shifted in the past, and whether the continents are drifting, must draw their best evidence, both for and against, near the axis of the earth.

There has recently been published a fresh determination of the position of Sabine Island on the coast of north-east Greenland which tends to show that there is a definite westerly drift of some metres per year. Similar observations of Jan Mayen are even more startling. For these and other reasons, therefore, the geo-physicist, whom we may call the mathematical cousin of the geologist, must keep his attention on the polar lands.

In the biological sciences also there are major problems to which the data of high latitudes alone can give the key, such as the drift of oceanic waters and the movements of plankton and their associated salts. The biologists, however, are already active in these investigations and need no spur to action. The many-sided character of the work of the Discovery Committee in this branch, over all the waters of the Antarctic ocean, is evidence of how carefully work on this aspect of the polar regions is being carried out.

Lastly, I would ask your permission to consider yet another aspect of the polar regions, one which is perhaps more psychological than geographical, namely, their value as an outlet to that spirit of adventure and urge for exploration which has always been an attribute of man, and which will not diminish however small the world may grow. It is a spirit which is at work equally in the small child climbing the apple tree, the schoolboy exploring his own small horizon, the undergraduate forming alpine clubs to scale the peaks of his own college, and the city clerk spending his week-ends living dangerously in sailing dinghy or on motor bicycle.

In all of these there is a curious combination of an urge to test one's abilities and yet a desire for a secondary and more useful object in the deed itself, and this dual purpose is particularly evident in most of the young men who come to the Scott Polar Research Institute in Cambridge seeking ways in which to visit the Arctic.

Looking over the files of the geographical journals of the past few years, it is possible to see how many young men turn annually to the Arctic to satisfy their need for an outlet. If we include the official expeditions of governments such as that of the Soviet, we shall find that every summer more than fifty groups of investigators go to the Arctic and, were it less expensive, the number would easily be trebled. Only a few of these groups go for purely scientific work, and still fewer for hunting alone. They are, in fact, as a rule imbued chiefly with a desire to see strange places and endure strange things, and only in a secondary way to bring back useful results. There has been of recent years a happy tendency for these groups to go and come back without undue fuss and publicity. I would suggest that this use of the Arctic as an outlet to a healthy and laudable desire is one which should not be left out of any assessment of values, even though it must necessarily apply only to a small number of people.

These suggestions as to aspects of interest in high latitudes will, no doubt, appeal to some and bore others, but in conclusion I would beg of you, as geographers, not to ignore these uninhabited zones, and I would like to repeat the words of a recent booklet on the subject, that whether it likes it or not, the world must take an interest in the polar regions.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

ECONOMIC NATIONALISM AND INTERNATIONAL TRADE

ADDRESS BY

PROF. J. G. SMITH, M.A.,

PRESIDENT OF THE SECTION.

The Council of the Association has recently suggested that the sections should endeavour in their proceedings at the annual meeting to appeal occasionally to the interests of an audience somewhat wider than that whose main interests lie in the purely technical aspects of the sciences studied. This clearly prescribes for me the general field of my Presidential Address to this Section this year; and, at a time when serious dislocation in normal international trading relations is the major factor hindering economic improvement and preventing a return even of that measure of prosperity which the world enjoyed before the depression entered on its acutest phase, the part of that field calling for special attention is not difficult to choose. This is the growth or accentuation of Economic Nationalism, or Self-Sufficiency, Autarchy, Isolation or Insulation, undoubtedly one of the most powerful of the disturbing influences now at work in the economic sphere. It is with it that my address will mainly be concerned.

I.

Economic self-sufficiency is no new phenomenon. The tendency to national exclusiveness is as old as human nature itself and it by no means calls for unrestricted condemnation. Indeed, in spheres other than the economic, nationalism and national movements have made no small contribution to the general progress and the happiness of mankind; and we could contemplate, if not always with unfeigned admiration at least with a considerable degree of equanimity, the diversity in civilisation, in language and in culture which is due to the multiplication of small countries and to the determination of national groups to resist by every possible means attempts at assimilation by larger and by more powerful peoples.

Generally, when national movements arise they spring from motives other than economic; and in earlier times purely economic weapons were not of importance in the struggles which ensued. This, of course, was due not to reluctance to employ any weapon which came to hand, but rather to the fact that the economic sword had not really been tested and there was as yet no ground for confidence that it would prove effective. In modern times, however, it has, or is thought to have, become indispensable. It may, therefore, be worth while to consider some of the reasons for this belief. Before doing so, it is necessary to draw a contrast between the world of to-day and the world of a short time ago. For the purpose in view the period immediately prior to the War will serve very well.

II.

First and foremost, the peace treaties of 1919 and following years increased the number of countries and national boundaries in Europe. In all these new areas trade barriers were immediately set up to protect industries the establishment of which was encouraged and often financed by the states themselves so that they might have under direct control in their own territories as many as possible of the processes necessary for the production of armaments. As it is not difficult for producers of very wide ranges of commodities to persuade governments that their own special products are essential, or, alternatively, that their factories can readily be adapted for the manufacture of war materials, the field embraced in these new protective systems was progressively extended until it soon covered the whole range of agricultural and industrial activity. Important, however, as was this stimulus to economic self-sufficiency it might have spent its force and gradually petered out if the structure of international relations had not at the same time been radically altered by a change in the mutual indebtedness of nations, which occurred with such rapidity as to render impossible smooth readjustments to the entirely new conditions thus created. This transformation from debtor to creditor, which was the experience of the United States of America, and from creditor to debtor, the outstanding example of which was Germany, called for a complete reversal of the general attitude towards the Balance of Trade which up to that time had been current in the countries concerned. It demanded some re-orientation of ideas, also, on the part of other countries where the differences between the new and the old positions were of degree rather than of kind. Unfortunately, the line of least resistance was followed everywhere, both by statesmen and by peoples; and difficulties were accentuated instead of being surmounted.

A country which is on balance a debtor has gradually to build up credits abroad so as to pay the interest on its debts, to meet amortisation instalments or make provisions of some other kind for repayment. It can only do this by contriving to have a favourable balance of trade and this, in turn, can be secured only by an increase in exports, or a reduction in imports. A large increase in exports, however, is not always easy to effect for a country which is already highly industrialised. Such a community is largely dependent on foreign sources for its supplies of raw materials. For it, therefore, increased exports of manufactured goods means increased imports of raw materials which, in turn, have to be paid for by further exports. This is impossible unless the volume of foreign trade as a whole is increased at the same time. It is just because this latter increase is not taking place, or is comparatively insignificant in amount, that older industrial debtor countries fail to build up the balances required from them by their creditors and that creditor countries, in turn, find it difficult to expand their export trade and at the same time pursue a policy of drastic restriction of imports. Further, if a country previously debtor becomes creditor the problems attending readjustment appear to it to be almost insuperable. In every case, in both debtor and creditor countries, there was marked reluctance to attempt any solution which might offer a reasonable promise of success. This was especially unfortunate ; for no cause has contributed more to the present dislocation of international trade and to the financial and currency troubles accompanying it than this one outstanding fact—the reluctance or the inability of the countries concerned to handle the problems presented to them by their changes from general debtor or general creditor position to that of general creditor of or general debtor to the rest of the world.

Of the theoretically appropriate policy in the new situation thus created there never was any doubt. Creditor countries should have accepted additional imports from their debtors and encouraged them to build up favourable trade balances in the shortest possible time. This implies, of course, that exports from the creditor countries should have been discouraged and a drastic reconstruction of internal productive systems undertaken. Of the practical difficulties in the way of such far-reaching changes the economist is well aware ; and he would have offered his sincere sympathy along with the maximum of encouragement to any statesman attempting the task. But to statesmen who not only shirked a duty admittedly difficult but who adopted a policy calculated even to increase the obstacles in the way of ultimate reconstruction he cannot be equally indulgent. The offer of loans to debtor countries by their creditors was a profound mistake ; and disaster was inevitable when the borrowing and lending was mainly short-term. Long-term loans, which would have been more helpful by permitting time for readjustments, were discouraged by legislative restrictions in the debtor countries themselves as well as by the natural reluctance of the lenders to risk their money for any length of time in areas where disturbances, both economic and political, were liable to occur without preliminary warning. In such a nervous atmosphere alarms were inevitable ; and a climax was reached in the summer and autumn of 1931. Since then the forces making for economic self-sufficiency have suffered little check in any country in the world.

It is from the events of this year, 1931, that the existing highly-developed system of barriers to international trade sprang, armed as it were overnight. The seed, however, had been sown long before ; and tentative efforts by debtor countries to control transactions in foreign exchange and to reverse adverse balances of trade were not unknown several years prior to this date. But now, in addition to extensions of tariffs and the raising of existing rates, the device of the quota was developed to the full, and condemnation was passed on anything which, like the most favoured nation clause in commercial treaties, was designed to disentangle foreign trade from the obstacles which encumbered it. The more liberal of existing trade agreements were everywhere denounced and restrictive measures or one-sided bargains substituted. Currency difficulties in any country were used by its trade rivals as a pretext for further tariff increases on its merchandise. In a brief space of time the whole structure of foreign trade as it existed before the war was swept away ; and nothing systematic or definitely planned has, so far, taken its place.

III.

Apart from the predominant influence just noticed which precipitated the onset of this policy of economic nationalism in all its violence it is probable that, in any case, there would have been some accentuation of tariffs and high protection during the period considered. Conditions which formerly favoured freedom of trade in international intercourse have altered or have given way altogether to new alignments of economic forces which inevitably suggest protection as the more desirable policy to pursue. It is worth while making a digression at this stage in order to examine these influences and to assess their importance in the general economic progress of the world since the early days of the free trade movement in Great Britain.

Before the discovery and opening up of large tracts of agricultural land in countries outside Europe the cultivation of the soil in the older countries was carried on under conditions of diminishing returns. Population, especially in the recently industrialised areas, in the first half of the nineteenth century was growing rapidly. This meant a rising cost of living due to continuous increase in the prices of foodstuffs; for the production of the latter could only be expanded at an enhanced cost per unit. Current economic doctrine, at that time dominated by Ricardo and his followers, compared the product of industry to a cake to be divided among those who had contributed to its making. If wage-earners obtained a larger share profits were lower. It was, therefore, thought to be in the interests of industry to pursue a policy of free imports; for free imports, especially of food, meant low cost of living, low wages and, consequently, higher profits. The interests of agriculturists were overlooked and in the struggle which ensued the industrialists gained a decisive victory in England. Free Trade won and the French commercial treaty of 1860 marked the end of the fight for a time. Much freedom of trade was won also in continental countries a little later than in England, although in their case agricultural opposition was never completely crushed.

Contrast this with the position to-day. Under stress of the War agricultural production was expanded everywhere, a technique almost entirely new was introduced and scientific aid of every kind enlisted, with the consequence that agriculture has come to be conducted, although perhaps only temporarily, under conditions of increasing returns. The rate of increase of population in the principal industrial countries has fallen and food prices are low. Ricardian economics are no longer authoritative and fears of scarcity have vanished. Industrialists, therefore, no longer have the motives they once had for maintaining free imports; and they are strengthened in the opposition they now offer to their former policy by the difficulties they encounter in export trade. Since many of them are mainly dependent on this trade they are driven to seek alternative markets at home to replace those they are losing abroad. It is only natural, therefore, that they should become advocates of the partial or complete exclusion of goods which are likely to compete with them in the single remaining market they control. The greater the fall in their exports the more uncompromising the support they lend to the movement towards economic self-sufficiency.

Again, in the first half of the nineteenth century freedom of trade facilitated the discovery of new markets and of new openings for capital. Notwithstanding warnings of the danger to investments in countries politically unstable, where effective supervision by foreigners was impossible, there was a very great export of capital from Europe to the rest of the world. In this England took the lead, although Ricardo was among those who pointed to the dangers; and, as export of capital is mainly export of goods and a country cannot hinder imports if it wishes to export, the free trade movement was of necessity welcomed in Europe by industrialists as well as by financiers. Now, however, foreign investments have lost their attraction. Interest rates are scarcely commensurate with the risks involved and the danger of loss of capital has in no way diminished. Moreover, the time is past when even the most powerful government dare collect interest or principal of debts from foreigners for its own subjects by threat of military or naval demonstration. Holders of foreign securities have learned much through open repudiation of debts by revolutionary governments and through currency devaluation. They have also learned that if free trade is a necessary concomitant of freedom of foreign investment it is not worth retaining the former merely to assure a continuance of the latter.

In the early days of industrialism international trade promoted division of labour in every meaning of that term. This, in turn, permitted such a lowering of costs that the standard of life was raised in almost every country in the world. Moreover, international intercourse quickly disseminated everywhere knowledge of new inventions and of new commodities with consequent expansion of trade and production. In a period of rapid change such as that, freedom of trade offered the maximum of opportunity to those wishing to seize it. Any policy except that of unrestricted freedom would have created obstacles.

Conditions are now very different. Modern large-scale rationalised industrial units are exceedingly vulnerable. Unless they can operate at or near the output for which they are designed and find markets at prices covering costs for all they produce they must soon go under or be reconstituted. It is only natural, therefore, that there should be an insistent demand from their managers and shareholders for guarantee of the home market, the only market from which the foreigner can with certainty be excluded, and that Empire Preference should be welcomed by them for the security of whatever overseas trade agreements of this kind are expected to promote.

Again, scientific progress and technological invention which used to lend support to a free trade policy are now among the most powerful of forces encouraging economic nationalism. Standardisation of processes and of output, development of intricate machine tools which can be operated by comparatively unskilled labour after a brief period of training, wide distribution of electrical power and the growth of technical education in every branch of industry enable new factories to be set up with equal prospects of success almost anywhere throughout the world. So, Lancashire finds competitors in India and Japan ; and Irish Free State workers come to the Midlands for a few months' training and return home to operate factories for hollow-ware, gloves, hosiery, and many other commodities in little centres selected at random which never before had an industry of any kind. When industries are thus set up in new environments adaptation of size of unit to the market for the product is possible to a greater degree than in older industrial areas; for imports can be rationed or prohibited and the permitted extent of the industry strictly controlled by the government. It frequently happens, therefore, that such new concerns, unhampered by evil traditions of management or by restrictions imposed by labour, succeed in producing at reasonably low costs per unit within the closed national boundaries. Thus, the policy appears to be justified by its early results, although the situation of industries in isolation from the main centres of their activity is likely at a later stage to create difficulties not easy to surmount. But even if justification on purely economic considerations were not so easy to discover as it is, cogent reasons of a social or political nature can readily be offered for a policy of self-sufficiency in as many industries as possible. Diversification and actual increase, even if small, of employment may well be worth some sacrifice ; and in a world overwrought and nervous concerning armaments and the future of peace the fact that every industry is or may be important for war adds much to the responsibilities of statesmen when they are called upon to outline the appropriate policies in trade and industry for the countries they govern.

Price movements and currency troubles, too, have not been without their influence on this trend in the direction of closed or self-contained economic systems ; for it is only within the limits of such a system that even a partial measure of success can be attained in attempts to maintain a stable level of wholesale prices, much less of prices in general. Apart from the detailed control on the monetary side of the volume of credit, the destination of credit, velocity of circulation, volume of saving and investment and so on which need not be touched on here, it is necessary to control the volume of production and of imports as well as many individual prices of goods and services, and the volume of exports if stable price levels are to be secured. Thus, quotas, foreign exchange regulations, occasional prohibitions of certain imports and certain exports are inevitably part of such a scheme of money management. Moreover, the consequences of attempts to keep price levels stable are such as to encourage or provoke further measures of repression in the field of foreign trade ; for a stable price level usually conceals several different movements and a fall in the prices of such commodities as are exported may be accompanied by a rise in the prices of foodstuffs and materials which it is imperative to import, a definite worsening of the terms of trade which stimulates demands for further restriction or control. This was the experience of Sweden when she succeeded in keeping her wholesale price level stable between 1930 and 1934. The other significant example of an experiment of this kind, that in the United States of America, especially between 1925 and 1929 when the general price level was kept stabilised, led ultimately to conditions of monetary inflation. Subsequent events there give little encouragement to those who looked for an end to the policy of self-sufficiency in the continent of North America. The precise relation between monetary troubles and the movement towards economic self-sufficiency—which is cause and which is effect, whether both are due to a third group of fundamental causes, will appear later ; but there is no doubt that monetary management of any kind for any purpose calls for increasing control over the course of international trade and that the task of management is easier the more nearly the economic system involved happens to be self-contained.

The movement towards economic self-sufficiency, therefore, has its roots deep in the past. In the political sphere in the nineteenth century nationalism sought for unity and fought oppression to win self-determination. Then, at the beginning of that century and during the latter part of the eighteenth century, economic organisation was simple. Machinery was relatively unimportant and production was on a small scale. By this time, also, economic activity had become increasingly free. The fetters forged by the mediæval guilds and mercantilism had been cast aside. Markets were unrestricted and mobility unimpeded. A domestic capitalist system had been evolved and with it had come political freedom and political democracy. This general scheme of organisation lasted until well on towards the middle of the century without radical change ; and contemporary economic theory regarded it as its problem to explain the economic processes of a society dominated by small competing units entirely free from political interference. In the ideal world of these theorists Free Trade was a necessary condition for territorial division of labour. Free movement of capital and unimpeded mobility of population were equally important in their view ; and anything which offered obstacles to the attainment of the ideal of a single price in a single market co-extensive with the world was, on that account, condemned. But towards the end of the nineteenth century large aggregates of capital came to dominate the field. It was not that the earlier small competing units of the classical economists had become less numerous but rather that they had become less significant. As industrialisation proceeded the growing scarcity of economic opportunity favoured, even demanded, the consolidation and the integration of trade and industry. As the size of units increased economic opportunity became still more circumscribed and competition grew still more relentless. Under these circumstances legislation and public opinion were powerless to prevent the trend towards monopoly ; and the cartel movement spread, at first within national boundaries, and, later, it was extended to the international sphere.

Meantime, nationalism, which originally had merely political aims, changed its character and became, fundamentally, an economic movement. This was due, in some part, to the attainment of most of its former ambitions, but mainly, to the causes just described and to the continuous expansion of economic activity which now absorbs by far the greater part of the energy of the whole of society. Thus, the world of the first quarter of the twentieth century provided an environment exceptionally favourable to the growth of a very militant movement for economic self-sufficiency.

This long-term influence has been reinforced, temporarily, by the conditions attendant on the great depression. New areas of production have been brought under monopolistic control or centralised supervision in order that governments may be enabled to support trade and industrial organisations in their efforts to regulate production and prices. National cartels have been strengthened and international cartels have been difficult to maintain. Governments everywhere have used the opportunities thus presented to them to turn to narrow national account the general tendency already in force towards large-scale organisation and monopolistic control. It may be that these short-term forces will effect deeper and more permanent changes in the economic system of the world than could ever have been accomplished by the longer-term forces which they supplement.

IV.

In designing and improving methods for securing national economic isolation statesmen often appear to act on the assumption that absolute self-sufficiency is an ideal capable of practical realisation. This, assuredly, is not the case. Apart from the fact that the price which would have to be paid is prohibitive, experience has shown that new devices by new traders can make headway even against the most drastic restrictions yet devised. But at a price which seems reasonable in the short-run or the real burden of which is not immediately apparent, a very considerable degree of economic self-sufficiency can be attained by small as well as by large nations especially if the measures pursued are in harmony with the long-term forces favouring the trend. Little attention, however, is paid to this proviso when regulations are being drafted ; and, even when circumstances are propitious for the success of an attempt at further isolation, disaster often ensues through too vigorous use of double-edged weapons, which, when wielded at all, demand more skill in management than is ever likely to be available.

Much can be learned from a study of the partial closing of markets in European countries to agricultural products from the remaining countries in the world. These older industrial counties aim at developing regulated agricultural production for reasons partly creditable and partly sinister. German import duties on wheat and rye, for example, may be anything in the neighbourhood of 300 per cent. of the general world market prices. France plans to be, and is in fact, largely self-contained in cereals. Wheat production is encouraged in England by guaranteed prices and by enactments designed to secure that all is sold which is produced. In every European country some or every branch of agriculture receives subsidy or high protection. The consequences of these measures for the newer extra-European agricultural countries are serious. As example, consider the case of New Zealand with exports entirely agricultural and the largest foreign trade per head of population of any country in the world. The story of her troubles is set out in the adjoining table of indices which covers the years of intensification of agricultural self-sufficiency in Europe.

Commenting on this table a New Zealand Government official publication points out ' that in the aggregate the volume of production has been well maintained but the outcome of trading operations may be summed up as follows : Between 1928 and 1932 the index figures indicate that the

DOMINION OF NEW ZEALAND.

Year.	Volume of Production.	Volume of Exports.	Volume of Imports.	Index-number of Export Prices.	Index-number of Import Prices.	Volume of Goods available for Home Consumption.	Aggregate Value of Exports.	Aggregate Value of Imports.
1926 . .	100	100	100	100	100	100	100	100
1927 . .	108	108	96	—	—	102	—	—
1928 . .	117	112	100	—	—	111	—	—
1929 . .	122	116	114	—	—	121	—	—
1930 . .	124	119	106	—	—	118	—	—
1931 . .	117	120	69	—	—	92	—	—
1932 . .	114	132	66	—	—	83	—	—
1933 . .	122	151	66	58	78	82	90	51

Prices are in New Zealand pounds.

volume of exports increased by 18 per cent. In exchange for the greater quantity of exports, after making provision for payment of interest and other fixed claims, we received in return, for 1932, 34 per cent. less quantity of imports compared with the position in 1928. The net effect of this was that for 1932 the quantity of goods available for consumption in the Dominion was 25 per cent. lower than in 1928. On the same basis the shortage for 1933 was 26 per cent. This was a real loss due principally to (*a*) having to set aside a larger quantity of produce to meet fixed obligations overseas; and (*b*) the fact that the terms of barter in Great Britain have gone against us, with the result that in exchange for a given quantity of primary products we now receive less manufactured goods than formerly—that is to say, the prices of primary goods have fallen more than the prices of manufactured goods.' What can New Zealand do if this continues? Nothing, except divert some of her population to new local industries, uneconomic secondary industries is the term employed, and keep out every article she can produce at home.

As a contrast, consider the case of Canada. Like New Zealand's, her total foreign trade per head of population is large. Indeed, she usually comes third in order of magnitude of this item and runs Denmark closely for second place. But, unlike New Zealand, she is an important manufacturing country with much developed mineral wealth, as well as being a producer and large exporter of agricultural commodities. Her industries have been built up with imported capital behind high tariff walls; and she pursued for years what was, in essence, a mild policy of economic self-sufficiency when other new countries were developing in more narrow grooves. Her foreign trade in commodites for 1934 amounted in value to $1,145 million, which was an increase of nearly 25 per cent. on the figure for 1933. It is estimated by the Dominion Bureau of Statistics that Canadians purchased in 1934 some $300 million of foreign securities or of Canadian securities held abroad and that Canadian governments and corporations retired $75 million in bonds owned abroad, while purchases of Canadian securities and investments by foreigners amounted to $355 million. Thus, there was a net export of capital in that year of $20 million which cannot but be regarded as satisfactory, especially as the increases in foreign trade in commodities was due in equal shares to increases in both imports and exports of goods. It is difficult to resist the conclusion that Canada is now reaping the reward of her foresight in developing variety in her economic system instead of continuing a narrower specialisation in the production of primary agricultural commodities. Probably she will continue to enjoy comparative prosperity in a disordered world, if she is content with a moderate diversity in her economic life; for the price to be paid for an over-ambitious programme of self-sufficiency is high, especially in a country the main wealth of which consists of primary products and which is, on the whole, still a debtor on balance to the rest of the world. This price is nothing less than a definite lowering in the standard of life of its people.

Equally with other countries exporting agricultural products the United States of America have experienced the special difficulties during the depression in which the fall in the prices of foodstuffs was so much greater than the fall in the prices of manufactured goods. But even before this crisis became acute the foreign trade of that country with Europe was diminishing. Some of the loss, no doubt, can easily be ascribed to other causes (there is no difficulty in finding quite a number); but the main cause was the attempt to initiate and develop self-sufficiency in agriculture by those countries in Western Europe which used to be considerable importers of foodstuffs from the United States. The extent to which the export trade of the latter was shifting before American economic conditions began to change (largely for reasons special to America itself) is well exhibited by a comparison between the year 1913 and the year 1925. During that period there was a reduction in exports of about $100 million (close on 4 per cent. of the total). But those to Europe fell by 20 per cent., those to the rest of North America by 7 per cent., while exports to Asia and to Africa were in each case more than doubled. There was an increase, too (though a less striking one of only 8 per cent.), in exports to South America. The falls in every case were largely in agricultural products; but the increases that took place were mainly in manufactured articles, although Asia took a little more of foodstuffs. Such changes as these almost certainly have a long-term trend. In any case they are in a different category to those which accompanied the low level of prices in the years immediately subsequent to 1929.

If the great depression had been allowed to run its course in a fully competitive world economic system in which no obstacles were presented to a reasonably free marketing and distribution of commodities, the prices of producers' goods would have fallen more in proportion than the prices of consumers' goods. This would have called into action a number of readjusting forces, and if the experience of previous periods of recovery from depression had been repeated, demand would have revived in such a way that a new position of equilibrium would, in a short time, have been attained. But the course pursued by this depression has differed very markedly from that of any other which the world has yet experienced. Market competition has been much restricted and prices of producers' goods have been maintained or have fallen less than the prices of consumers' goods, with the consequence that there has been an exceptionally serious diminution in the production of all durable goods. Agricultural commodities, the most important group of consumers' goods, suffered the heaviest fall in price of all; and, although there has been a slight increase in consumption in consequence of this great fall in price, demand for foodstuffs is very inelastic and could never have increased to the extent required for a restoration of equilibrium. For such a result a diminution of output is necessary. It was some time before this was realised by the principal agricultural communities producing for export. These have instituted or are instituting restriction schemes which are exceedingly difficult to handle with effect. But the positive measures taken by many countries which are usually importers of foodstuffs to maintain and even to expand their agricultural production create still greater difficulties and lead to the absurd phenomenon of some governments paying bounties for the production of food for the non-production or destruction of which other governments pay equally large compensation.

V.

Prior to 1929 the long-term influences which prompted or rendered easy a policy of considerable national self-sufficiency had suffered a check. The movement towards stabilisation of tariffs and liberalisation of commercial relations between the different nations of the world seemed likely to gather strength; and the excessive nationalism engendered by the War was subsiding slowly. But in the latter part of that year there was a collapse of confidence; and the onset of the great depression created an entirely new situation. Since then short views on international commercial policy have been dominant everywhere.

It is a mistake, however, to conclude that the motives which have prompted measures of restriction in all countries since 1929 have had as their aim the destruction or even the curtailment of international commercial relations. Examination of the discussions in legislatures and study of the trade agreements actually concluded indicate that the principal object of all countries was (and is) to increase the volume of their foreign trade as a whole. But the volume of exports at the current low world prices, especially in the case of primary products, got out of line with the volume of imports. Strict control of the latter, therefore, was imperative if balances of trade (or rather the balances of income and outgo accounts) were not to be upset; for the consequences of this are a drain of gold reserves, depression of value of currency units and threat to the financial solvency of governments.

The course of events can be well illustrated by taking Great Britain as example; but it must be borne in mind that the special conditions of this country do not permit of strictly parallel comparisons elsewhere. The very great fall in gold prices which set in towards the end of 1929, due mainly to the financial collapse in that year in the United States of America, caused heavy curtailment in the foreign demand for British exports. On the other hand, British demand for foreign goods increased because of their new and lower prices. The difference, therefore, between the total value of visible imports and total value of visible exports was greater than before. This would not have mattered much if services rendered to foreigners and interest payments due by foreigners had not shrunk at the same time; for the gap could then have been largely filled by a reduction in the annual amount of new capital invested abroad or, with greater difficulty, by a realisation of part of the foreign securities held by Englishmen which still retained a reasonable value. As a matter of fact the gap was not filled to a sufficient extent in either of these ways. The consequence was an adverse balance in the income and outgo account of foreign trading which was estimated at £104 million in 1931 and £56 million in 1932, and an insistent demand on London for gold. Some gold did leave England and the Bank of England took the action which was usual and appropriate when this happened. Money rates, therefore, rose, prices tended to fall, exports were encouraged and imports were discouraged. Further adjustment, however, was necessary; for the situation, though not without precedent in kind, was unparalleled in extent. The fall in prices ought to have been accompanied by a fall in costs which did not take place. It is not necessary here fully to explain why; but it is evident that wages, one of the main elements in cost, cannot easily be reduced, and costing schemes in general are not sufficiently elastic to meet very rapidly changing conditions. When it was realised that this readjustment was not possible the alternative remaining was to prevent gold prices falling still further. This demanded a continuous export of gold as long as world prices went on falling, a policy which would not have steadied prices in Great Britain even if it had been possible to pursue it; for the loss of gold would only have led to still lower price levels at home. When, ultimately, the gold standard had to be abandoned in 1931, the only weapons left were tariffs and the whole apparatus of restrictions under which economic self-sufficiency cloaks its aims. These expedients had already been utilised by other countries when they sought to improve their balances of trade so as to maintain price levels and protect monetary standards. It is probably correct, therefore, to conclude that one of the principal reasons underlying the institution during the past few years of the very great mass of restrictions on international trade is the protection of currencies and the financial solvency of governments. Under normal circumstances a country by imposing tariffs and restrictions on imports can hope to protect its currency from attack and maintain it at or near gold parity without experiencing an intolerable downward pressure on prices; for its limitation of imports is not accompanied by a fall in its exports. The success of this policy, therefore, depends on the extent to which other countries freely admit its goods. If every country simultaneously restricts imports the trade of each is depressed by the tariffs and quotas of the others more than it is stimulated by its own. The object sought, improvement in trade balances, is not attained. Instead, the general effect is contraction in the volume of international trade with increase of unemployment and additional currency difficulties all round.

VI.

Much can be learned from a review of the growth of high protective policies and of restrictive economic nationalism during the years of the depression. Few countries were without import duties of some kind in 1929. The obvious and immediate step, therefore, when trade balance difficulties were encountered, was to raise those duties so as to guarantee to home producers a larger or more exclusive share of the domestic market, and, in this way, relieve the growing unemployment caused by the fall in prices combined with the constancy of costs. Budgetary difficulties, too, due to reduced public income led to general or flat increases in duties in many countries so that revenue might be maintained; and governments of debtor countries (Australia, Latin America, e.g.), which were large borrowers on private or public account, finding their burdens increased owing to the decline in prices and their lower returns from exports, were driven to reduce all imports which were not indispensable so that national receipts and national payments might be balanced. Retaliation then followed from countries at the moment less embarrassed; for these were finding their usual export trades hindered by the tariffs and restrictions of those nations which had first experienced difficulties. There were, therefore, further instalments of tariffs in ever-widening circles; and by the latter part of 1931 the export trade of all countries had as a consequence shrunk to a very marked extent.

Meantime, France had revived the quota method of control under which limitations are imposed upon the quantities of particular goods that may be imported over an allotted period of time. Other countries followed, the assumption (or justification) being that quotas are temporary measures of defence designed to limit imports to the quantities which can be absorbed in a period of restricted demand. It is probable, however, that their real attraction was their certainty in result (which is usually greater than can be assured by tariffs) combined with the fact that treaty obligations frequently rendered tariff changes immediately impossible.

At first quotas were fixed permitting supplying countries shares in proportion to their exports during a period preceding restriction. Soon, however, they were turned into weapons with which to bargain for increases in exports. They are now regularly employed by way of threat to extract concessions or counter-advantages from other countries in the shape of reduced duties, release of blocked funds, guaranteed purchases or other commercial privileges. Their use has been extended far beyond the purpose for which they were originally devised. Fortunately they are not popular with traders; for their administration involves much interference with the ordinary routine of business.

In the confusion following the financial difficulties which came to a head in September 1931 when Great Britain abandoned the gold standard and depreciation overtook the currencies of many other important countries, centralised control over the transfer of funds abroad was adopted by nearly all the governments whose monetary systems were then altered in basis and even by some whose currencies still continued to be linked to gold. The original purpose of this control was to prevent speculation and to protect the values of the currency units from the consequences of the withdrawal of funds for deposit or investment abroad. In actual working no difficulties at first were placed in the way of importers obtaining exchange for payment for food, raw materials or other commodities deemed to be essential. But, very soon, governments began to use exchange control as a supplement to other means of restricting imports; and by direct refusal of facilities they were able, more effectively than by tariffs and quotas, to discourage foreign transactions whenever they desired. This power to discriminate led easily to the next step—the granting of preference or priority in exchange on the basis of the country from which the imports were to come. It was argued that favour ought to be shown to those who were good customers and that it was desirable to obtain as near a correspondence as possible in imports and exports with every trading country. Further development soon followed and control over foreign exchange became a bargaining weapon, just like quotas, whereby the threat to withhold or delay payment for imports from, or of debts due to, a given country was used to exact commercial privileges or special trading facilities.

At this stage it became evident that the bargaining power arising from this exchange control of countries whose products were mainly foodstuffs and raw materials was inferior to that of the older manufacturing and commercial countries in Europe; for the latter were creditor countries and the prices of their products had not fallen as much as those of the products of the former. It was natural, therefore, for the financially more powerful countries to require that exchange funds arising out of their purchases should be reserved for the purchase of goods from their subjects and for the remitting of interest on investments held by their citizens. Further, a number of exchange clearing arrangements were set up between these weaker countries and their creditors as well as between the older countries themselves. In these provision was made for the direct balancing of credits derived from all the transactions between the pairs of participating countries and, occasionally, even for the reciprocal admission of allocated volumes of specified classes of goods on terms akin to barter. This whole episode of exchange control is a curious mixture of repression and restriction of trade combined with ingenious devices for mitigating the damage done by measures which are admittedly short-sighted.

Primarily, quotas and exchange control were means by which a government sought to safeguard its general balance of trade. Their use for this purpose can readily be justified as a defensive measure in the exceptional conditions now prevailing in international trade to-day. It might even be admitted that a country which relies for its livelihood on the export of a few special commodities has the right to safeguard its market for those goods and secure for them reasonable terms of entry to other countries when commercial treaties are being negotiated. But the extension of the principle of general balance of trade which offers a basis of control for the total trade of a country with all foreign countries to the case of import and export trade with every individual external group is a development which cannot but prejudice the future rehabilitation of world trade on any sound or equitable foundation.

This new concept, then, of bilateral trade balancing, this unwarranted extension of an old and useful general guide, is due to the realisation that it is possible, by using quotas and exchange control, to re-arrange trade relations with individual foreign countries on what can be a substantially equal barter basis. Such an ideal makes a wide appeal in a period of depression when normal trade outlets are choked; and it is significant that more than one-third of the commercial agreements concluded by European countries, both among themselves and with countries outside Europe, during the past two years have been dominated by the principle that as far as possible in every case imports should approximately balance exports. Now this insistence upon the equalisation of imports and exports between two countries where equality did not exist before is much more likely to scale down the higher of two unequal figures than to raise the lower. The country with the larger volume of exports has almost certainly to reduce its shipments to the volume it imports from the other country, with the consequence that its exporting industries suffer loss, part of which in turn is passed on to the producers of the materials it utilises whether they be fellow citizens or subjects of another group of foreign countries.

But the case against bilateral trading rests firmly on the fundamental economic facts upon which every international exchange of goods is built. Difference in climate, in natural resources, skill of peoples, efficiency and standards of life in the different countries of the world determine the type and amount of product which any selected country can export, and at the same time they prescribe the special character of the imports it requires. Inequalities in the amounts passing to and fro between each pair of countries are in the normal course of events. Anything else could scarcely be expected. But these inequalities usually balance off in the aggregate transactions of world trade and finance in consequence of triangular or multilateral movements of services, trade and capital. Moreover, multilateral trade is the means by which younger countries develop their productive resources ; for they obtain capital from one group of countries which may not desire to be paid the interest due to them in the form of the borrowers' goods, but, instead, may be willing to receive it in the form of products of a third group of countries which, in turn, find it convenient or imperative to have the commodities that are produced with the aid of the borrowed capital. In this way countries other than the borrowers and lenders share in the increase of wealth that attends the use of the additional capital. The many-sided trade occasioned by transactions of this kind has largely determined present economic structure and the distribution of economic activities among the peoples of the world. Reference has already been made to the fact that the inequalities in trade between all the separate pairs of countries in the world are cancelled and disappear when they are consolidated, and that this process of adding up the sums on each side of the general world balance sheet of international economic relations is accomplished through triangular or many-sided movements of services, trade and capital. It is obvious, therefore, that anything which interferes with the freedom of movement of one of these factors may damage an essential part of a very delicate machine which it may be exceedingly difficult to repair. Unfortunately, the general control and practical cessation of foreign investment in every country is an outstanding example of such interference. But alarmist movements and withdrawals during the depression of short-term funds held abroad by certain creditor nations have wrought even greater havoc ; for the countries suffering the withdrawals met them largely by their normal commodity exports to the creditor countries at a considerably reduced level of prices. They then had nothing left with which to buy anything from the countries which had been the other sharers in the triangular or multilateral trade. Thus a short circuit occurred, cutting out intermediate links in the chain. Even when the withdrawals took the form of exports of gold from the debtor countries the exhaustion of the liquid resources of the latter led to similar results.

If trade had been comparatively free when the change took place in the capital item in the balance, a readjustment would have been possible and the intermediate links could have been restored. The withdrawals (coupled with the cessation of capital exports by the creditor nations which preceded the withdrawals) tended to affect the price levels of the countries involved. This, in the absence of trade restrictions, would of itself have altered the totals of exports and imports, slowed down the pace of the machine, as it were, without stopping it altogether. Freedom to search for new markets would then have speeded it up again in a very short time. But the new trade barriers prevented those rapid adjustments in the quantities of imports and exports which usually occur when there is variation in capital movements; for every country aimed at protecting its own domestic production from the dislocation that might follow a rise in its imports. The consequence was further increases in the gaps between commodity prices in different countries which, in turn, led to additional import restrictions and to general slowing down of trade.

When restrictions are being imposed for the reasons just described due regard has to be paid to the possibility of retaliatory measures. Therefore, the victims are selected with care. They are invariably the countries in trade with which the restricting country has an excess of imports over exports on consolidated account of goods and services. The effect of this is a reduction of trade balance between the two parties in question and consequent further curtailments of the opportunities for triangular or multilateral trade.

Attempts to gauge the contraction in triangular merchandise trade since 1929 have been made by the Economic Intelligence Service of the League of Nations. The difficulties in the way of accurate estimation are considerable; and much allowance must be made even when guesses are obviously well-founded. Of the general truth of the conclusions there is no doubt. The following table (taken from *Review of World Trade*, 1933) setting out the results of a careful examination of the trading accounts of 22 countries which together handle about three-fourths of the international commerce of the world, shows how the percentage proportion of bilateral trade has increased during the depression at the expense of triangular trade.

	1929	1931	1932	1933
Bilateral Trade . .	79·7	81·5	82·5	83·4
Triangular Trade .	20·3	18·5	17·5	16·6
	100·0	100·0	100·0	100·0

This tendency is exceedingly serious for countries which have a highly specialised production and which, therefore, are dependent on the sale and export of a small number of commodities. Chile, Greece, Bolivia and certain agricultural countries are examples. It is only because of triangular or multilateral trade that such nations can effect satisfactory balances on income and outgo account; for, frequently, they cannot dispose of enough of their products in the countries from which they borrow in order to offset the payments due from them to these creditors for goods inported and for interest on loans. The pressure exerted on them, then, in consequence of the growth of bilateralism, to increase their exports to countries which do not want their products leads to low prices which, in turn, stimulate further production, so that the total of receipts deemed necessary may not be impaired. It is in this way that the contradiction arises of financial distress accompanied by excess supplies of certain categories of goods which is so marked a feature of the present depression. But it would be a mistake to conclude that bilateral trade treaties can never benefit either or both of the contracting parties. This can happen when the currencies of each are reasonably free from fluctuation, when neither is greatly indebted to the other, especially on short term, when there is mutual confidence in each other's political stability and each has need of the other's specialised products or is willing to purchase them. A possible example is the case of Sweden and Great Britain. Such instances, however, do not controvert the fact that other countries lose more than is gained by the two more fortunate nations. At the best such agreements merely divert trade. They can do nothing to enlarge it.

VII.

What are the prospects for the future? Will trade barriers disappear or be modified? Will all these exceptional contrivances for safeguarding trade balances be forgotten when the present emergency passes? It is too soon yet to give an answer to these questions; but in any case the restoration of comparative freedom in international trade will be slow. Until the most fundamental cause of all restrictions is removed—disparities in the price levels of the same commodities in different countries due to different degrees of currency depreciation—it is unreasonable to anticipate much progress. But at the same time it is well to guard against exaggeration of the extent to which self-sufficiency is actually a conscious deliberate policy of the principal industrial and commercial countries in the world to-day, and to avoid the conclusion that every restrictive measure on imports is actuated by considerations mainly non-economic and national. On the contrary, it would be more correct to assume that the aims of restriction are to enlarge the volume of international trade as a whole, however paradoxical this may seem. It is reasonable, therefore, to expect that barriers will be removed when it is discovered that they hinder rather than foster the attainment of this object.

Some relaxation of the quota system has already been devised. There is a tendency now to use it not to place absolute limits upon the volume of imports but, rather, to set a maximum limit to the quantities of goods to which a lower scale of duties apply, there being reciprocal agreements that imports above this limit shall be admitted on a higher scale of tariffs. This plan is designed to avoid serious disturbance in a given price level within the importing country for each commodity coming under the scheme. It has been embodied in treaties between Austria and Hungary, Roumania and France in reference to wheat, and in several other treaties between countries in central and eastern Europe in reference to other commodities. If there must be prohibitions or restrictions, it is fairly well adapted for the protection of the internal price levels of commodities whose domestic production is considered desirable or in the case of which there are official marketing schemes which have to be nursed with care. This system of tariff quotas as distinct from import quotas would seem, therefore, to offer help to countries engaged in planning internal production in certain products the prices of which it is desired to stabilise without at the same time restricting an import trade which is tending to expand. But the uncertainties and the abuses inherent in all systems of quantitative control are exceptionally great in the administration of any quota scheme. Unless there is a return in practice to the early original purpose of quotas, and governments refrain from using them as special bargaining weapons, the prospects for increasing freedom in international trade are none too bright.

In the treaty of 1860 between France and Great Britain there was embodied for the first time the principle of competitive equality in trade, or the assurance of equal opportunity to all friendly competitors, the principle generally referred to as the most-favoured-nation principle or clause. The example thus set was followed in the majority of trade agreements concluded since that date between the important commercial nations of the world. This led to a considerable extension of freedom of trade; but, occasionally, intensification of economic nationalist movements offered opposition to the simple working of the clause. It is not surprising, therefore, that since 1929 it has been overlooked or has been evaded by the institution of many new types of preferential trade arrangements. To the question, shall the principle be maintained or re-established, or is it to disappear and be no longer embodied in future commercial treaties, a conclusive answer cannot now be given. Reasons, however, can be offered for the view that it will not be abandoned completely but that it is likely to be retained in a modified form to play a part again in the general liberalisation of trade.

Even if some measure of quantitative regulation of international trade survives the depression it is improbable that important industrial countries will consent to abandon the rights they now possess in the way of assurance, which is given them by the most-favoured-nation clause, of equal opportunities for their exporters to supply the imports required by other countries. If they did, their merchants would soon complain, with justice, of unfair and unequal conditions of competition. That importance is still attached to the survival of the principle and that its complete abandonment, therefore, is unlikely appears from the report of the Committee on Tariffs and Commercial Policy of the London Economic Conference of 1933. This Committee suggested modifications that might make its application more elastic and better suited to the changed conditions of trade in 1933. 'There was a general opinion,' the Committee reports, 'in favour of the maintenance of the most-favoured-nation clause in its unconditional and unrestricted form—naturally with the usually recognised exceptions—stressing the points that it represents the basis of all liberal commercial policy; and that any general and substantial reduction of tariffs by the method of bilateral treaties is only possible if the clause is unrestricted, and that this method would avoid the constant resumption of negotiations.

'However, certain delegations manifested a strong tendency in favour of allowing new exceptions in addition to those hitherto unanimously admitted, on the ground that, although the unconditional and unrestricted most-favoured-nation clause does, under normal conditions, secure for trade the indispensable minimum of guarantees and prevents arbitrary and discriminatory treatment, if insisted on with too great rigidity, it may obstruct its own purposes in a period of crisis and difficulty such as we are now passing through.'

An additional exception of importance which, however, has not yet won general acquiescence was suggested by the American delegation to that London Conference and repeated at the Pan-American Conference in the following December. The proposal was that, under certain conditions, the benefit of multilateral pacts for the reduction of trade barriers which are open to adherence by all countries should not be claimed by non-participating countries. The general underlying idea is that if collective agreements are made among groups of countries which are prepared to reduce barriers to trade between themselves, other countries not willing to undertake the same obligations should not benefit by such pacts merely because they have general most-favoured-nation agreements with some of the participants. Rigidity of interpretation of this kind has held up several Danubian pacts which aim at closer economic relations between countries in central and eastern Europe. Perhaps, too, it was responsible for the breakdown of the Ouchy Convention in 1932 between Holland, Belgium and Luxemburg. It will not be easy to get a general informal understanding among nations that they should not press their claims unreasonably and so destroy the chances of success of all collective agreements for the reduction of trade barriers. There are signs, however, that such an understanding is not impossible of attainment. This is fortunate; for on it will depend the future successful working of the most-favoured-nation clause.

The favourable attitude towards the problem of the most-favoured-nation clause on the part of the London Conference Committee on Trade and Commercial Policy was only one of many indications that the delegates on that occasion were ready to recommend a definite reversal of the worst of the restrictions now hindering trade. There could not but be general agreement that the unsettled monetary situation, which called for stabilisation and general adjustment of international financial relations, was the most fundamental of the problems demanding solution and that, failing success here, no useful purpose would be served in proceeding with discussions on the removal of the ordinary barriers to trade. When, therefore, it became apparent that agreement concerning currency stabilisation was impossible, owing to the reluctance of certain governments to give up the power of control over internal price-levels which they considered currencies unlinked to gold conferred upon them, there was no option left to the representatives of other governments except to decline to enter into either short-term or long-term undertakings concerning trade policy and related questions. But it is important to note that there was a fairly general consensus of opinion that the shrinkage in world commerce was due to a considerable, although an undefined, extent to high tariffs and all the other barriers, such as quotas and exchange control, which had been devised since 1929.

In accordance, then, with this general feeling, in order that there might be a favourable atmosphere for international discussion and for possible concerted action, a customs truce was agreed to, which embraced countries handling fully nine-tenths of the trade of the world. The deliberations of the Committee, as far as they went, indicated agreement, on the part of the responsible representatives of most governments, with liberal views on trade policy and with the opinion that restrictions generally were undesirable. But it is one thing to express adherence to an ideal, and another to make sacrifices in its pursuit; and there is no doubt that the breakdown of the Conference on the monetary problem brought relief to the embarrassed trade delegates of more than one nation. It was demonstrated, however, that it is only through international conferences of this kind that progress can be looked for in the straightening out of the present tangle of barriers to trade.

The failure of the Conference led to immediate denunciations of the tariff truce and to a temporary reaction in favour of additional restrictive measures. Further meetings for discussions on trade policy ought not to be convened until currencies are reconstituted upon firm and permanent foundations; for mutual suspicions that trade concessions may be undermined by currency manipulation create an unfavourable atmosphere for fruitful deliberation.

While the prospects for general international agreement to scale down tariffs and remove other barriers do not offer hope for early action, regional agreements carefully chosen as starting points may indicate the path to continuously widening areas of comparative freedom of trade. Reference has already been made to the proposed Danubian pacts and to the Ouchy Convention of 1932 which failed through the insistence of the stronger nations on their rights under the most-favoured-nation clause. Where, however, important and influential nations are concerned which can command the acquiescence of weaker nations in less rigid interpretations of this principle of competitive equality much progress is possible. Perhaps the Ottawa agreements of 1932 in which Great Britain, her colonies and self-governing dominions all participated are a case in point. But if these Ottawa pacts illustrate the possibility of a wide extension of areas enjoying comparatively unimpeded trade they also clearly indicate the underlying conditions necessary for success. There is no need, here, to review the results of the Ottawa Conference and assess its value to the mother country and to the dependencies. But it would not be easy to refute the criticism that this series of trade agreements between the several parts of the British Empire have been trade-diverting rather than trade-enlarging in their effects. Moreover, they demand sacrifices on the part of some of the participants which in the long run may prove to be intolerable.

Certain historical analogies are instructive. Nineteenth-century Europe offers examples of several movements in which a number of small contiguous independent countries formed a customs union, within which trade was largely free, and so built up an economic unit better balanced than any of the constituents singly could ever hope to be. The German States in 1830 came together in this way and abolished tariffs over a wide area in central Europe where, previously, there had been more than a score of States large and small. Unfortunately such movements are never wholly, perhaps not even principally, economic; for they have their roots deep in national sentiment. Economic union, therefore, has been followed by political union, just as the establishment of a powerful consolidated homogeneous kingdom in France followed the abolition of provincial tariffs there in the eighteenth century. It is the feeling or suspicion that there is this tendency for political union to follow customs agreements among neighbouring states with similar cultural institutions which inspires opposition to the proposed Danubian pacts and other trade conventions in central and eastern Europe. It may be that the tendency does not work in the reverse direction and that the growing independence of units which have hitherto been in close political union is shown in their determination to assert themselves in the economic sphere. It may also be the case that it is felt that a measure of economic independence or self-sufficiency is necessary for the proper enjoyment of the newly granted political independence. Whichever is true the attainment of real economic unity in the British Empire will not be an easy task.

VIII.

It will now be abundantly clear that the short-term influences making for economic self-sufficiency draw much of their inspiration and derive most of their impetus from instability of currencies and the unforeseen and violent movements of prices which always accompany unstable standards of value. The first and most pressing problem, therefore, is that of currency stabilisation; for on its solution depend not only the disappearance of those novel and harmful restrictions on international trade already examined, but also, which is much more important, full economic recovery everywhere throughout the world. That must be the excuse, if one were needed, for a glance at some of the considerations bearing on the choice of policy to be pursued in connection with this general question of currency reconstitution.

It will be remembered that the principal cause of the failure of the World Economic Conference of 1933 was the realisation that it was not then possible to secure agreement even among the more important nations, much less the general consent of representatives of all the countries present, on a programme of currency stabilisation. Much has happened since then and more than one nation has discovered how to contrive a more even balance on income and outgo account through the medium of a currency freed from gold which can be manipulated so as to ward off awkward price movements at home and the immediate need for internal economic readjustment. It is probable, therefore, that if another world conference were to meet now, general agreement concerning action would not be any easier to obtain than it was two years ago. This, however, ought not to interfere with joint or single action on the part of some of the financially stronger nations whose lead the weaker would necessarily have to follow. Indeed, the latter, during a period of international monetary chaos like the present, can indulge without much hurt to themselves or the rest of the world in experiments aimed at self-sufficiency and permit fluctuations in the external values of their currencies without serious repercussions elsewhere. But the fluctuations of the rates of foreign exchange in the large and influential financial centres are very damaging to international exchange and it is a mistake to assume that such movements necessarily produce equilibrium. Experience here reinforces theory in demonstrating that the contrary is almost certainly true and that they cause more dislocation than they cure. It is evident that it is only by an international monetary standard of some kind permitting of stability in foreign exchange rates that the temporary excesses in the trend towards economic self-sufficiency can be cured and prosperity restored.

If this be granted and if agreement in the re-establishment of an international standard is not to be looked for immediately, the case for single-handed action by Great Britain is considerably strengthened. We have most of any country to lose by a permanent shrinkage in international trade, and the position of London as a leading world centre of finance carries with it much prestige and considerable responsibility, a fact as important in matters political as it is in matters economic. The question, then, can be put very simply, although it is not equally easy to supply an answer. Which is to be the policy of this country if and when it decides to give a lead to the rest of the world—stabilisation on gold or stabilisation on sterling as a paper pound ?

The latter makes a more cogent appeal to thoroughgoing economic nationalists than the former. For this there are many reasons. Reference has already been made to the most important—the greater control over its domestic economy which is possessed by a government whose monetary system is not intimately linked to a general international standard in the way demanded by a general foundation of gold. Of less significance are the difficulties which would ensue from the correction of the present maldistribution of gold. These, it is felt, would involve retreat from positions of self-sufficiency which have not yet been consolidated and which, if lost, could only be recovered in a future crisis or depression. Further, it is pointed out that important countries, including Great Britain, have for some time worked an exchange system without the use of gold and that the experience gained demonstrates the possibility of avoiding all the difficulties which accompany the working of the gold standard, especially those due to variation over long periods in new supplies of the metal and the occasional maldistribution of general stocks which, it is asserted, can never be effectively avoided. It is only by stabilisation on a sterling paper basis, therefore, the argument continues, that Great Britain (and the world) can escape another economic crisis in the course of time.

The case against stabilisation on a paper basis rests primarily on prudence and expediency. The insulation from external economic influences so desired by the nationalists is a dangerous privilege for which a very high price has invariably to be paid. Further, monetary management on a paper standard demands constant vigilance, a continuity of policy and a trust in the moderation of governments which few people are willing to concede. Most important of all is the fact that the world is not yet ready to abandon an international standard based on gold. The problem, therefore, is not whether to return to gold, but when, and on what terms.

To the question 'when' the answer at first sight appears to be definitive—not until there is a general state of equilibrium between the price levels of the important commercial countries of the world. As long as sterling is undervalued as regards the currencies still on gold and uncertain, probably overvalued, as regards the dollar, stabilisation is undesirable. It would merely repeat the disastrous consequences of the mistake of 1925. But here there is a vicious circle. It is uncertainty with regard to the futures of currencies and, predominantly, of sterling which is the main cause of the lack of harmony between foreign exchange rates and the price relationships of the leading countries. Until there is assurance concerning the future gold basis of sterling equilibrium between price levels is unlikely to ensue merely as a consequence of market fluctuations in rates of exchange. Rather than rely, therefore, on price levels, which are so much the playthings of doubts, alarms and apprehensions, to bring exchange rates into harmony with one another it would appear the better course partly to reverse the process, stabilise sterling on a gold basis tentatively, and by maintenance of steady sterling exchange rates look forward to internal prices elsewhere adjusting themselves to the new situation thus created. There is little to be gained by waiting on further developments before initiating such a plan. On the contrary, delay is adding to the difficulties that will be encountered whenever stabilisation on any basis is ultimately attempted; for the present downward trend in sterling creates trouble for countries financially weaker than Great Britain, encourages competitive currency depreciation and further curtails the volume and value of international trade.

If the case for early stabilisation, then, be granted, the implementing of the policy calls for a very careful, gradual and tentative approach. Anything in the way of a full and immediate restoration of the gold standard is impracticable; but the preliminary steps required should not present serious difficulties. It is not proposed now to enter upon a detailed examination of those steps or of the further steps involved, and the degree of co-operation which may be needed from the central banks of the United States of America and the leading gold countries in Europe. Neither is it necessary to discuss the part which might conceivably be played by that recent addition to the machinery of the London Money Market, the Exchange Equalisation Account, in consolidating and maintaining the new situation when a *de facto* becomes a *de jure* stabilisation. It is sufficient to register the conclusion that until this task is performed there will be continued encouragement to ill-timed attempts to attain and maintain economic self-sufficiency, to the detriment of full recovery in international trade throughout the world.

SECTION G.—ENGINEERING.

THE STABILITY OF STRUCTURES

ADDRESS BY

J. S. WILSON, F.C.G.I., Hon. A.R.I.B.A., M.I.C.E.

PRESIDENT OF THE SECTION.

The subject I have chosen appeals to me because I have had to devote much time to various aspects of it and, by experimental research have endeavoured to contribute something to the solution of some of its problems.

From the engineering point of view, stability is a somewhat dull subject, yet the history of its development is of great interest. Instead of trying to deal with the subject in a comprehensive up-to-date way, I propose to describe some of the more interesting episodes in its history.

The meaning of stability is not easy to define. In dynamics and mechanics we have stability of steady motion and stability of equilibrium, of position and of friction. To the civil engineer the word is usually applied to the power of a structure to withstand for an indefinite time all the loads and forces that may be brought to bear on it.

As an indication of the wide range covered by my title I may call your attention to a few examples. The most stable structure ever built is probably the Great Pyramid of Egypt. It consists of large blocks of limestone carefully shaped and piled together to the height of 480 ft. on a base measuring 830 ft. square. Another instance of a great pile: a pile of bricks laid one on another, is a tall chimney such as the celebrated one at St. Rollox in Glasgow. This had a height of 435 ft., and at its base a diameter of 40 ft. It was pulled down a few years ago after having stood since 1842.

A masonry dam built across a valley to impound water is another form of structure the stability of which must be beyond question, as failure would lead to disastrous flooding.

Then we have the arch, the most beautiful and fascinating form of construction invented by man. In its simple form we have arches across rivers of imposing size and graceful stability, while in cathedrals and other great buildings we have it in the groin, dome and buttress.

In each of the above instances, strength and stability depend mainly on the resistance to compression offered by stone or brick. A complementary form of structure dependent on the resistance to rupture by the pulling asunder of its parts, is the suspension bridge, the stability of which depends almost entirely on the tensile resistance of the chains or cables. The greatest structure of this form is undoubtedly the George Washington Bridge over the Hudson River, New York, with its span of 3,400 ft.

In most iron and steel structures the resistance of the material to both tension and compression contributes to their stability in equal proportions, as is found in the great girder and cantilever bridges.

Reinforced concrete, in which the great strength of concrete to resist compression is combined with the power of steel to resist tension, owes its development largely to the facility with which it can be built and shaped. It has been applied to many large structures which present problems in stability of considerable interest.

Tunnels of masonry or brickwork, and cast-iron lined tube tunnels, subject to the pressure of great depths of earth, are forms of structure the stabilities of which are not easy to calculate.

In estimating the stability of a structure, the principal factors are the strength or resistance to rupture of the material and the balance or direction of the forces or loads brought to bear on it. The ultimate strength of a simple part of a structure can be calculated without difficulty by applying to it the breaking stress determined by experiment for the material used. It is not easy, however, to estimate the strength of that element to withstand the long-continued action of loads and forces to which it might be subjected in use. Thus, the elementary part in question might be required to withstand, for an indefinite time, a load of ten tons applied in a particular way. The part could be designed so that it would require 100 tons, ten times the working load, to break it, and it would no doubt fulfil the requirement and carry the ten tons satisfactorily. On the other hand, it might be made with a breaking strength of only thirty tons and be able to carry the imposed loading equally satisfactorily. The second design requiring so much less material, would be the more economical and more correct one. Although put simply and somewhat crudely, that is the essential problem underlying the measure of stability having regard to the economical use of material, and it is interesting to note that, so far as applies to civil engineering structures, the advance made in its solution during the last fifty years has not been great.

The rupture or breaking down of a structural element by a force is dependent on the detail of its incidence and the resulting intensity of the stress induced in the material. To make clear the manner in which the stability of some forms of structure is gauged, it is necessary to outline the approach to the problem.

To fix the directions of, and arrange for the balance of loads and forces, the conception of action along lines was introduced at an early stage. The position of such a line with respect to the boundary of a member offering resistance, governs the distribution and intensity of stresses in the material. In estimating the intensity of stress, the position of the line in a lamina of the part under consideration is usually considered, and in it the distribution of the stress follows the 'trapezium law,' which is a particular case of Galileo's solution of the beam problem. Thus if the line representing the centre of action of the load or thrust is on the centre of the section of the member, the stress intensity would be the same throughout the section. If the line of action is off the centre, then the intensity is increased on the side towards which the line has moved. The diagram representing the distribution of stress is a trapezium, the centre of gravity of which is on the line of action.

In a pier or buttress which supports and at the same time resists the thrust of an arch, the line representing the resultant of the weight and thrust of the arch is deflected downwards by the weight of the buttress, and the buttress may be so shaped that the deflected line is everywhere near the centre giving a uniform intensity of stress in the masonry, and uniform pressure on the ground below the foundations. On the other hand, the balance may not be so good, and the line may be towards the outer side of the buttress, giving high concentration in the masonry and ground.

The maximum intensity of stress in the masonry compared with the stress which will crush the particular material is a measure of the stability; similarly with respect to the natural formation below the foundation, the comparison is between the maximum pressure it is considered capable of carrying, and the highest pressure with which the masonry bears on it.

If the resulting line of action is anywhere outside the boundary of the part, then the part would be without stability unless the material of which it is composed were capable of withstanding tensile stresses.

The tracing of the position of the line of action of the thrusts and loads in an arch, which must be kept well within its thickness, is the basis of the design and measure of the arch's stability.

Historically the problem of the masonry arch is extremely interesting. The arch form of construction has been known for thousands of years, and several magnificent arches built by the Romans are still in a very good state. Although the arch is a form of construction very generally used, their occasional failure in the past has kept alive a feeling of uncertainty, if not of mystery, as to their strength and stability. Real progress in the theory of the design and strength of the arch is comparatively recent. Thus in 1870 the late Prof. W. C. Unwin, one of our greatest students of engineering construction wrote[1]:—

'. . . it is but recently that a theory of the strength of arches has even seemed possible, and the theory has not yet been so far developed as to be applicable for practical purposes to the complex conditions of masonry bridges. Hence, in dealing with arched structures, the engineer is compelled to proceed in a manner not rigidly scientific. He adopts assumptions not in strict agreement with the nature of the materials he is using, if only such assumptions permit him to form a theory embracing the most essential circumstances of the problem, and if any error so introduced either favours

[1] Chatham Lectures.

the resistance of the structure, or is capable of elimination by comparison of the results of the theory with existing and successful structures of the same kind. In fact, he is often content, so to speak, with formulæ of interpolation, or formulæ which permit him to determine from known structures or given dimensions the proper proportions of other structures of different dimensions.'

In a masonry arch the line of thrust might occupy one of a variety of positions any of which would satisfy the requirements of equilibrium. For the purposes of design or estimating stability, some particular line must be chosen and this can only be done by making assumptions, the validity of which must have regard to the method of construction and the probable conditions of stress in the masonry. One of the assumptions referred to by Unwin relates to the position of the line of thrust at the crown or springings. Since Unwin wrote, one of the advances made has been the introduction of definite hinges, at the crown or at the springing level, or at both places, to ensure the line of thrust passing through those points. These hinges render the problem of strength and stability much more definite, but with respect to arches without hinges the position is still very like that described by Unwin, although much has been done by comparing and analysing existing structures, and many 'formulæ of interpolation' have been proposed. In the monumental work by Séjourné,[2] particulars are given of all arches of appreciable size throughout the world: details of construction are given, and the proportions are analysed and compared.

Up to the first half of the nineteenth century, knowledge of the strengths and characteristics of materials and of the branch of engineering science now known as 'applied mechanics,' was not sufficient to establish or disprove the accuracy of various theories relating to the design or stability of a masonry arch then in vogue or from time to time propounded; efforts to make progress in the problem depended almost as much on dialectics as on mechanical principles.

An interesting incident occurred at the time the bridge across the Thames at Blackfriars was proposed in 1759. Of the competing designs the one by the architect Mylne for a bridge with elliptical arches was chosen, although at that time only one bridge with elliptical arches existed—Ammanutis' bridge in Florence. A design for a bridge with semi-circular arches was submitted by Gwyn, an equally well-known architect. Some persons objected to the elliptical arches, and even Dr. Johnson expressed himself on the stability of the two forms of arch. Boswell records that 'Johnson's regard for his friend Mr. Gwyn induced him to engage in a controversy against Mr. Mylne, and after being at considerable pains to study the subject he wrote three several letters in the *Gazetteer* in opposition to his plan.' Johnson's letters appeared in the *Gazetteer* for December 1, 8, and 15, 1759, from which the following extracts are given :—

'Those who are acquainted with the mathematical principles of architecture are not many; and yet fewer are they who will, upon any single

[2] *Grandes Voûtes,* by Paul Séjourné, 1913–1916.

occasion endure any laborious stretch of thought or harass their minds with unaccustomed investigations. We shall therefore attempt to show the weaknesses of the elliptical arch, by arguments which appeal simply to common reason, and which will yet stand the test of geometrical examination. Any weight laid upon the top of an arch, has a tendency to force that top into the vacuity below ; and the arch thus loaded on the top stands only because the stones that form it, being wider in the upper than in the lower parts, that part that fills a wider space cannot fall through a space less wide ; but the force which laid upon a flat would press directly downwards, is dispersed each way in a lateral direction, as the parts of a beam are pushed out to the right and left by a wedge driven between them. In proportion as the stones are wider at the top than at the bottom, they can less easily be forced downwards, and as their lateral surfaces tend more from the centre to each side, to so much more is the pressure directed laterally towards the piers, and so much less perpendicularly towards the vacuity.

' Upon this plain principle the semi-circular arch may be demonstrated to excel in strength the elliptical arch, which approaching nearer to a straight line must be constructed with stones whose diminution downwards is very little, and of which the pressure is almost perpendicular. It has yet been sometimes asserted by hardy ignorance, that the elliptical arch is stronger than the semi-circular ; or in other terms, that any mass is more strongly supported the less it rests upon the supporters. If the elliptical arch be equally strong with the semi-circular, that is, if an arch, by approaching to a straight line, loses none of its stability, it will follow, that all arcuation is useless, and, that the bridge may at last, without any inconvenience, consist of stones laid in straight lines from pillar to pillar. But if a straight line will bear no weight, which is evident at the first view, it is plain likewise, that an ellipsis will bear very little ; and that as the arch is more curved its strength is increased. Having thus evinced the superior strength of the semi-circular arch, we have sufficiently proved, that it ought to be preferred. . . .'

Johnson goes on to state that " the elliptical arch must always want elevation and dignity," and that the only bridge of the elliptical kind had " stood two hundred years without imitation."

A correspondent of the journal maintained that although an elliptical arch may not be as strong as a semi-circular one, ' the semi-ellipsis may yet have strength sufficient for the purposes of commerce ' ; also ' that the convexity of the semi-ellipsis may be increased at will to any degree.' In the third letter, Johnson points out that the advocate of the elliptical arch does not promise that ' it will stand without cramps of iron, and melted lead and large stones and a very thick arch,' and recommends all ' those who may still doubt which of the two arches is the stronger to press an egg first on the ends, and then upon the sides.'

Contemporary writers disclosed the fact that Johnson consulted Mr. Simpson and Mr. Müller, both professors at Woolwich Academy. Neither favoured the semi-circular arch in preference to the elliptical, and he then procured ' from a person eminently skilled in mathematics and the principles of architecture, answers to a string of questions drawn up by himself, touching the comparative strength of semi-circular and elliptical arches.'

Throughout a long period in the eighteenth and nineteenth centuries mathematicians and others applied themselves to finding the exact form of the line of thrust that would ensure equilibrium in a mass of masonry bridging a void. The upper boundary of the mass was a horizontal surface representing the road surface and the lower one the intrados of the arch, shaped to conform to the line sought. The effect of hollow spaces over the haunches was investigated also. The influence of a moving load was regarded as negligible in comparison with the weight of the masonry or could be allowed for by adding an extra layer of masonry over the upper surface.

The shape of this arch of equilibrium was compared in great detail with those of the ellipse, cycloid, parabola, catenary and semi-circle or segment of a circle. Different writers strongly advocated one or other of these curves as being the true curve for an arch. The elaboration with which this was done seems remarkable, for many must have known that to build an arch to conform to a particular curve with the exactitude suggested is practically impossible. When the centering on which an arch is built is removed and the arch supports itself, the compression of the mortar in the joints and of the voussoir stones, allows the arch to drop an amount which is quite sufficient to alter the shape appreciably ; thus, the arches of Perronet's famous bridge at Neuilly dropped on decentering enough to alter the radius curvature at the crown from 150 ft. to 244 ft., and if intended to be elliptical, it might have conformed actually more closely to a cycloid.

Differences of opinion on the correct proportions of arches were very sharp. Two writers of ability and experience at the beginning of the last century disagreed on important principles of design, for instance, Samuel Ware, Professor at Woolwich, in a pamphlet published in 1822 maintained that the thickness of an arch at the crown should be proportional to the radius of curvature. In opposition to this John Seaward in an equally learned paper on the subject published in 1824 argued that Ware was entirely wrong and that the span should be the governing factor and added :—

'An ingenious writer in a late publication has strongly recommended that in the forming of an arch, the depth of the voussoirs should be made to bear a certain ratio to the radius of curvature at the crown, without any reference to the span of the arch : by which I presume it is intended that the depth of the voussoirs should bear some certain relation to the lateral pressure. Much as I admire the talents of the gentleman in question, I feel obliged, in this particular, to differ from him *toto cœlo.*'

' . . . if there be two arches of the same span, but the one having double the radius of curvature to the other, it is certain that the liability of the equilibrium being destroyed, would not be greater in the former than it would be in the latter : therefore on that account it is clear that the flat arch would not need a greater depth of voussoir ; although according to the doctrine held out it would have been necessary to make it double. Indeed, it is demonstrable that with the same depth of voussoirs the flat arch (provided the abutments are immovable) would be by far the strongest ; because, from the increased lateral pressure, it would require a much greater force to disarrange the parts and destroy the equilibrium.'

Such contradictory statements made by those who set out to be authorities on the subject were of little help to engineers or architects who had to take the responsibility for the actual building of an arch. The effect of the conflicting ideas can be illustrated by reference to Blackfriars bridge in Norwich. It is the first of the only two bridges known to have been designed and built by Sir John Soane, the architect of the Bank of England. It is a single arch bridge and was built in 1783. The contractor was John de Carle, stonemason of Norwich. Sir John Soane's specification describing the method to be adopted in constructing the bridge is preserved.

Although the Portland stone arch is of ample proportions, the architect appears to have had little confidence in the simple arch principle, and as will be gathered from the following extracts, he required the masonry of the bridge to be cramped and fastened together with iron in every possible way, so as to eliminate all possible risks of failure.

'To build the Arch with Portland Stone, the Voussoirs of which it is to be constructed, are to be of the Number, form, Workmanship and Dimensions expressed in the Drawings: the Arch Joints are to be wrought exceedingly true and exact and be perfectly smooth and to be set dry in Milld Lead of four pounds to the foot and in order to prevent flushing the extremities of the said Joints next the Soffite of the Arch are to be flarched off and pointed up after the Center is struck as shall be directed. In the middle of each joint of each Voussoir is to be inserted two Cubes of Cast Iron of the weight of three Pounds each let equally into each Stone, and Channels are to be sunk from the Tails of the Voussoirs to the cavities for the Iron Joggles and the said Cavities and Channels are to be run full of lead.'

'To provide and fix four Tyes or Chain Bars across the Bridge in the Positions marked in the drawing of Swedish Iron three Inches broad and three quarters of an inch thick with strong Corkings at each end to lay hold of 4 other bars each nine feet long and one inch square to be let down into the Ashler and fixed therein with Lead.'

'To cramp all the Cross Joints of the Key Course and in the Arch joints thereof are to be twelve Joggles to consist of Bent Hooks nails staples and other Irregular Pieces of Small Iron filled and crammed into Dovetail holes to be cut into the Arch Joints of the Key Course and these adjoining of the two next Courses down to the middles of the Stones and to Run the same with Lead.'

Some years ago I inspected and reported on this bridge. I found it in very good condition. There was little, if any, evidence of the cramps. It was to be expected that their corrosion would have burst pieces off the masonry but in this instance the iron must have been very effectively protected from moisture or the architect may have finally decided to leave much of it out: it certainly could not have added appreciably to the stability. Many fine buildings have suffered badly from the corrosion of iron cramps. For many years architects and builders of the past were extraordinarily lavish in their use of cramps. They put them in plain ashlar walls and places where they could have had no beneficial effect. The obsession for cramps in masonry is very like the present tendency to embed steel in all concrete. Concrete properly reinforced, is an admirable material for construction, but large masses of concrete frequently have steel wire and rods laid in them, the proportion of the steel being so entirely inadequate in comparison with the concrete that its addition suggests a magical rather than a mechanical influence.

For the longest spans, reinforced concrete has now superseded masonry; but fine masonry arches of 300-ft. span have been built. The construction of spans of increasing length has been made possible by improved technique in building. To avoid high stresses arising at the springing and key stone, as a result of the settlement or elastic deformation of the centering, as weight is added during building, and as a consequence of the initial deformation of the arch itself when the centering is removed, gaps are left in the arch, and special forms of construction are now introduced to act as temporary hinges, so that when the bridge is completed and the gaps filled in, the position of the line of thrust is fairly definitely known.

To economise in the quantity of masonry and make it possible to use higher compressive stresses, arch bridges are now made with ribs of a width comparable with the depth of the arch, instead of the arch being made continuous for the whole width of the bridge.

In reinforced concrete arches either permanent hinges of steel are introduced or else all the reinforcing bars are drawn together at the critical points to form a temporary hinge, and the surrounding concrete is filled in only on completion.

Reinforced concrete arches with spans as great as 590 ft. have been constructed.

The stability of a masonry dam is a problem that has exercised the minds of engineers and mathematicians for many years. The failure of the Bouzey dam in France in 1895 gave prominence to the problem. The Bouzey dam was straight with a length of 1720 ft., and the water held up had a maximum depth of about 40 ft. When the dam failed, the upper 30 or 35 ft. of its height for a length of 560 ft. was swept away, and the flood, passing down the valley, caused great havoc, and eighty-six people lost their lives.

Investigations after the disaster revealed many points of interest. In the original design, the maximum pressure on the masonry was the only factor considered in calculating its proportions. In the course of the investigations after the disaster it was shown that the resultant of the thrust combined with the weight of the masonry was so placed that a tensile stress of 1·3 tons per sq. ft. must have been imposed on the masonry. Laboratory tests proved that the maximum tensile strength of the masonry was only 60 per cent. higher. In opposition to the theory that the parts that failed had overturned by virtue of this weakness, it was held by some that failure was by shearing. The shearing stress being calculated as 1·32 tons per sq. ft. by some, and as 3·2 tons per sq. ft. by others.

Rankine, in 1871, had recommended that no horizontal joint in a dam should be expected to withstand any tensile stress, in other words, there should be no uplifting tendency. After the Bouzey disaster—it was considered advisable that at the upstream face there must always be a definite compressive stress, and the French Government introduced the regulation that on horizontal joints there should be a vertical compressive stress at the water face equal to not less than the water pressure at the joint. Such compression in the masonry would tend to prevent access of water to any joint or crack.

The late Sir Benjamin Baker, in 1904–5, at the time when I was his chief assistant, was faced with the problem of raising the Aswan dam. (At present the dam is being raised a second time.) The investigations after the disaster in France had shaken confidence in the accepted method of gauging the stability of a dam, and in 1904 a memoir was published entitled *Some Disregarded Points in the Stability of Masonry Dams*, by Prof. Karl Pearson and Mr. Atcherley. By mathematical investigation the authors concluded that although a dam might satisfy the usual conditions regarding the stresses on horizontal planes, it might still be subjected to dangerous tensile stresses on vertical planes in the vicinity of the downstream toe. That conclusion seemed most unlikely to engineers interested in the subject, but however incredible it might seem, it demanded attention as coming from so eminent a mathematician. In arriving at their results, the authors of the memoir based their calculations on an assumed law governing the distribution of shearing stress across the base. The unsatisfactory state of affairs could only be cleared up by determining the distribution of shear and other stresses.

Jointly with my friend the late William Gore, I made an attempt to do this, and we embarked on a series of elaborate experiments with india-rubber models.

It is just thirty years ago, and although I was busily engaged assisting Baker, and Gore was assisting the late G. F. Deacon, we did the whole work in our own time independently of the office work. Rubber had been used already by several workers as an elastic medium for strain investigations, but I think the methods we devised for getting at the stresses were an advance on earlier work. Our investigations were described and discussed at the time at the Institution of Civil Engineers [3] and in *Engineering*,[4] in which journal there was a long correspondence on the subject.

The models were made of slabs of rubber 1 in. thick with a smooth white surface, and shaped to represent the transverse section of a dam. The model was strained by weights carefully adjusted to represent the water pressure against the face and the weight of the masonry, on the assumption that the masonry had a specific gravity of 2·25. The model was divided into sections, and the ' masonry weights ' were hung on transverse pins put through the rubber. Plates pulled by cords against the water face represented the water pressure. To ensure the exact relative positions of the loads, the model was so shaped that when fully strained it had the correct profile. A network of lines was ruled on the rubber, and large-sized photographs on plate-glass were taken under the strained and unstrained conditions. Corresponding lengths on the two negatives could be measured accurately, and from them the strains and stresses were calculated. The intensity of shear at various points was measured by

[3] *Minutes of Proceedings* Inst. C.E., vol. 172, 1907–8.

[4] *Engineering*, 1905, 1907.

comparing angles on the two plates. Our investigations enabled us to plot curves of stress-distribution on section lines at various heights. The curves were of quite different shape. We found no evidence of the reputed tensile stress at the downstream toe. The shear stress diagram was practically a triangle with the maximum at the downstream edge, and the vertical stress distribution agreed substantially with the ' trapezium law.'

These experiments helped materially to clear up the situation and to re-establish confidence in the method that had been in general use for estimating the stability of masonry dams.

During the last few years investigations, both experimental and mathematical, of problems relating to the design of large concrete dams and curved dams, have been made in the United States. The influence of heat, both natural and that generated by the setting of cement, on stresses and stability, has received much attention. In these gigantic structures, monolithic construction and the use of too large masses of concrete has been found accountable for serious cracking. In discussions on these problems, the investigations I made with Gore have been referred to as ' the English Tests.'

The suspension-bridge or ' philosopher's bridge,' as it has been called, is a fascinating type of structure. In the course of the development of its design and stability there have been some astonishing occurrences. In its most elementary form the suspension-bridge formed of strong flexible climbing trees or roots has been used by primitive peoples for centuries. Examples made of wrought iron appear to have been in existence in the eighteenth century. Samuel Brown, who was granted a patent in 1817, designed and constructed some of the earliest in this country. His main suspension chains were made of long open welded links or long plate links connected together with round bars and shorter plate links. The chains, which were made up with several links side by side, connected with common hinge pins, were of uniform strength throughout their length, and the road or platform was suspended by vertical rods from the short links. In addition to the main chains Brown put chains at the platform level to prevent undulation. Within its limitations it was a satisfactory form of construction. In a bridge which carries a series of loads on a flexible chain, the loads and the chains are only in equilibrium when the chain assumes an appropriate shape, and to support any additional weight or rearrangement of weights the chain changes its shape slightly. With a moving load the tendency of the platform of a suspension-bridge to undulate with the passage of the load has handicapped the development of this type of bridge. An early attempt to use it for a railway proved a complete failure.

Telford's famous bridge across the Menai Straits, with a span of 570ft., completed in 1826, is of the simple suspension type. At first the platform was too flexible and caused anxiety, but that part was altered and made stiffer. The bridge is still in service, and is standing proof that in principle and construction it was sound. A few years later, a stage in the quest for stability in suspension-bridges reflects in a remarkable degree the ignorance in the mechanics of design of some engineers of those days. The wrong ideas of these men led to the suspension-bridge being regarded with suspicion for many years.

A supposed improvement was introduced by a Mr. James Dredge, with the object of reducing the amount of iron required, and it was claimed also that his bridge was stronger and less flexible. Claims for the improvement were demonstrated with models (which could not have been exactly representative) and the soundness of the construction was vouched for by those who were supposed to have expert knowledge, while the excellence of the scheme for building bridges according to the new principle was pressed by several eminent persons. After a large number of bridges had been built in this country and in India, all confidence in the type, and indeed in suspension-bridges generally, was severely shaken when a large bridge of Dredge's improved type collapsed under its own weight when on the point of completion, and a second one failed to carry its test load and collapsed later.

A patent for the above 'improvement' was granted to James Dredge in 1836 for a 'Taper Chain Bridge.' Dredge conceived the notion that instead of carrying all the component links of the chain the whole length between the supporting towers and hanging the platform on vertical suspension rods, the links or components of the chain could be deflected down in a diagonal direction at successive intervals, and made to terminate at their connections to the platform and so displace the suspension rods. Thus in a bridge with eleven bays and ten cross girders, starting at the tower with six links in the chain at each side, the two outer links would be carried down diagonally from the tower to the first cross girder, leaving ten links (five on each side). Then from a point over the first cross girder the outer two links would pass diagonally to the second cross girder, and so on for the five bays, leaving only two links at the centre of the bridge. The scheme converted the bridge virtually into two cantilevers or brackets projecting from the towers towards the centre. The saving of iron was enormous, and appealed so strongly to those who advocated the new principle that exaggerated statements, in perfectly good faith, were made, as the following extracts from the journals of the day show. Though fundamentally wrong, any criticism that may have been made was rendered ineffectual by the weight of the approving authority and by the difficulty experienced at the time with the Menai bridge.

Lord Western wrote to the Editor of *The Times* as follows :

'Sir, If you will notice, in any way, in your widely circulating paper the improvement in Bridge Architecture detailed in this letter of mine to Lord Melbourne, you will materially assist in bringing forward genius and the promulgation of an improvement in the department of science of considerable national importance, which is my only motive.

'On Saturday last I introduced Mr. Dredge, the Inventor of this improvement in bridge building, to the Marquis of Northampton, at his evening assembly. He brought his models and drawings with him, and they attracted great attention and admiration. On the Monday morning following, a trial of strength of the old system of building relatively to Mr. Dredge's, with two models of bridges, each formed out of the same weight of iron wire, namely six ounces, was made in the Marquis's garden, the Marquis and Lord Compton and others present. The model upon the old system was first loaded. It bore 18 half-hundred weights, and with the next half broke down. The model formed upon Mr. Dredge's principle sustained 34 half-hundreds when upon the addition of another half hundred, the wooden structure on which the chains were hung (answering to the towers of masonry, which form the fulcrum to suspension bridges) gave way altogether, and the bridge came down, but the chains were unbroken; and upon Mr. Dredge's calculation, would have sustained 500 more, making in all 2300 lbs. Mr. Dredge can build bridges on this plan, at one-third the expense of the present method: he requires only one-third the quantity of iron, and his bridge will be stronger and freer from vibration and pendulous motion.

'I am, Sir, Your obedient Servant,

'WESTERN.'

The long letter to the Rt. Hon. Viscount Melbourne from Lord Western contains many interesting passages:

'Having heard that Government is about to expend a further sum of money on the reparation of the Menai Bridge, which is said to be in a perilous state, I cannot refrain from entreating your attention to the vast improvement that has been made in the construction of suspension bridges by Mr. Dredge of Bath. . . .' 'He [Mr. Dredge] insists on the possibility of reconstructing the iron work of the Menai Bridge at a less sum than the superfluous iron would sell for, so much less is requisite than was there used; and he pledges himself to the power of the bridge, if the irons are altogether altered and reconstructed on his principle, to be capable of supporting on transit 1000 tons. The Menai bridge is believed to have cost near £150,000 and to have consumed in its construction about 2000 tons of iron and to be declared only capable of sustaining 733 tons on transit. Before I submit . . . a detail of some experiments Mr. Dredge has made . . . I will endeavour to give some explanation . . . of the fundamental principle upon which his mighty fabric is erected. I must give it merely as it has struck my unlearned common sense, and which it has, from its simplicity, with a force so irresistible that it makes me believe I fully understand it.'

'I conceive the grand foundation may be said to be the rendering the chains strongest, and indeed very much the strongest, at the base, tapering them, by regular degrees to the centre, where they come at last, in fact, to a cipher. From the cipher commence, therefore, their size, weight and strength, which regularly increase, by degrees, quite up to its base, which base, you know, in a suspension bridge is the tower of masonry on which the chains are hung. In truth it is the application of that principle horizontally which is so obviously necessary in all perpendicular erections, of superior size and strength at the base, and tapering away to a cipher on its ultimate summit—as for example, the obelisk, the pyramid, the church spire; and which principle he shows to be as effective horizontally applied as it is in the perpendicular, indeed, it may be said to be far more effective, as it has to support, in so difficult a position, comparatively with the perpendicular, its own intrinsic weight and a heavy transit load besides.

'The main chains of the Menai bridge are the same size throughout, creating thereby an enormous intrinsic and superfluous weight, exceeding that which it has to sustain on transit, and this it is which constitutes the grand vice of the present system, and which, sooner or later, Mr. Dredge's must supersede. Mr. Dredge's bridge may be well imagined by supposing a church spire laid horizontally, and met by another of equal dimensions at the point. . . .

'Thus his genius has led him, by the simplicity and perspicuity of his conceptions to effect a discovery which I firmly believe will turn out of great national importance, the recognitions of which by the country will, I am sure, be felt by him as the highest possible reward.'

'Mr. Dredge's principle of suspension bridge building completely overthrows the theory and practice of a Telford, a Brunel, whose experience and talents we are bound highly to respect, and to whose genius I readily offer the humble tribute of my admiration; can we then be surprised that the public should evince some fear, and some reluctance, hastily to adopt Mr. Dredge's novel principle or theory, in substitution of that which has been so long acted upon? They ought, therefore to pause, they ought to inquire if there are any persons about to direct the construction of other suspension bridges: it is a duty they owe to those for whom they may be acting, to examine fully into the merits of a novel system which *promises fairly* such advantages, before they determine to persist in the further adoption of the present, of the correctness of which the state of the Menai bridge and the vast expenditure it occasions, may well create a doubt, independently of the obviously faulty principles in which it is, I think, clearly shown to be constructed.'

The praise of influential people was supported by some of the technical papers. For instance, the *Surveyor, Engineer and Architect* commends Lord Western and 'those other high honourable and likewise discriminating noblemen and gentlemen' who took an interest in Dredge's improvement, and the article goes on to state that 'on the part of the profession and of scientific men generally' there was a disposition to 'throw cold water on it,' and continues: 'It is true that Mr. Dredge does not belong to the profession or lay any claim to a niche in which avowed science deposits her numerous mummies, living or dead, and this, in conjunction with the pretty common feeling that nobody has a right to invent anything but themselves, may tend to warp their judgments, which everyone knows are very straight.'

Dredge's first bridge was built in 1836, across the Avon at Bath; it had a span of 150 ft., and it and others which followed must have had a slight margin of stability, more by accident than design, through their timber platforms being sufficiently stiff to withstand the compression.

Dredge attended the Newcastle Meeting of the British Association in 1838, and read a paper on his bridges and 'Mathematical Principle' to the Mechanical Section. He had such confidence in his designs that he made the most preposterous statements. For instance, he told his audience that whereas the main chains of Telford's Menai suspension-bridge had a sectional area of 260 sq. in. and a total weight of 1,900 tons, under his 'Mathematical Principle' 30 sq. in. of sectional area and a weight of 70 tons would have been sufficient.

According to his own account of the meeting, several members were critical, but he convinced them in a way which suggests that members of 'Section G' of those days were easily satisfied. He wrote: 'The above paper excited a discussion in which several members opposed my plan. I produced a drawing of a bridge, copied from the *Saturday Magazine*, March 1834, at Wandipore, which clearly proved that the principle in the construction of bridges I now advocate was acknowledged 195 years ago; whereupon my plan received the unanimous approbation of the Mechanical Section.'

Dredge made good use of all the praise and influential support he received. In proof of his principle and claims he published elaborate calculations, and it is remarkable that his principle and calculations appear to have been approved by several who were considered to be experts and whose opinions carried weight. *The Surveyor, Engineer and Architect* denounced criticism as a striking example of professional prejudice, congratulated Mr. Dredge on his two bridges in Regent's Park and announced that three additional bridges had been ordered by the Commissioners of Woods. At least twenty-seven bridges were built, including five in Regent's Park, London, four in Wiltshire, and a number in India.

The failures began in India. A bridge of 200-ft. span collapsed before it was completed, and another one failed to carry its proof load and collapsed also. A paper published in 1849, in which the failure of these bridges is referred to, states that seven bridges in India had had to be remodelled by engineers there on an 'improved principle.' The description of the alterations suggests little improvement on Dredge's design.

The disastrous source of weakness in Dredge's bridges was, of course, the timber roadway platform. With no appreciable strength in the chains at the centre, the stiffness of the platform was all-important. In India, that part had failed by buckling, and sooner or later all the bridges must have suffered badly. Dredge seemed unable to appreciate the weakness, for in his book published in 1851, he argues that platforms always have ample margins of strength, and that in 'large structures the platform may be lighter in consequence of the horizontal strain being more efficient to prevent undulation than the heavy trussing and cross-planking which are used in the old system for the purpose.'

I have not been able to follow the later history of these bridges, but I believe that no single example exists.

Several suspension-bridges, built before any of Dredge's, are still in use. In all these the chains are of uniform strength throughout, and the whole weight of the bridge is suspended from them.

The flexibility of these bridges under heavy moving loads is a source of trouble, and of wear and tear of the platforms. Nevertheless, when the chains are pulled by the loads into a line of equilibrium, so long as the anchorages are secure and the towers are sound, the stability depends solely on the tensile strength of the chain, and under these conditions almost all suspension bridges have a substantial margin of strength or stability.

If overloaded, long before rupture of the chains could occur, the excessive sagging or deformation of the platform would act as a warning. Where the ultimate strength depended mainly on the resistance to compression of the platform, as in Dredge's bridge and others built about the same time, the failure by the buckling of the platform would be sudden and disastrous. The failure of Dredge's bridges, in spite of the confidence with which they were recommended, created a strong prejudice against suspension-bridges of all kinds and retarded their development.

One of the early suspension-bridges still in use, is that across the Thames at Marlow, built by W. Tierney Clark, F.R.S., in 1829. I examined and reported on this bridge some years ago and found it in a remarkably good state. In the development of the stability of suspension-bridges this one is of particular interest, for it was the first built with stiffening girders. The ends of the cross girders in this bridge are all stiffly connected by parapets made in the form of girders, and any cross girders on which a heavy load might rest cannot deflect the suspension chain, as it would do if the parapet girders were not there.

In the modern suspension bridge the stiffening girder is as important a feature as the chain or cable, and its introduction has made it possible to construct the gigantic bridges in the United States. The interaction of the stiffness or flexibility of the girder with the curvature of the suspension cable, is the governing factor in the stability of the modern suspension bridge. It is a problem of considerable complexity and the calculations are laborious.

It would be difficult to find more striking evidence of the advances made in the hundred years the British Association has been doing its work advancing science, than is provided by the comparison of great suspension bridges of to-day with the early ones I have referred to. The latest example with its span of 3,400 ft. and others of more than 1,500 ft. compare with Telford's of 570 ft. and the others of 50 to 200 ft. Cables composed of thousands of steel wires, four times as strong as iron, laid side by side to form cables 3 ft. in diameter, take the place of the iron chains; and the flexible timber platform, so easily deformed by moderate moving loads, is now replaced by deep steel stiffening girders with upper and lower decks, providing double tracks for both electric railways and street trams and road width for many cars. Instead of the stability of the structure being a matter of dispute, and of the extraordinary uncertainty I have tried to describe, the stability is now determined and gauged by calculation, some of which is very elaborate; but it is based on applied mechanics.

The important aspect of stability which is governed by the characteristics of the materials—their resistance to compression and tension and to the repeated application of stress—on which economy of construction depends, I have not dealt with. That side of the problem has not advanced as much as might have been expected. Engineers of a hundred years ago had much more confidence in their materials than we appear to have. In many of their structures, which are still standing and which have proved their stability, the stresses are, according to modern standards, dangerously high. To have added episodes relating to that side of the subject would have made this address too long. I have restricted myself to the part which is within the scope of 'Applied Mechanics,' a branch of engineering science closely associated with this section, for it was named and developed by Rankine, a staunch supporter of the British Association, and three times President of Section G.

SECTION H.—ANTHROPOLOGY.

RECENT PROGRESS IN THE STUDY OF EARLY MAN

ADDRESS BY

SIR ARTHUR SMITH WOODWARD, F.R.S.,

PRESIDENT OF THE SECTION.

WHEN meeting in East Anglia it is appropriate that the Section of Anthropology should devote some special attention to Prehistoric Archæology. In this part of England as long ago as 1797, John Frere made the first scientific observations on palæolithic implements which he had dug out of a superficial deposit at Hoxne. During recent years Mr. J. Reid Moir has excited wide interest by his discoveries of the oldest known stone implements which he has collected with remarkable zeal and discussed with acute observation. Here also arose the 'Prehistoric Society of East Anglia,' which has been so well supported during its career of over twenty years, that it has gradually widened its sphere until now it becomes the 'Prehistoric Society' devoted to advances in its subject in all parts of the world. We are, indeed, now confronted with problems much greater than those which the pioneers in western Europe dealt with, when they were laying the foundations of research in prehistory. Traces of men who lived before the dawn of history in widely separated parts of the earth's surface have been discovered in increasing abundance during recent years; and a study which at first was more or less local has now become one of world-wide scope.

Among the several branches of science which contribute to our understanding of the subject, those of palæontology and geology are of considerable importance. Dr. Friedrich E. Zeuner has recently demonstrated this by his valuable paper on the Pleistocene chronology of central Europe in the *Geological Magazine* for August 1935. The period of man's existence on the earth has been so short that there has been no appreciable evolution among the mammals associated with successive human races; but many migrations and extinctions are observable, so that these mammals can often be used for determining the relative ages of the isolated deposits in which human remains and implements occur. In some cases also the mammals are probably enough to show the nature of the climate and the local conditions under which they lived. The contemporary geological changes, though small, likewise help in explaining migrations and perhaps some extinctions; while the peculiar circumstances of the Great Ice Age, under which early man flourished in the northern hemisphere, varied so much from time to time, that they have been used in forming a plausible chronology. As a palæontologist and a geologist, therefore, I propose to discuss some of the latest developments of prehistory.

It has long been recognised that the earliest men of which traces have been found in Europe did not originate on this continent but were immigrants from some other region. Western Europe, at least, was a kind of refuge to which successive races retreated. It is thus important to examine the numerous associated mammals to ascertain whence they came; for most of these mammals seem also to have been immigrants to Europe just before or during the Pleistocene period when man began to live here, and they may give a clue to his origins.

Sir W. Boyd Dawkins was one of the first to take a broad view of the mammals which accompanied the successive races of early man in Europe, and he eventually published a map to illustrate their mixed origin. In addition to some which were already in the middle of the European continent, others seemed to have come south from the Arctic regions, others had passed directly west from the middle of Asia, while a few could only be explained as having come north from Africa over old land bridges to Gibraltar and southern Italy. These mammals might not all have lived together, but they at least showed how varied were the routes open to the movements of primitive men.

It now appears that the tracing of the warmer types of mammals to an African source was a mistake. It was due to the erroneous reference of certain fossil elephant teeth from Spain and Sicily to the existing African species, and to the wrong idea that the dwarf elephants found fossil in Malta were closely related to the same species. It was also supported by the fact that the cave hyæna of Europe proved to be identical with the spotted hyæna, which at present lives only in Africa to the south of the Sahara. Recent researches seem to have proved that during the Pleistocene period there was no direct communication between Europe and Africa, either through Gibraltar or through Sicily and Malta. Geologists are satisfied that certain shells which are characteristic of northern seas could not have entered the Mediterranean to be found there in Pleistocene sea beaches if the Straits of Gibraltar had not been open. Others have remarked that among the numerous remains of mammals which occur in some of the caves at Gibraltar, there is nothing distinctly African. Dr. Raymond Vaufrey has more recently examined the fossil mammals and stone implements found in the caves and other Pleistocene deposits of Sicily and Malta, and he shows clearly that although these islands were connected with Italy at the time, they never had an extension to Africa.

The supposition that Sicily and Malta are remnants of a former land bridge between Europe and Africa has been so widely accepted that Dr. Vaufrey's conclusions need to be emphasised. There is no doubt that the fossil elephants found both in Sicily and Malta are dwarf forms of *Elephas antiquus*, which was widely distributed in Europe in early Pleistocene times. The fossil hippopotamus of these islands may also have been derived from the species which had already reached southern Europe in the Upper Pliocene. All the fossil mammals, indeed, have European or Asiatic, not African affinities. Associated with them there are no traces of Palæolithic man, such as must have occurred had the islands been a route for migration between Europe and Africa. I agree with Dr. Vaufrey that the two fossil human molar teeth from Malta which have been referred to Neanderthal man, are of both doubtful age and uncertain relationship. No Palæolithic implements have been found in Malta, and only very late Palæoliths occur in Sicily above the deposits in which the remains of dwarf elephants and hippopotamus are met with. The earliest stone implements in Malta are Neolithic.

The latest discoveries of fossil mammals in the caves of Palestine and Syria, as interpreted by Miss Dorothea M. A. Bate, show that during the early half of the Pleistocene period, Asia and north Africa were much more closely connected than they have been since. The country was comparatively well watered, with luxuriant vegetation and forests, and mammals could readily migrate both east and west. Even so characteristic an African animal as the wart-hog (*Phacochœrus*) was then living in Palestine. The connection of Asia with Africa was thus as definite as that with Europe; and the explanation of the partial identity between the Pleistocene mammals of Africa and Europe is probably, that they had a common source in Asia and diverged west in two different directions, one southwards, the other northwards.

This conclusion is supported especially by the apparent origin and former distribution of the spotted (or cave) hyæna, *Hyæna crocuta*. In the Pliocene deposits of the Siwalik Hills in northern India, there are jaws and other remains of hyænas which are not quite *H. crocuta* but may well represent its ancestors. By the Pleistocene period the typical *H. crocuta* was already in existence in India, as shown by a tooth discovered in the Karnul caves, Madras. Remains of the same species have also been found in Pleistocene deposits in central Asia and even in China. They are likewise widely spread over Syria and northern Africa, where only the striped hyæna (*H. striata*) lives to-day. *H. crocuta*, therefore, is not an African animal. It originated in Asia, spread thence in different directions in the Old World, and has survived only in southern Africa, which is at one extremity of its former wide range.

The origin of the lion is not so clear, but as it still lives in Asia and was widely spread there until recent times, it is at least as much an Asiatic as an African mammal. The same may be said of the leopard and the caffer cat, which are also found sometimes among the European Pleistocene mammals. As the tiger of Asia is still as characteristic of temperate regions as it is of the tropics to which it seems to have migrated only within comparatively recent times, and as the finest examples occur in the Altai Mountains, the original home of the great cats is probably in the north. The fine cave lion of Pleistocene Europe, therefore, seems to have lived under congenial conditions, though they were very different from those under which the African lion exists to-day.

The hippopotamus, which is also at present an African animal, arrived in Europe probably before man, but it survived during the early part of the Pleistocene period when man was here. Even if it did not originate in Asia, it was in India nearly in its present form when the Siwalik rocks were deposited. It may therefore have reached Europe from Asia ; and recent discoveries in the caves of Syria show that it was also widely distributed in the direction of Africa. The occurrence of the animal in Europe, even so far north as Yorkshire, has generally been regarded as proving that mild conditions, with open waters, prevailed over Europe when it lived here. A few years ago, however, Mr. Marius Maxwell found in the Lorian Swamp of Kenya Colony a peculiar race of hippopotamus which existed in a region of scrub out of reach of water in which it could habitually swim. The Pleistocene hippopotamus of Europe, therefore, may have been adapted to unusual conditions of life.

It is interesting to observe, in conclusion, that none of the characteristically African antelopes occur among the European Pleistocene fauna. Remains of the gazelle have been found, but this animal is as much Asiatic as African. The Saiga antelope and *Nemorhœdus*, which are Asiatic to-day, the one living on steppes, the other on mountains, are the only other antelopes which reached Europe in Pleistocene times ; and *Nemorhœdus* seems to have been the ancestor of the little rock-climbing *Myotragus*, which is now extinct, but has been found in caves in the Balearic Isles and perhaps in Sardinia.

The Pleistocene mammals of Europe, therefore, show that when they flourished on this continent, the only direct land communication was through Asia. The earliest races of men must have reached western Europe by that route ; and as a succession of stone implements, remarkably similar to that which is now so well known in Europe, has already been found with early Pleistocene faunas in Africa, it might at first be supposed that there were parallel migrations of the same men from the Asiatic to the African continent. Implements like languages, however, afford no certain clue to the races which made and used them, and the same tools must have been invented independently more than once. As the late Sir Baldwin Spencer remarked, 'In Australia we have in use at the present day a practically complete series of stone implements, representing all the various stages of culture known in prehistoric Europe,' yet all these implements are the handiwork of a single race of modern man, *Homo sapiens*, at one and the same time. It is therefore unfortunate that hitherto no human remains have been found in undoubted association with any of the earliest implements and Pleistocene mammals in Africa. Two years ago a committee of geologists which met in Cambridge expressed itself as satisfied with evidence which Dr. L. S. B. Leakey submitted in order to prove that he had discovered modern types of human skull and lower jaw with very primitive implements and early Pleistocene mammals in Kenya Colony. In fact, it appeared as if the same types of implements in the same geological stage in Europe and Africa had been made by two distinct genera of men. Quite lately, however, Prof. P. G. H. Boswell, under the guidance of Dr. Leakey, has examined the geological formations in the region where the discoveries were said to have been made, and he is now convinced that there is no proof of the association which has been claimed. The human remains in question seem to have been obtained from disturbed deposits, and may have been buried at a comparatively recent date. With later types of stone implements and remains of modern mammals, the only satisfactory fragments of the human skeleton which have hitherto been found in Africa belong to the genus *Homo*. Many of the fossil forms are related to the surviving South African bushman, and if any of these passed directly from northern Africa into Spain, as has sometimes been supposed, they must already have learned to make rafts by which they could cross the Straits of Gibraltar.

The only fossil hitherto discovered in Africa, which suggests that that continent may have produced man, is the immature skull from a deposit of uncertain age (probably Pleistocene) at Taungs in Bechuanaland, which was named *Australopithecus* by Prof. Raymond A. Dart in 1925. It belongs to an ape, and seems to exhibit more human characters than the skull of any of the existing apes; but Prof. Dart's complete account of the fossil has unfortunately not yet been published.

The earliest known jaw of an ape, *Propliopithecus*, was discovered long ago in the Oligocene of Egypt, and numerous jaws of apes related to the existing chimpanzee are now being found in the Miocene of south-east Africa. Equally abundant, however, are the jaws of apes in the Mio-Pliocene deposits of northern India, and some of the teeth preserved in them exhibit a remarkable approach to those of man. I still think, indeed, that according to our present knowledge the links which connected apes with man are most likely to be found in south-central Asia. As the late Joseph Barrell pointed out, the east to west ridge of the Himalayan Mountains was gradually raised up at the time when northern India was covered with a great forest which swarmed with apes of many kinds. The formation of the ridge separated off a northern portion of the forest which became subject to comparatively inclement conditions. The apes stranded in this northern portion would be disturbed by the extensive destruction of the trees, and the survivors would be driven to be ground-apes and change their habits of feeding. They would thus be modified in the direction of man. Regarded from the zoological point of view, of course, man is an arboreal mammal which has left the forest. His remote ancestors, by continuing to live in the forest, preserved their jaws, teeth, and limbs nearly on the primitive mammalian plan, while the brain alone made progress; and, as Dr. H. S. Harrison has remarked, if there had been no trees during the Tertiary era, man would probably not have appeared in his present form.

These considerations, with the geographical distribution of the few oldest known remains of fossil man, led the late Dr. Davidson Black to make plans for a systematic examination of the later Tertiary deposits of south-central Asia. In 1925 he reviewed the whole subject in an important paper published by the Geological Society of China. In the summer of 1932 he actually traversed a route from eastern China, through northern India, to Syria and the western coast. Dr. Black, unfortunately, did not live to see the realisation of his project, but we are glad to learn that Father P. Teilhard de Chardin will take his place in researches beginning in India this autumn.

It is very interesting to notice that if central Asia was actually the region in which the human family originated, the few known fragments of the oldest fossil men are distributed geographically just as a palæontologist would expect them to be. The late Dr. W. D. Matthew pointed out that if each race of animals evolved at a single centre, a succession of waves of increasingly advanced genera must have radiated outwards from that centre. The latest and highest types would be found at the actual place of evolution, and they would be surrounded by rings of less advanced types of lower and lower degree until the lowest would occur at the outer limit.

The fragments of the oldest fossil men hitherto discovered are indeed very few, but although allowance for negative evidence may cause some hesitation, it is at least noteworthy that they are all on the periphery of the Euro-Asiatic continental area. *Eoanthropus* and Heidelberg man were found on the western margin of Europe, *Pithecanthropus* at the southern margin of Asia, and *Sinanthropus* close to the eastern coast of Asia. If human types were evolving near central Asia, the places of these actual discoveries are in a distant partial ring round the source.

It is, of course, impossible to be sure that all the primitive men just mentioned were living at approximately the same geological period. They date back to a time evidently before burials, and three of them were found in river deposits, while the fourth was met with under peculiar conditions in a cave. If, however, the geological and palæontological arguments for their correlation be considered, I think it will be agreed that they must have been nearly contemporaneous. The geological age of *Eoanthropus* from Piltdown, Sussex, is perhaps the most difficult to determine, because it was found in a flood-deposit which contains mammalian remains and flint implements of more than one stage at the end of the Pliocene and beginning of the Pleistocene periods. Attempts have been made to sort the fossils according to their colour ; but the varied staining has no special significance, owing to the irregular distribution of the different ferruginous materials in which they were buried. The colour of the first pieces of the skull of *Eoanthropus* itself, indeed, were altered by Dawson, who dipped them in bichromate of potash with the intention of hardening them.

Notwithstanding the difficulty of interpreting the discoveries at Piltdown, I think there is no doubt that the skull of *Eoanthropus* is of the same age as the river gravel itself. It is not waterworn, and the brain-case, the delicate fragments of the face, the half of the lower jaw, and the canine tooth were lying separately in four different places, all close together. If these remains had been transported far, and especially if they had been washed out of an earlier deposit, they would not have been associated in this way. Two lower teeth and a piece of the lower jaw of a typically Pleistocene beaver, found isolated, also seem to be contemporaneous with the gravel ; and two teeth of the ordinary Pleistocene *Hippopotamus* appear to be in the same state of mineralisation, and are likewise not waterworn. Very similar are the base of an antler of a red deer (*Cervus elaphus*), which is characteristically post-Pliocene, and a piece of the metapodial of a small deer which has evidently been broken and scratched by man. Most significant of all the fossils which are obviously contemporaneous with the gravel and the human skull, is a piece of bone, 16 in. long, which has been worked by man nearly into the shape of the blade of a cricket bat. Direct comparison shows that this piece was flaked from the middle portion of an elephant's femur which was about 5 ft. in length. It, therefore, represents an elephant larger than the mammoth of Middle Pleistocene and later date, and doubtless belongs to one of the gigantic Lower Pleistocene elephants, such as *E. meridionalis* or *E. antiquus*.

Highly mineralised and waterworn fragments of teeth of *Mastodon* and *Rhinoceros* (probably *R. etruscus*) are exactly like the fossils from the Pliocene Crags of eastern England, and must have been washed out of a local Pliocene deposit which has been completely destroyed. With them may also be associated some broken fragments of a much mineralised tooth of *Elephas*, which most resembles the Upper Pliocene *E. planifrons.* The fossils clearly contemporaneous with the gravel and with the skull of *Eoanthropus*, therefore, represent a Lower Pleistocene mammalian fauna ; while the more highly mineralised fragments have been derived from an earlier formation.

If this mammalian fauna be compared with the fossil faunas occurring in the terraces on the sides of the valley of the Thames, it is found to agree best with that in the 'High Terrace' which remains from 80 to 90 ft. above the present level of the river. This terrace, which is obviously older than the 'Middle Terrace' where the mammoth and woolly rhinoceros are found, is generally admitted to date back to a warm episode at the beginning of the Pleistocene period. The Piltdown gravel with *Eoanthropus*, 80 ft. above the present level of the river Ouse in Sussex, may thus be ascribed to the same remote date in the history of man.

The lower jaw of Heidelberg man, *Homo* (or *Protanthropus*) *heidelbergensis*, was found in a river deposit at Mauer, near Heidelberg, in direct association with mammals which are typically Lower Pleistocene in western Europe, though they also include at least two species which are survivals from the Upper Pliocene. In this case the mammalian remains are numerous and well preserved, so that they can be readily named. If, as I suppose, the primitive molar of an elephant at Piltdown is derived from an older formation, not contemporaneous with the gravel in which it was found, there cannot be much difference in age between Piltdown and Heidelberg man.

The remains of *Pithecanthropus* were discovered in a river deposit at Trinil in Java, which is a very unstable volcanic region on the southern edge of the Asiatic continent. It therefore, seems possible to date them not only by the associated mammalian remains, but also by the fossil shells in the marine formations, both earlier and later, which now form part of the island of Java. The successive marine deposits, as might be expected, are marked by an increasing percentage of existing species of shells among the fossils. As determined by Dr. L. J. C. van Es, the river deposit at Trinil rests unconformably on a marine formation which is shown by its fossils to be of Middle Pliocene age. The gap in the geological series indicated by this unconformity is filled in other districts by marine deposits which contain 66 to 70 per cent. of existing species of shells, and may, therefore, be regarded as Upper Pliocene. Hence the conclusion that if a marine formation equivalent in age to the Trinil river deposit were found, it would contain more than 70 per cent. of existing species of shells and might thus be referred to the Pleistocene. The percentage of existing species of freshwater shells in the Trinil deposit supports this conclusion, and as the associated land mammals (*Stegodon*, *Hippopotamus*, etc.) much resemble those in the Lower Pleistocene Narbada river deposits of India, *Pithecanthropus* evidently dates back to the beginning of the Pleistocene period.

The skulls and lower jaws of *Sinanthropus* were met with not in a river deposit, but in a cave which had evidently been occupied for a long period by man. They were associated with rude stone and bone implements, and even with remains of fires. The deposits in which they occurred are proved by the Chinese geologists to be older than the widespread loess of China, which in places contains the remains of the woolly rhinoceros (*R. tichorhinus*), and in other places the mammoth (*Elephas primigenius*). These, it will be remembered, are two of the characteristic fossils of the 'Middle Terrace' of the Thames valley, which dates back to the latter half of the Pleistocene period. With *Sinanthropus* are found remains of a large extinct beaver, *Trogontherium*, and a rhinoceros very like *R. mercki*, which are specially characteristic of the 'High Terrace' of the Thames already mentioned as the probable equivalent of the Piltdown gravel. If, therefore, the widely distributed mammals just enumerated were living at the extreme eastern and western limits of their range in the Old World at one and the same time, as seems most probable, *Sinanthropus* dates back to the early part of the Pleistocene period and must have been a contemporary of *Eoanthropus*.

These facts, I think, are enough to show that in the beginning the human skull was much more varied than it is at the present day. There were, indeed, several distinct approaches to modern man before his type became fixed and persistent; just as there were parallel lines of evolution, effective and non-effective, in the ancestry of other modern mammals. That the four known examples of the earliest men were all closely related, is proved by the skull of *Sinanthropus*, which exhibits a remarkable combination of the special features of the other three. In the contour of the top of the head, with the great depressed bony brow-ridges, it is so like the skull of *Pithecanthropus*, that some anatomists have actually referred it (though without good reason) to the latter genus. In the fine spongy texture of the skull it agrees with *Eoanthropus*, and differs from all other known skulls of men and apes. In its relatively broad base and in the shape of the occiput, it also agrees with *Eoanthropus*. In its lower jaw and teeth, it most resembles *Homo heidelbergensis*.

It is also interesting to notice that at the east and west extremes of their range, these dawn men had attained much the same grade in the habits of daily life. *Sinanthropus* made small stone implements by the rude working of flakes, and they are as varied in shape as the implements met with in the Mousterian deposits of Europe. He cut deer antlers into short lengths, and seems to have used the bases of the antlers as hammers. Bits of brain-case seem to have been made into cups ; some of the upper jaws were evidently used as files, and some of the lower jaws as small picks, with the coronoid process as working tip. The long bones were often broken to extract the marrow. *Sinanthropus* was also acquainted with the use of fire, and numerous successive hearths were discovered in his dwelling place. *Eoanthropus* similarly made rude stone implements by the chipping of flakes of varied shape, and he also worked bone in such a way as to suggest that he had previously used wood. He also had hammer stones, and he split long bones, doubtless for extracting the marrow. He was similarly acquainted with the use of fire, as shown by the discovery in the Piltdown gravel of charcoal and burnt flints, which include stones indistinguishable from the ' pot boilers ' of later periods.

Up to the present, unfortunately, the earliest men in other parts of Euro-Asia are known only by stone implements, but these are so widely scattered that there is an extensive area which may be hopefully searched for primitive human remains. The greatest difficulty is one which I have already mentioned, the apparent absence of intentional burials.

The next stage in man's development is much better known, because by this time he had learned to bury his dead in security. As examples have been found in caves so far apart as France and Palestine, burial had doubtless become a general custom. Many whole skeletons are therefore available for study.

This stage is that of Neanderthal or Mousterian man, which is geologically the latest to retain several specially ape-like characters associated in a single individual. Its Asiatic origin is now still clearer to a palæontologist than that of earlier man. Burials in caves which seem to be approximately of the same date, reveal a comparatively high Neanderthal type in Palestine, a low and bestial type in western Europe. On Matthew's principle already mentioned, the first is therefore nearest to the original source. The accompanying stone implements support this conclusion, for whereas in western Europe the implements are merely trimmed broad flakes, in Palestine there are also many narrow blades which resemble those made by later (Aurignacian) man in Europe. The Asiatic type of Neanderthal man was indeed progressing in skill to meet his increasing needs.

Since 1913 our conception of Neanderthal man has been based on the admirable description of the skeleton from La-Chapelle-aux-Saints by Prof. Marcellin Boule in his classical memoir in the *Annales de Paléontologie.* This and the earlier accounts of more fragmentary remains from the Neanderthal cave in Germany and the Spy cave in Belgium, have led to the prevalent idea that the type of man in question exhibited too many degenerate features added to his ape-characters, to be the ancestor of the modern *Homo sapiens.* A few years ago, however, Dr. Ales Hrdlička pointed out that other skulls of Neanderthal man, especially those from central Europe and the fragment found by Mr. Turville Petre in Galilee, Palestine, were less different from the skull of modern man than most of the western European examples, and *Homo neanderthalensis* might, after all, prove to be the ancestor of *Homo sapiens* if he could be traced to his source. At last, through the discoveries of Miss Dorothy Garrod and Mr. Theodore McCown in the caves of Mt. Carmel, Palestine, we seem to be approaching that source. They have disentombed a series of buried skeletons which are nearly complete ; and according to the preliminary reports on the collection by Mr. McCown and Sir Arthur Keith, they belong to a race which exhibited a remarkable mingling of the characters of Neanderthal and modern man. They seem to show us modern man in the making.

Even the latest phases in the development of stone-age man appear to have begun in Asia, as already generally admitted. It is usually difficult to distinguish the skeletons of domestic animals from those of wild animals, but Raphael Pumpelly's discoveries in Turkestan show that domestication of several familiar animals was probably beginning there at a very early date in Neolithic times.

Until typical *Homo sapiens* had come into being, man's only outlet from Asia seems to have been by land in the direction of Europe and Africa. As soon, however, as he had attained this final stage of development he must have been able to construct rafts or boats, by which he crossed the narrow seas of the East Indies to Australia, and perhaps the equally narrow seas at Behring Straits to North America.

Australasia.

Australia is shown by its past and present animal life to have been separated by sea from the rest of the world during the whole of the Tertiary era, including Pleistocene times, and it was isolated too early to be inhabited by the ancestors of the apes. Man is therefore certainly an immigrant from overseas, and we know that he reached the country when various relatively large Pleistocene marsupials were still living there, because a fossil human skull has been found at Talgai in Queensland directly associated with their remains. This skull is essentially the same as that of the existing Australian aborigines, who have retained a mode of life like that of the latest Palæolithic hunters of the mainland. Some of the immigrants evidently took with them a semi-domesticated dog, the dingo, of which fossil remains have been found in old inhabited sites.

It is remarkable that very few traces of men who might be related to the ancestors of the Australians have hitherto been recognised in their homeland in Asia. The skulls of *Homo wadjakensis* from an old lake deposit at Wadjak in Java, discovered and described by Dr. Eugene Dubois, may perhaps be placed among them. The skulls named *Homo (Javanthropus) soloensis* more recently discovered by Dr. W. F. F. Oppenoorth in an old deposit near the Solo river in Java, seem to be intermediate between the skulls of *Pithecanthropus* and the modern Australian, though they have not yet been described in detail. As many have observed, the skull of Rhodesian man (*Homo rhodesiensis*) from a cave in northern Rhodesia, also exhibits several resemblances to the skull of the modern Australian. Other skulls dug up in South Africa have also been described as exhibiting Australian characteristics. Sooner or later, therefore, fossil ancestral types of Australians will probably be found widely distributed in the tropics of the Old World.

North America.

In at least part of the first half of the Pleistocene period there must have been a direct connection between Asia and North America in the region of Behring Straits. There may have been an isthmus of land, or there may have been only islands and continuous ice; but there was certainly a passage which allowed such mammals as the mammoth, bison, sheep, goat, elk, wapiti, reindeer and black bear to reach America for the first time. So far there is no evidence that man accompanied these animals, and it may be that by then he had not yet reached the north-east corner of Asia. The woolly rhinoceros similarly never passed from Asia to America, although it was abundant and widely spread through the northern lands in the Old World. Its absence from America shows that in some cases there were impediments to emigration.

The earliest traces of Palæolithic man hitherto discovered in North America date back only to the later part of the Pleistocene period. Last year Mr. J. Dorsch, when collecting for Mr. Childs Frick, found at Fairbanks, Alaska, some small end-scrapers and conical cores, which Dr. N. C. Nelson recognised as identical with those which he had collected a few years before in large numbers in the Gobi desert. These seem to have been made by some of the latest Palæolithic men; and the only stone implements hitherto found in North America in direct association with the remains of typically Pleistocene mammals show that, when man arrived in that country, he had already learned the supreme art of trimming stone by pressure-flaking. In pattern, indeed, his implements resemble those of Solutrean man in Europe, and even include the familiar Solutrean leaf-shaped blades, besides the characteristic spear points.

The Yuma points, however, as these American spear points have been termed by Prof. E. B. Renaud, of Denver, are accompanied by more elaborate points of a peculiar type which has not hitherto been found in the Old World. These are known as Folsom points, from Folsom in Union County, New Mexico, where they occur associated with the remains of an extinct species of bison. The Folsom points are somewhat elongated and pointed blades, with a truncated base which is usually a little excavated; and the middle of each face is hollowed by the skilful removal of a longitudinal flake, which allows it to be clasped by a projection from the end of the spear. These points were, therefore, hafted differently from any of those known from the Solutrean of western Europe. They show that the American late Palæolithic man evolved new ideas on the spot.

The skeletal characters of this race of man are still not known with certainty. The only human bones and teeth hitherto dug up closely resemble the corresponding parts of the surviving North American Indians, and it is uncertain whether any of them are as old as the remains of the Pleistocene mammals with which they are supposed to have been sometimes associated. The Solutrean-like implements, however, have lately been satisfactorily proved to be contemporaneous with extinct mammals of Pleistocene age in several localities, especially in New Mexico, Texas, Colorado, Nevada, and Nebraska.

Two years ago, I had the privilege of visiting one of these localities, by the kind invitation of Dr. John C. Merriam, President of the Carnegie Institution, Washington, and Dr. Edgar B. Howard, of the Pennsylvanian University Museum, Philadelphia. It was on the dry prairie between Clovis and Portales in Curry County, New Mexico. Excavations were then in progress by Dr. Howard and a party of fellow-workers, and the results have lately been described by Dr. Howard himself in a valuable well-illustrated memoir on ' Evidence of Early Man in North America,' published in the *Museum Journal of the University of Philadelphia*, vol. xxiv, Nos. 2–3, June 1935. I can appreciate and endorse his conclusions.

The locality near Clovis is in the course of an old river which deposited gravel and then dried up into a series of shallow lakes which eventually became filled with silt and sand, probably windborne. There are sand-dunes around to-day. In the sandy silt of the old lakes there are well-preserved remains of the mammoth and extinct species of bison, besides freshwater shells which indicate a colder climate than that of New Mexico at present. There are also stone implements, including Solutrean-like blades and less elaborately worked scrapers ; and in one spot the explorers found a mass of charcoal which contained burnt bones and chipped flints, evidently the remains of a contemporary hearth. Beneath the sandy silt several Folsom and Yuma points were obtained, and still further down, below the handiwork of man, there were remains of horses and camels.

In Burnet cave, near Carlsbad in New Mexico, Dr. Howard also found a Folsom point and bone awls directly associated with remains of extinct bison and musk ox, and traces of old hearths ; and in Gypsum cave, near Las Vegas in Nevada, Dr. M. R. Harrington, of Los Angeles, discovered stone implements with remains of horses and camels and the small ground-sloth *Nothrotherium*, again with the charcoal of old hearths. Several other equally clear cases of the association of human implements with typically Pleistocene mammals in the south-western States of America might be cited, but these are enough to show the nature of the evidence which has been obtained. There can be no doubt that during the latter part of the Pleistocene period, when extensive northern ice still reduced the normal temperature of more southern latitudes, man who made stone implements by the technique which is still practised by the modern North American Indians, was very widely distributed over the continent.

It is generally supposed that a few of the typically Pleistocene mammals survived in North America to a later geological date than any in Europe. The remains of the Ohio mastodon, for example, occur in post-Pleistocene swamp deposits; and dried mummies of the little ground sloth *Nothrotherium* have been found in southern caves with coprolites, which show that it fed on the same vegetation as that which still exists in the neighbourhood. It seems, therefore, very difficult to determine the geological age of the earliest man in North America as compared with the successive late phases of stone-age man in the Old World. The only hope centres in satisfactory discoveries of human remains and implements in the deposits on the fluctuating edge of the northern ice sheet.

South America.

Some of the typically Pleistocene mammals in the southern part of South America also appear to have survived until comparatively recent times. Man was almost certainly associated with them, but nothing is known to distinguish this race from modern South American Indians. The supposed ancestors of the human family reported by Florentino Ameghino from the Tertiary rocks of Argentina, are due to erroneous interpretation of the fossils, as already pointed out by Hrdlička and others.

The first fossilised remains of man in the South American continent were discovered exactly a hundred years ago in the caves of Minas Geraes, Brazil, by the Danish naturalist, Dr. Peter Wilhelm Lund, whose centenary has just been celebrated by the scientific men of Brazil in Lagoa Santa and Bello Horizonte. Under the direction of Prof. Anibal Mattos, three volumes have been published in Bello Horizonte, giving an account of Lund's researches, with a Portuguese translation of his scientific papers. At first Lund hesitated to conclude that the human skeletons which he found in the caves were as old as the bones of extinct mammals with which they were associated: he thought they might be burials or otherwise accidentally introduced into the old deposits. In the end, however, after much experience of many diggings, he became convinced that, although the fossil skeletons were very like those of the existing Botocudos, they must have belonged to man who was contemporary with the mammals which afterwards became extinct.

Some years ago the late Dr. Francisco P. Moreno, Dr. Rudolph Hauthal and I, described the discovery of the dried skin and other remains of an extinct ground sloth (*Neomylodon* or *Grypotherium*), with fragments of other extinct mammals, in a cave in Last Hope Inlet, Patagonia. Here again, the presence of fires, cut and worked bone, and masses of hay cut for food for the ground sloth, led us to infer that man lived in Patagonia with the various Pleistocene mammals which are now extinct.

Remote Islands.

The races of men who eventually reached New Zealand and other remote islands, were so far advanced in civilised life that they scarcely concern a palæontologist. They only interest him on account of the disturbance of the existing wild life and the extinctions which they have caused. The ethnologist now joins the human anatomist in attempting to explain the distribution of these people and to discover their relationships. They occupy a lowly sphere in the *modern* world.

SECTION I.—PHYSIOLOGY.

THE PITUITARY BODY AND THE DIENCEPHALON

ADDRESS BY
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THE pituitary body, the 'Glans pituitam excipiens' of Vesalius (1543), from the time of Galen to the seventeenth century, was looked upon as an organ for separating the waste products from the brain and diverting them into the nose and pharynx. In the transformation of vital into animal spirits the residues were removed as pituita or phlegm, and the act of sneezing was held in high esteem as a means of clarifying the mind. In 1660 Victor Schneider described the structure of the mucous membrane of the nose, and in 1672 Richard Lower finally disposed of the older theory. Lower indeed ventured to suggest that the pituitary secretes, not into the nose, but into the brain.

The gland was termed the Hypophysis Cerebri by Soemmerring in 1772, and Rathke, the embryologist, discovered its dual mode of origin in 1832. Clinical medicine gave the first clue to its function: the disease Acromegaly was described in 1886 by Pierre Marie, and somewhat later associated with overgrowth of the pituitary body.

Experimental research upon the organ may be said to date from 1895, when Oliver and Schäfer discovered that the gland contains an active principle, which, when injected into the blood, raises the blood pressure and increases the activity of the heart. In 1905 Alfred Fröhlich described a pathological condition in man, associated with obesity and genital infantilism, to which he gave the name 'dystrophia adiposogenitalis.' Since that time, and particularly during the last few years, great advances have been made in the knowledge of the functions of the pituitary body, and of that part of the brain to which it is attached. The work of Harvey Cushing calls for special mention, for to him and his pupils many of the most valuable contributions are due.

ANATOMICAL AND STRUCTURAL FEATURES.

The structures formed from the wall of the posterior part of the primary cerebral vesicle or diencephalon are perhaps more diverse in character than those of any other portion of the central nervous system. In addition to nerve cells and nerve tracts the diencephalon gives rise to organs obviously secretory, the choroid plexus, and, in fishes, the saccus vasculosus. The paraphysis, when present, is probably glandular in function. Two prominent evaginations of the brain wall, one above and one below, form respectively the pineal body and the nervous lobe of the pituitary. In their development these two bodies show a remarkable resemblance. No true nerve cells are found in them, but they contain peculiarly modified neuroglia and ependyma cells. Both pineal and pituitary present in some animals appearances strongly suggestive of glandular function, their acini opening into the third ventricle. In reptiles the pineal body and the nervous lobe of the pituitary are composed of branching tubular structures resembling glands which discharge their contents into the cerebrospinal fluid. In birds the nervous lobe of the pituitary retains this hollow character. In mammals both organs are for the most part solid, though in some the nervous lobe of the pituitary retains to a variable extent its original cavity in free communication with the third ventricle. The pineal body is said to be missing in crocodiles, and the nervous lobe of the pituitary fails to develop in the cartilaginous fishes. The receptors for light, the retinæ, arise from the wall of the diencephalon, and the dorsal or pineal eye, when present, is probably a receptor of a similar nature. The pineal eye is but a part of a complex system in which glandular structures at its base are to be regarded as forerunners of the pineal body of the higher vertebrates. A highly specialised form of ependyma, extending from the pineal recess over the front of the posterior commissure into the iter, was named by Dendy the subcommissural organ. Its function is unknown, but its histological appearance is suggestive of its being a receptor, open to stimulus by the cerebrospinal fluid which bathes its surface while passing from the third ventricle into the iter.

The pituitary body is the only one of the diverse structures of the diencephalon which receives an accession of epithelium from an outside source. This it gets at a very early stage of development by the ingrowth of Rathke's pocket from the buccal epithelium. The pouch or pocket retains its original cavity in most mammals as the cleft of the pituitary, and its dorsal wall comes into intimate contact with the nervous outgrowth, maintaining and even increasing this intimacy during the life of the individual. The union of buccal epithelium with the nervous element appears indeed to be to some extent a symbiosis. Transplantation of the pituitary body in the tadpole is said to be successful only when a certain amount of nervous tissue is included with the epithelial. The invasion of the nervous lobe of the pituitary by this epithelium takes place normally to a variable extent, and it is not uncommon to find masses of these cells attached to the floor of the third ventricle or scattered individually in the cerebrospinal fluid in the neighbourhood of the infundibulum.

The coming together at an early stage of development of the pituitary of two hollow processes, the one from the mouth and the other from the wall of the diencephalon, has naturally suggested that their union denotes an old association between the brain tube and the alimentary canal. Julin pointed out the resemblance of the early stages of development of the pituitary to that of the subneural gland of the Ascidian larva, a gland which is often spoken of as the Ascidian hypophysis. Kupffer regarded Rathke's pocket as the vertebrate representative of an ancient mouth, the palæostoma, denoting an ancestral communication between the anterior end of the gut and the brain tube. The history of the pituitary is one of great significance, and its epithelial components make up the greater part of the organ in all vertebrates.

With the development within the cranium of the epithelium of Rathke's pocket the several structures which make up the pituitary body are completed. These have been named the pars glandularis, the pars intermedia and the pars tuberalis; the two latter portions being developments of that part of the epithelium which is more particularly associated with the pars nervosa. The epithelial structures arise from the same source and show little differentiation in the early stages of growth of the organ. Changes in structure, no doubt associated with changes in function, occur later, but it is probable that even in the adult the gland possesses a reserve of cells from which more specialised types may arise as occasion requires.

Although the division of the pituitary body into components, showing different structural characteristics, is the rule in mammals, great variations in their relative amounts occur in different species and also in individual animals of the same species. The pars glandularis is the predominant feature in all vertebrates; the pars intermedia, pars tuberalis and pars nervosa are much more variable. The close connection between the epithelial derivatives and the diencephalon is always found.

The pars glandularis or anterior lobe of the mammalian pituitary contains three distinctive kinds of cell, differing in their relative proportions and positions in different animals. The chief element is the chromophobe or mother-cell. It closely resembles the type of cell characteristic of the pars intermedia, though whether the two are identical in structure and function cannot be stated. These cells appear to be the least differentiated of the elements arising from Rathke's pocket, and evidence points to their being able to undergo further development with the formation of the two other types met with in the lobe, acidophil and basophil cells. Severinghaus states that Golgi bodies appear in the chromophobe cells of two kinds, filamentous networks and perinuclear rings. The nature of the Golgi body indicates the type of cell which is in process of development; the cells possessing the network become acidophil, and the ringed cells form the basophil element. The chromophobe cells are the most abundant, but it is as yet undetermined whether they are functionally active as such, or are merely reserves from which the secretory elements are subsequently formed. In the human pituitary body Rasmussen estimates the chromophobe cells at 52 per cent. of the total, the acidophil at 37, and the basophil cells at 11 per cent. Variations in their relative numbers have been described in different physiological conditions. Charriper and Hatterius state that in the female rat the basophil cells predominate during oestrus, and the eosinophil cells during the interval. Modifications of the cells have been described as occurring in pregnancy, after castration, and in other conditions. The histological picture can be very varied, and can be rapidly changed.

Mode of Secretion.

In all vertebrates the epithelial lobe is characterised by extreme vascularity. In elasmobranch fishes the arrangement of its cells in acinar formation around blood vessels is a striking feature. In the mammalian pituitary the circulation is sinusoidal, and provision is made for the cellular secretion to enter directly into the blood. The epithelial lobe is obviously an endocrine gland which pours its products into the general circulation. Its secretion would, therefore, appear to be destined more for general purposes in the body than for action localised to its immediate neighbourhood.

The pars nervosa, when suitably fixed and stained, holds masses of fine granular particles in especial abundance around the blood vessels. These granules probably represent a storage of the secretion peculiar to the lobe. Their mode of origin is not yet settled. They may be derived from the epithelial investment, and more particularly from the breaking down of the epithelial cells which penetrate the pars nervosa from the pars intermedia, but the granules are found in all parts of the lobe, and not merely in the neck where penetration by epithelium is most evident. A study of the comparative anatomy of the posterior lobe, especially in reptiles and birds, suggests that the nerve elements play some part, and that the modified neuroglia or ependyma cells may be secretory. There are examples of secretion by cells of nervous origin, the chromophil cell of the medulla of the suprarenals being a prominent one. The pineal body contains material which acts upon the melanophores of the tadpole, and there appears to be no cell other than the parenchymatous, a modified form of neuroglia, to account for it.

The hormones of the posterior lobe differ in certain respects from those of the pars intermedia. The pressor substance is peculiar to the pars nervosa, occurring in the pituitary body of all vertebrates which possess a pars nervosa, and absent from those which have none. On the other hand many of the activities possessed by extracts of the posterior lobe are also shown by extracts of the pars intermedia, though as a rule less strongly. It is probable that this material is elaborated by cells of the pars intermedia, pars tuberalis, and even by cells of the pars glandularis. Hyaline material is of common occurrence, especially in the neck of the posterior lobe, and similar material is found in acinar-like structures in the pars tuberalis and pars intermedia. In some animals, and occasionally in the human pituitary, the formation resembles small thyroid vesicles. The material is sometimes a secretion and at others a product of the actual breaking down of cells which have wandered into the pars nervosa. In some cases it has been traced into the veins of the lobe, and from there to the adjacent wall of the brain. Its origin is clearly epithelial.

Three ways are open to the secretion of the posterior lobe: direct absorption into the blood vessels; penetration into the adjacent nervous floor of the tuber cinereum; and direct entry into the cerebrospinal fluid. There is evidence that all three routes may be taken. The histological features of the posterior lobe are suggestive of its being a brain gland which furnishes a secretion for local action in the diencephalon. The blood vessels of the lobe are relatively much less numerous than those of the anterior lobe, and are capillaries, not sinusoids. Their arrangement is peculiar. Popa and Fielding have described a venous portal system in the human pituitary body. Capillaries in the pars nervosa, intermedia and tuberalis, unite to form veins which run through the infundibular process to break up again into capillaries in the hypothalamus. Their anatomical arrangement suggests that they collect the products of the posterior lobe and convey them directly to the nervous tissue of this part of the brain. It is customary to speak of nerve ' centres ' and to regard them as subject to the direct influence of physical and chemical stimuli. The term ' centre ' is convenient, but misleading. By analogy with what is known of the manner of working of the nervous system stimuli act upon some form of receptor which is adapted to respond to a specific form of stimulus. The passage of material from the pars nervosa into the cerebrospinal fluid points to the possibility that there are such receptors in the diencephalon. The subcommissural organ occurs to one as a possible receptor, but there is no experimental evidence bearing upon its functions. This organ, too, while highly developed in many animals, is not nearly so conspicuous in the adult human brain.

Connections of the Pituitary Body with the Brain.

In all vertebrates some part of the pituitary body is closely bound up with the floor of the third ventricle. Even in cartilaginous fishes the ventricle runs backward for some distance to end in the large-paired saccus vasculosus, and its ventral wall is invested with epithelium. In the mammalian pituitary abundant non-medullated nerve fibres have been described by Greving and by Pines. They are said to arise chiefly from the cells of the supraoptic and paraventricular nuclei. The fibres converge into the infundibulum, and spread out in the posterior lobe to form basket-like endings in the pars nervosa. Many of them penetrate the epithelium of the pars intermedia, and according to Croll end in knob-like structures in the cells. Croll points out that non-medullated fibres are relatively few in number in the posterior lobe which is also sparsely supplied with blood vessels, and regards them as secretory rather than vasomotor. Roussy and Mossinger also find nerve fibres arising from cells in the supraoptic, paraventricular and inferior hypothalamic nuclei, apparently secretory in function, which enter the pituitary to supply the pars intermedia, pars tuberalis and islands of epithelium in the pars nervosa. They state that lesions of the tuber cinereum must damage some of these fibres and thereby affect the gland. Sympathetic nerve fibres have also been described as entering the gland with the arteries, and Dandy has traced fibres from the carotid plexus along the vessels of the stalk and into the anterior lobe.

Experimental work supports the view, expressed by Harvey Cushing, that nuclei in the diencephalon supply nerve fibres to all parts of the pituitary body, and exercise a controlling influence upon its secretion. An example of pituitary response through the nervous system is furnished by the observation of Fee and Parkes that removal of the pituitary of the female rabbit within one hour after copulation prevents ovulation, but later removal than this has no such inhibitory effect. It is known that the injection of a suitable extract of the anterior lobe of the pituitary brings about ovulation, and it is reasonable to infer that the stimulus of mating induces reflexly in the rabbit sufficient hormone for the purpose in about an hour's time. Zondek speaks of the pituitary sex hormone as the motor which sets the reproductive cycle going, and Harvey Cushing adds the comment that the emotional self-starter is probably in the diencephalon.

The hypothalamus, comprising the tuber cinereum, mammillary bodies, infundibulum and pars nervosa of the pituitary body, optic chiasma and subthalamic tectal region, forms an important part of the diencephalon which has been slow to reveal its secrets. The region is difficult of access for experimental purposes, and its exposure is attended by damage which may obscure the results obtained. Moreover, both Harvey Cushing and Beattie have shown that some anæsthetics prevent the occurrence of reactions which might otherwise be expected to result from stimulation of its parts. Much information has been obtained from the clinical examination of patients suffering from lesions of the hypothalamus, but the mass of information thus yielded is extremely difficult to interpret. Harvey Cushing has demonstrated in the conscious human being an immediate and striking response to perfusion of the third ventricle by solutions of pituitrin and of pilocarpine. The response was so rapid that the drugs could not have been absorbed into the blood vessels, but must have acted locally, a fact which strongly suggests the presence in some part of the third ventricle of a receptor mechanism. The effects were those of a general vaso-dilatation of the skin blood vessels, profuse sweating and a fall in blood pressure. The patient's temperature fell, as did also the basal metabolic rate, both remaining low for some time. The same dose of pituitrin given intravenously to the same patient had the opposite effect upon the circulation, producing pallor with no sweating, and increased intestinal peristalsis. Injected subcutaneously the dose had no appreciable effect except as an antidiuretic. Perfusion of pituitrin through the ventricles of dogs gave rise to vascular dilatation, salivation, excessive panting, pulmonary œdema and gastro-intestinal hypertonicity, results which were prevented by a previous use of atropine.

Harvey Cushing assumes as a working hypothesis that, under emotional stimuli, the posterior lobe of the pituitary body discharges its secretion into the cerebrospinal fluid, or by the venous portal system into the hypothalamus, where it diffuses through the ependyma and influences nuclei in this part of the brain to bring about a parasympathetic effect.

Beattie and his co-workers have obtained somewhat similar results from the direct stimulation of various parts of the hypothalamus in animals, and they support Cushing's hypothesis of the presence of a parasympathetic centre in the hypothalamus. They found that stimulation of the lateral margin of the infundibulum gives rise to increased peristalsis and secretion in the stomach, which disappears on section of the vagus. There is also increased tone and movement in the bladder. Stimulation of the tuber cinereum produces slowing of the heart and other cardiac effects revealed by the electrocardiograph.

Evidence has been accumulating that there is also an important sympathetic mechanism in the hypothalamus. Claude Bernard in 1849 discovered that puncture of the wall of the fourth ventricle produces a glycosuria. Harvey Cushing and his pupils have shown that in dogs a puncture of the third ventricle, or injury to various parts of the hypothalamus, are almost as effective as the Bernard piqûre. Stimulation of the exposed pituitary body gives a similar result. Cushing believes that the glycosuria resulting from the Bernard piqûre may be explained by the injury of descending nerve fibres from the hypothalamus lying superficially in the middle line of the floor of the fourth ventricle. Karplus and Kreidl showed that in cats stimulation of the hypothalamus lateral to the infundibulum produces dilatation of the pupil, separation of the eyelids and retraction of the nictitating membrane. They also obtained profuse sweating of the feet and a rise of arterial pressure, all dependent upon an intact sympathetic system. Houssay and Molinelli in 1926 stated that weak stimulation of the hypothalamus gives rise to a considerable increase in the secretion of adrenaline. Beattie, Brow and Long have shown that the posterior part of the hypothalamus is the portion related to the sympathetic system. Its stimulation produces the secretion of adrenaline. Beattie states there are probably two distinct mechanisms in the hypothalamus, an anterior or parasympathetic, and a posterior or sympathetic. There is further evidence for the location of a higher co-ordinative sympathetic mechanism in the posterior part of the hypothalamus. Bard has shown by serial sectioning of the brain in living cats that the condition, designated by Cannon 'sham rage,' occurs after ablation of cortex, corpora striata and the cranial half of the diencephalon, and disappears when a section is made between the diencephalon and the mid-brain. The phenomena of sham rage are largely those of intense stimulation of the sympathetic system. The diencephalon is one of the oldest portions of the brain, and the hypothalamus exists throughout the vertebrate series. Rioch, in a study of this region in carnivora, finds evidence of a general pattern in its nuclei and tracts. Eaves and Croll have shown that the grey matter of the hypothalamus is more severely affected in chronic epidemic encephalitis in the human subject than any other part of the brain with the possible exception of the substantia nigra, and that the pituitary body is frequently involved in the lesions.

Evidence is accumulating that the hypothalamus is an important, if not the main, site of integration of the basic activities which are common to the life of all vertebrates. The metabolism of solids and of water, with its accompaniments of hunger and thirst, the regulation of body temperature, emotional reactions, sleep, mating and reproduction, may have an anatomical basis in this part of the brain. The pituitary body is an essential part of the mechanism whereby the hypothalamus is enabled to carry out and control its vital activities.

Hormones of the Pituitary.

Many hormones are now allocated to the pituitary body, and more may be discovered. It is as yet impossible to say that the numerous preparations which have been made represent substances actually secreted by the gland, and until the hormones can be isolated in a pure state we cannot be certain of their properties. The hormones of the anterior lobe are carried by the blood to all parts of the body, and their ultimate effects are complicated by the enhancement or otherwise of the internal secretions of other glands upon which they act. The secondary results may indeed be more pronounced than the primary.

The mode of action of the active principles of the posterior lobe is even more obscure. It has already been noted that effects of a different nature are produced according to the way in which the extracts are exhibited. We cannot at present be certain whether they act locally upon the diencephalon, or more generally through the blood stream. Possibly both methods may be utilised.

In disturbances of the human pituitary body, and especially in those occasioned by the growth of adenomata, there is the further complication, stressed by Harvey Cushing, that the pituitary body lies in a rigidly enclosed case. The growth of one element must be at the expense of another. An adenoma of the growth-producing cells not only exercises its own action by increasing production of the growth hormone, but it leads to a diminishing output of other hormones, the lack of which shows its own train of symptoms. Hence arise so many of the different syndromes associated with pituitary disturbance. Secondary effects still further complicate the picture. The hypothalamus may be involved, and differences of opinion arise as to whether symptoms are attributable to the pituitary or to the brain.

The Anterior Lobe.

Hormones have been more or less completely separated from the anterior lobe which stimulate growth and exercise a controlling influence over many important organs of the body, the gonads, thyroids, parathyroids, thymus, cortex of the suprarenals and the mammary glands. Extracts have also been prepared which exert a powerful influence upon metabolism, especially of carbohydrate and fat.

The growth hormone has been so far isolated by Evans to yield a white hygroscopic powder, stable in dry air, and containing about 15 per cent. of nitrogen. From Cushing's observations in adenomata it is probably a product of the acidophil cells. The growth hormone has been successfully used to produce giants in growing rats and dogs. It has also induced conditions in adult dogs similar to acromegaly. The hormone appears to stimulate the osteoblast to increased bone formation. It would be interesting to test its effects in cartilaginous fishes, the pituitaries of which are lacking in acidophil cells. Impure extracts bring about splanchnomegaly and other changes which may be due to their admixture with other active principles.

The gonad-stimulating, or gonadotropic hormone, is probably a product of the basophil cells. In a basophil adenoma recorded by Teel typical hypertropic changes occurred in the ovary. Zondek and Aschheim, and Smith and Engle, found that implantation of anterior lobe tissue in immature female rats and mice brings about rapid sexual maturity. Zondek and Aschheim prepared two extracts of the anterior lobe, which they called prolan A and prolan B, the one acting as a stimulus to the maturation of the Graafian follicle, and the other bringing about its rapid luteinisation. Collip has shown that the material of these authors, prolan, is obtained from the placenta and from the urine of the pregnant animal. Evans and others believe that prolan is not the true gonadotropic hormone. It is termed by Collip the A.P.L. or anterior pituitary-like substance, and is probably activated by the true gonadotropic hormone of the pituitary.

It has long been known that removal of the anterior lobe of the pituitary results in rapid atrophy of the gonads, male or female.

Extracts of the anterior lobe exert a similar influence upon the thyroids. Removal of the anterior lobe is followed by atrophic changes in them, while the injection of suitable extracts leads to their hypertrophy, even in the hypophysectomised animal. Loeb and Aron independently ascertained that extracts of anterior lobe produce in the guinea-pig hyperplasia of the thyroids, exophthalmos and other changes similar to those found in Graves' disease. Shockaert has obtained striking results of the same nature in young ducks, and Houssay and others have produced them in various animals. It has been shown that exophthalmos may be caused by the injection of suitable extracts, even after removal of the thyroids. Marine has obtained exophthalmos by the use of methyl cyanide, and looks for its cause in the lessened oxidation acting through the diencephalon upon the pituitary body and the sympathetic system. Graves' disease appears to be a syndrome in which the pituitary body and the diencephalon play an important part.

The thyrotropic hormone has been prepared in a state of considerable purity, but it is not known from which type of cell it arises. Anderson and Collip have noted that repeated injections of this preparation bring about some immunity to its actions.

Houssay and Sammartino have noted atrophic changes in the parathyroids of dogs after removal of the anterior lobe, and Anselmino and Hoffmann have produced enlargement of these bodies by the injection of extracts of the lobe. Other workers have also obtained evidence of a parathyrotropic hormone in the anterior lobe.

Removal of the anterior pituitary sets up atrophic changes in the cortex of the suprarenals, and Evans has shown that this can be prevented by the use of suitable extracts of the lobe. Houssay finds that the zona fasciculata and zona reticularis are the parts mainly affected. There is no change in the structure of the medulla or in its content of adrenaline. Collip has succeeded in separating the adrenotropic hormone from the others.

Riddle and Bates have prepared a hormone, prolactin, from the anterior lobe which induces lactation in the fully developed mammary gland, growth and functioning of the crop-gland in pigeons, and brings about broodiness and the inhibition of ovarian function in fowls.

Harvey Cushing and his co-workers have drawn attention to the changes in carbohydrate metabolism which are exhibited by patients and by experimental animals in hyper and in hypo-pituitary states. Houssay and Magenta found that after removal of the pituitary body dogs are especially sensitive to insulin, and become rapidly hypoglycæmic. Houssay and Biasotti showed that the glycosuria following pancreatectomy can be prevented in toads by removal of the pituitary body. Somewhat similar results were obtained in dogs. Removal of the pituitary diminishes the glycosuria caused by pancreatectomy, and dogs so treated may survive for six months without recourse to the use of insulin. The animals lost weight, but there were occasional periods during which they actually gained weight. Hypoglycæmia was a feature of the condition and some of the dogs required injections of glucose to keep them alive. Houssay believes that the pituitary is antagonistic to the pancreas in carbohydrate metabolism, and that the anterior lobe is the main factor. It is of interest to note that Houssay and Biasotti found that injury to the tuber cinereum or to the mammillary bodies has no influence upon the course of pancreatic diabetes.

Baumann and Marine have produced glycosuria and hyperglycæmia in rabbits by the daily injection of the anterior lobe, and Evans and his co-workers obtained the same result in two out of four dogs by the daily injection of the growth hormone continued for eight or nine months.

Repeated injections of anterior lobe extracts have also been found to produce ketonuria, lipæmia and cholesterolæmia, in addition to hyperglycæmia and increased resistance to insulin.

The Posterior Lobe.

The posterior lobe furnishes an extract, pituitrin, which is rich in physiological activity, but which has not so far been separated into more than two fractions, each possessing its own definite properties. The pressor effect was discovered by Oliver and Schäfer in 1895, and located to the posterior lobe by Howell. There are anomalies in its action upon the circulation. A second dose within half an hour of the first produces a fall in blood pressure. Noël Paton and Watson found that it has no pressor effect in the bird, and Hogben and Schlapp showed that it has no perceptible action upon the circulation of the tortoise and frog. On the other hand Krogh and Rehberg found that removal of the pituitary in the frog results in a generalised capillary dilatation, which may be overcome by the injection from time to time of small amounts of pituitrin. Krogh believed that the secretion of the posterior lobe is essential for the preservation of capillary tone, and this view has obtained wide acceptance. No part of the pituitary, other than the pars nervosa, yields an extract which has a pressor action upon the mammalian circulation though some of the other actions of pituitrin are obtainable from extracts of the pars intermedia. This of itself is evidence of there being at least two active principles in pituitrin, and confirmation came from the work of Kamm, Aldrich and others in the laboratories of Parke, Davis and Company. These workers obtained on a commercial scale a pressor substance, beta-hypophamine, vasopressin or pitressin, and a substance acting upon uterine muscle, alpha-hypophamine or oxytocin.

The pressor substance has little action upon uterine muscle, but stimulates other plain muscle, raising blood pressure and provoking peristalsis. Harvey Cushing has noted that in human subjects compression or destruction of the pituitary stalk by tumours is almost invariably associated with low blood pressures, while histological evidence of hypersecretion is often accompanied by raised blood pressures. Cushing has described a pathological condition associated with basophil adenoma of the pars intermedia in which the cells of the latter invade the pars nervosa. He regards these cells as the origin of the pressor principle, the excess production of which is primarily responsible for some of the phenomena accompanying the condition. Hofbauer in 1918 suggested that the toxæmias of pregnancy, and especially eclampsia, might be due to overaction of the posterior lobe of the pituitary body, and other observers have come to the same conclusion. Cushing is inclined to support this view. Numerous records of hypertension associated with basophil adenoma of the pituitary have been published by pathologists since their attention was drawn to it, though the exact mode of production of the secondary lesions is not yet understood. Kraus suggests that cholesterolæmia may be a factor. Ashoff believes that the deposition of cholesterol in the intima of the arteries is the starting point of atheroma, and that the deposition of calcium follows. Moehlig found that in rabbits, receiving a diet containing excess of fat, repeated injections of pituitrin produce atheroma and other evidences of arteriosclerosis. The phenomena associated with Cushing's syndrome, or pituitary basophilism, are ascribed by some to over action of the adrenal cortex, but evidence is accumulating in favour of their primary origin from the pituitary body.

Magnus and Schäfer described a diuretic action of posterior lobe extract in 1906. In experimental animals the diuretic effect of an intravenous injection is often very pronounced, but it is only temporary, and is succeeded by a cessation of urine secretion. Farini and Van der Velden, in 1913, independently ascertained that extracts of the posterior lobe, injected hypodermically, act as antidiuretics, and can be used to control the polyuria of diabetes insipidus in man. The work of Starling and Verney upon the isolated kidney of the dog showed that pituitrin increases the percentage and amount of chlorides in the urine while decreasing the water eliminated. Starling and Verney concluded that the pituitary body provides a substance which normally regulates the output of water and chlorides by the kidneys. Priestly showed that pituitrin inhibits for several hours in man the diuresis which normally follows the intake of large quantities of water, and this antidiuretic property is now well established. The hormone, if it has a separate entity, is found in vasopressin and not in oxytocin.

Maddock obtained persistent polyuria in dogs by the application of silver clips to the stalk of the pituitary, a result which Cushing believes to be due to a blockage of the secretion of the posterior lobe which is thereby prevented from passing into the blood vessels or directly into the cerebrospinal fluid of the third ventricle. Camus and Roussy (1920), and Bailey and Bremer, showed that polyuria might be equally well provoked by injury of the tuber cinereum and other parts of the hypothalamus. Richter has also proved that polyuria and polydipsia may be induced in the rat by puncture of the floor of the third ventricle in situations which cause no direct injury to the pituitary body. Eaves and Croll find that in the human subject severe lesions of the hypothalamus do not give rise to diabetes insipidus, but that relatively mild lesions may do so. The injection of pituitrin has been employed successfully in the treatment of many cases of diabetes insipidus, but not in all. Lesions of the hypothalamus are liable to interfere with the normal outlet for the products of the lobe by damaging the venous portal system or destroying the nerve fibres which convey secretory impulses to the gland. Removal of the posterior lobe in dogs does not always produce polyuria, and this is explained by Trendelenberg as due to the presence of the hormone in the floor of the third ventricle. That this is a possible factor will be apparent from the frequency with which cells of the pars intermedia are normally found in this part of the brain wall. Further evidence of the importance of the pituitary in the control of water metabolism is seen in the experiments by Brüll. The kidney vessels of a dog were perfused alternately with blood from a normal dog and blood from a dog which had had its pituitary body removed. Polyuria and retention of chlorides were obtained with the blood from the animal lacking a pituitary body.

Cushing expresses the view that grey matter in the hypothalamus, possibly the nucleus supraopticus, is an important cell station for the integration of nerve impulses regulating water intake and output, and that the hypothalamus and the posterior lobe of the pituitary body make up a neuro-epithelial structure, the parts of which are mutually interdependent in their functions.

The relationship of the secretion of the posterior lobe to the metabolism of carbohydrate and of fat is still obscure. Goetsch, Cushing and Jacobson obtained evidence of an influence of the posterior lobe upon carbohydrate metabolism, and looked to the reflex liberation of a pituitary hormone as the cause of glycogenesis in the liver. Burn showed that an extract of the posterior lobe, which he later identified in the vasopressin fraction, prevents the fall of blood sugar which follows an injection of insulin. Vasopressin has little immediate action upon the amount of sugar in the blood, and Dale regarded the pituitary principle as a direct antagonist to insulin. Hynd and Rotter found that in white rats, especially in those upon a carbohydrate diet, vasopressin induces a slight hyperglycæmia accompanied by a fall in liver glycogen and a rise in muscle glycogen. The amount of fat in the liver increases, as was first pointed out by Coope and Chamberlain, but soon falls and is followed by a greater accumulation of glycogen. The ultimate effect of the injection is the reverse of that first seen. Raab ascertained that pituitrin decreases the amount of fat in the blood, and is the more potent when injected into the ventricle. Moreover the effect is abolished by a variety of nerve lesions. On these grounds Raab believed that pituitrin acts on a nervous mechanism in the hypothalamus. In later work Raab concluded that a separate principle is the factor responsible, and that it is a product of the anterior lobe.

Smith has shown that injuries to the tuber cinereum may result in great obesity in rats, and Cushing has reported that one of Maddock's dogs, in which a clip was placed on the pituitary stalk, eventually became very fat.

The deposition of fat in various parts of the body and the increased tolerance for sugar are well-known features of some forms of pituitary disturbance in man, but the opposite conditions also occur. It is at present impossible to determine how far the posterior lobe of the pituitary is concerned in these alterations of metabolism. Many of the observations were made before the importance of the anterior lobe was discovered.

Houssay and Biasotti consider that the pituitary as a whole is active in metabolism, but that the anterior lobe is the more important. Harvey Cushing looks to a nervous control in the hypothalamus, in which pituitary and nervous mechanisms work together in the regulation of the metabolism of solids as they do in the case of water. Hunger and thirst are sensations of primary importance to the animal. The nerve impulses responsible for their production act on the diencephalic mechanism, and the pituitary body is called upon to make the necessary adjustments.

The action of pituitrin as a stimulant of uterine muscle was discovered by Dale in 1906. The hormone, now known as oxytocin, is a product of the pars intermedia, though stored in greater abundance in the pars nervosa. It is held by some to be an important element in the termination of pregnancy. The active principle is not confined to the mammalian pituitary, and it is said to be present in the Ascidian 'pituitary.' This fact alone points to a wider application of the hormone.

Ott and Scott in 1910 described the galactogogue effect of posterior lobe extracts. The material responsible can be formed by cells other than those of the posterior lobe, for it is present in the elasmobranch pituitary and must therefore have an epithelial origin.

The action of pituitrin upon melanophores has been described by Hogben and Winton and others. It is interesting to note that the expansion of the melanophores brought about by pituitrin is the reverse of that produced in tadpoles by extracts of the pineal body.

Zondek and Krohn have recently claimed the presence of a specific hormone, 'intermedin' which gives a characteristic erythrophore effect in the minnow. The hormone is said to be formed by the cells of the pars intermedia and liberated into the third ventricle. Traces of it may be found in the wall of the ventricle, but not in the blood or in the fourth ventricle. Its action is presumably upon a local nerve mechanism in the diencephalon, and is said to be specific.

Other activities of the posterior lobe have been described. Dodds and Noble have advanced the theory that the control of blood destruction is exercised by the posterior lobe through an influence upon reticulo-endothelium. They have obtained by the injection of extracts in rabbits hæmorrhagic lesions of the acid-secreting areas of the stomach, and rapid destruction of red blood corpuscles accompanied by an increase of macrocytes.

Other effects upon the blood are described. The production of ulcers in the stomach and upper parts of the intestine has been attributed to the action of pituitrin upon nervous mechanisms in the hypothalamus controlling the blood vessels of these areas.

A multiplicity of actions can undoubtedly be evoked by extracts of the posterior lobe, but one may well question if all be normal functions. The oxytocic principle is found in male as well as in female animals, and there is a remarkable similarity in many of the products of the pituitaries of all vertebrates, irrespective of their apparent physiological requirements. One is compelled to conclude that the active principles of the pituitary are such as are necessary for the regulation of common and fundamental processes in the life of the animal.

Conclusion.

The pituitary body is anatomically and physiologically bound up with the diencephalon in all vertebrates from the earliest stages of development. The diencephalon itself is the site of integration of nerve impulses concerned in the regulation of many of the fundamental processes of life. It possesses a diversity of structures, not the least important of which is that derived from the buccal mucous membrane, the epithelial elements of the pituitary body. The pituitary body provides the brain with an armamentarium of hormones. Some of these exert their actions directly upon peripheral tissues through the blood stream ; others act locally upon nervous mechanisms in the hypothalamus. All are under the control of this part of the brain.

The diencephalon and pituitary body form a working unit, and have functions of far-reaching importance in the control of fundamental physiological processes. It is probable that the pineal body is another part of the same mechanism, but its functions are still to be discovered.

SECTION J.—PSYCHOLOGY.

PERSONALITY AND AGE

ADDRESS BY
DR. LL. WYNN JONES,
PRESIDENT OF THE SECTION.

We meet this year in the shadow caused by the grievous loss of our ex-President, Dr. Shepherd Dawson. All who were privileged to work in close association with him could not fail to be impressed by his genial personality, by his concern for scientific accuracy in psychological work, and by his earnest and successful endeavours to advance the study of important social problems which demanded expert psychological knowledge and skill. His contributions have greatly enriched our science and will long remain a tribute to his memory.

I must now turn to indicate in what respects the scope of our study this morning has to be limited, bearing in mind that there are many possible approaches to the study of personality.

On the psychical side psycho-pathologists, and especially psycho-analysts, have in recent years made outstanding contributions. On the physiological side biochemists, and especially endocrinologists, have made some promising advances, although there is no unanimity of opinion as to the exact functions of the various crino-pathologies. When psychiatric, physiological, and biochemical experts have perfected their collaboration it is reasonable to expect that our knowledge of human personality will be enhanced. But leaving aside the approaches I have mentioned to their respective experts and considering only the more familiar approach of the ordinary psychologist, I propose to limit the field still further by directing your attention to one particular aspect of it—namely, an account of recent investigations with adult subjects. It will be expedient as far as possible to consider results of a definitely objective character such as would have appealed to the great pioneer, Sir Francis Galton, who, over fifty years ago, wrote: 'I do not plead guilty to taking a shallow view of human nature, when I propose to apply, as it were, a foot-rule to its heights and depths. The powers of man are finite and if finite they are not too large for measurement.' To-day the possibility of mental measurement is continually being taken for granted and disputes only arise as to ways and means, or as to its feasibility in special domains. Thus it has been usual to distinguish between tests of abilities on the one hand which easily satisfy the canons of measurement, and tests of affective and conative traits, the so-called tests of 'personality,' which satisfy those canons with difficulty, if at all. It may be occasionally convenient to restrict the meaning of personality in this way, but I see no valid objection to following a common practice and regarding personality in its widest connotation as the integration of all the marks of mind and body, as affected by nature and nurture. But as it is difficult to say anything scientific about a 'total personality' there must be some attempt at analysis. Up to a point there is considerable agreement. Thus there may be a general acceptance to include at least five great classes of factors of personality which, according to McDougall, seem to be in great measure, though not entirely, independent variables in the make-up of personality—namely, (1) the factors of intellect, (2) of disposition, i.e., the array of innately given conative or affective tendencies, (3) of temper, i.e., the general peculiarities of the mode of working of all the conative tendencies, (4) of temperament, i.e., the influences, direct or indirect, of bodily metabolism upon the psycho-physical processes of the nervous system, and (5) of character, i.e., matters of acquired organisation of the affective tendencies in sentiments and complexes.

Investigators, however, diverge widely when they attempt to elaborate such a scheme with a view to the actual testing of concrete personalities, and there is no limit to the number of traits which, it is claimed, can be tested in the sense that the values obtained may be represented by actual magnitudes or, at least, be placed somewhere along a continuum.

It thus becomes apparent that in our present study the dependent variable, personality, cannot usefully be employed. It involves a large number of dependent variables, every one of which in turn must be studied with reference to the independent variable, age. Here, in age, we have a variable which gladdens the heart of the tester. For there is usually, at least in this country, documentary evidence of it which ensures scientific accuracy. It is fortunate that such evidence is available, as otherwise after the age of twenty-five there would be little, if any, proof of age, whether of the living or dead, which would be conclusive in medical jurisprudence. It is true that common knowledge comes more or less to our aid, enabling us to make a fair approximation to the decade within which a person may be, but any closer approximation must be made with so many reservations as to be hardly worth consideration. Crow's-feet about the eyes or white hair often appear in the young from suffering or shock or for no apparent reason. To say that a person is thirty years of *age* is a definite reference to solar time, but that person may be sixty years *old* when judged by physical, physiological, or psychological criteria of oldness. And the last sentence would still hold if the words 'thirty' and 'sixty' are interchanged. Such considerations are vital as well as interesting with reference to individual biographies, but in psychology, no less than in other sciences, due regard must be placed on tendencies. If it becomes possible by laborious investigations to ascertain what is the tendency for a trait to change with advancing age it may be well worth the trouble. A failure to appreciate the significance of tendencies is obviously the cause of letters appearing periodically in the press, which attempt to draw a universal conclusion, possibly on the strength of some alleged practice by a few centenarians.

A word may now be added on the difficulty of distinguishing between the adjectives ‘ senile ’ and ‘ pathological.’ If a person of ninety were found as mentally alert as he was at fifty he would certainly be abnormal but decidedly not pathological. If, however, he showed the expected mental deterioration due to age, it would seem preferable to denote it a senile and not a pathological change. Similarly with presbyopia. In the early forties it is quite the normal occurrence for people to become aware of the steady diminution of accommodation power. It is true this is a sensory deterioration, but probably most of those who have experienced it would prefer to call it a senile rather than a pathological change. With a little ingenuity it might be possible to find a still less objectionable term, for there are individuals who resist the suggestion that it is a senile change and by refusing to wear glasses may do themselves harm, just as, at the other extreme, are individuals who harm themselves by concluding that they are already old at the first onset of the symptoms.

Other senile changes such as those which slow down the motions of a sprint runner occur in the twenties. Such senile changes may be contrasted, for instance, with definitely pathological changes such as dental decay during childhood. In the individual personality, then, there may be both pathological and senile changes occurring which cause a deterioration of functions long before the total personality has attained its maximum integration. Unfortunately, ‘ maximum integration ’ is a little vague, but it is probably true that most personalities are not fully integrated till long after maturity is reached. Moreover, there are functions which improve with age, at least up to middle age, others which deteriorate with age, and still others which are largely independent of age.

A few years ago the readers of many German newspapers were invited by Giese to give an account of the signs by which they noticed that they had become old, and to say at what age these signs first appeared. When these reports were analysed it appeared that the average age of becoming subjectively old was forty-nine years, but this age of becoming old varied widely with the individual—indeed from age eighteen to eighty-two.

The bodily signs were twice as numerous as the mental. The bodily signs in decreasing order of frequency from 17·4 to 1·2 per cent. may briefly be summarised thus : (1) Motor (muscles, back, teeth, bones, extremities), (2) nerves (including memory and insomnia), (3) sensory (eye, ear), (4) skin (hair, wrinkles), (5) fatigue, (6) sexual, (7) circulatory (heart, arteries), (8) metabolic (sugar, gout, fat), (9) digestive, (10) kidney, (11) respiratory.

It would, of course, be expected that the layman would be more likely to refer to bodily symptoms than to mental, and it was natural that the more educated should show a higher percentage of mental signs.

The subjects who reported mental signs were divided into three classes :

(1) The negatory type. About 18 per cent. of those who reported mental signs opposed the suggestion of being old and either indignantly refused to acknowledge it or perhaps referred to the health or longevity of their stock.

(2) About 38 per cent. ascertained that they were old by noting the

way they have been treated by the outside world in various situations and the like.

(3) About 44 per cent. reported experiences from their own introspections—it might be some intellectual change in reaction such as the emergence of old recollections, or it might be an affective change such as a disinclination for amusements.

Important is the fact that bodily and mental manifestations certainly do not go together and have widely different values for different individuals. Some lay great stress on bodily signs and hardly any on the mental, while others do just the reverse. It is not, of course, suggested that the percentages reported above would agree with medical diagnosis, as the subjects belonged to a sample of the general population. Moreover, many of the physical symptoms reported had probably a mental origin, for, as Prof. M. Greenwood stated in a recent lecture on 'The Temperamental Factor in Industry,' 'it is becoming realised more and more how easily emotional disturbances may result in bodily ills that can be cured only by dealing with their psychological causes.'

Before referring to some systematic experiments with adult subjects it may be useful to account for the fact that this is largely a new development. Child psychology has largely occupied the attention of psychologists during the last thirty years. The educational and vocational implications were so obvious and tremendous that it was only fitting that 'Children first' should virtually be the slogan. But it is equally clear that the study of children is in many respects less difficult than that of adults.

(1) Adult populations are relatively inaccessible.

(2) There are formidable statistical difficulties relating to the selection of samples.

(3) The widely different kinds of experience and mental backgrounds of adults make it difficult to differentiate between what is largely native and what is largely acquired.

(4) Care must be taken, on the one hand, that tests do not unduly favour the adult by involving his greater retention of some kinds of knowledge and acquired skill, or, on the other hand, do not unduly handicap him owing to his lack of practice in activities similar to those demanded by the tests, or by virtue of changes in his attitude towards testing or through his having formed habits which do not conduce to high scoring. Children have probably greater incentives to put maximum effort and in many cases they have probably enjoyed superior schooling.

(5) There is the danger of assuming that conclusions drawn in child psychology hold also for adults. Thus the relation of speed to power may be different for adults.

(6) Finally, the rate of growth (or of deterioration) is generally slow in maturity. During childhood it is easy to distinguish between the general mental capacity of two average children differing in chronological age by only one year, but who would care to differentiate between the average youth of twenty and the average man of forty? For biologically senescence depends on the increase of protoplasm and on the differentiation of cells. Thus the rate of growth depends on the degree of senescence,

and senescence will be at its maximum in the very young stages and the rate of senescence will diminish with age.

On all these grounds it is not difficult to account for the ceaseless activity in child psychology. In fact, progress has been so great that some consider future possibilities to be strictly limited. Without accepting such a view it is nevertheless true, as Professor Walter Miles has pointed out, that although psychologists have exhibited great interest in the child and the adolescent yet there remain five or six decades of human life relatively untouched.

At least four recent investigations merit our attention. They were initiated by Terman, Thorndike, Walter Miles, and Charlotte Bühler respectively. It is significant that each had already made outstanding contributions in child psychology, and each research was furthered by a grant, so that a band of experts were able to collaborate and produce results which would be quite unattainable by a single investigator who had to meet the charges out of his own pocket.

In 1926 there appeared the second volume of Terman's *Genetic Studies of Genius*. It is entitled *The Early Mental Traits of Three Hundred Geniuses*, and the investigations were carried out by Dr. Catherine M. Cox (now Mrs. Walter R. Miles) under the direction of Terman. Grants from the Commonwealth Fund of New York and the Thomas Welton Stanford Fund were available. It was concluded that youths who achieve eminence have, in general, a heredity above the average and superior advantages in early environment: they are characterised not only by high intellectual traits, but also by persistence of motive and effort, confidence in their abilities, and great strength or force of character.

Thorndike's *Adult Learning* appeared in 1928. His purpose was to study the changes in the amount and changes in the nature of ability to learn from about age fifteen to about age forty-five, and especially from age twenty-five to age forty-five. The research was done with the aid of a grant from the Carnegie Corporation. Some of the conclusions may be briefly summarised:

(1) The differences in rate of learning between old and young are small in comparison with the differences within either group, and when other factors than age are equalised the influence of age approaches zero.

(2) Adults learn much less than they might partly because they underestimate their power of learning, and partly because of unpleasant attention and comment. It is disuse and lack of practice and not inner degeneration which is likely to affect learning.

(3) Ability to learn a systematic logical language, Esperanto, rises from 8 to 16 and probably to 20: it is then stationary to 25 or later and then drops very, very slowly to 35 and somewhat more rapidly, but still very slowly, to 45 or later.

(4) The gain made in 50 or 100 or 500 hours of study of a modern language by a group of any age from 20 to 40 will be greater than the gain made by a group aged 8 or 10 or 12. The facts are in flat contradiction to the doctrine that childhood is the period for easiest learning to read, write, or understand the hearing of a language.

(5) Learning representing an approximation to sheer modifiability

unaided by past learning shows more inferiority in the case of adults than was indicated by the experiments taken as a whole. Actual learning of such things as adults commonly have to learn shows, however, considerably less.

(6) The curve of ability to learn from 22 to 42 is a very slow decline, and this decline is no greater for inferior intelligence than for superior.

Thorndike studied all sorts of learning and in each case analysed the curve of ability to learn in relation to age. Although he realises that a curve of total or average ability may be unattainable, yet he was able to conclude in general that nobody under 45 should restrain himself from trying to learn anything because of a belief that he is too old to be able to learn it. 'If he fails in learning it, inability due directly to age will very rarely, if ever, be the reason. The reason will commonly be one or more of these: He lacks and always has lacked the capacity to learn that particular thing. His desire to learn it is not strong enough to cause him to give proper attention to it. The ways and means which he adopts are inadequate, and would have been so at any age, to teach him anything. He has habits or ideas or other tendencies which interfere with the new acquisition, and which he is unable or unwilling to alter. In the last case mere age may have some influence.'

Thorndike's conclusions are particularly important when we consider schemes for adult education, and it is interesting to see how well his experimental findings agree with Cicero's dicta on age: 'But, you argue, the memory grows feebler. I believe it does unless you practise it, or if you are by nature rather dull. . . . What of lawyers, pontiffs, augurs, philosophers when they are old? How much *they* remember! The old retain their wits, provided their earnestness and energy lasts; and this happens not only with men who are illustrious and who have held high office, but also in a life of privacy and repose.'

Having reported facts concerning the relation of adult learning to age we may pass on to consider some of the most important human abilities in their relation to age, and important in this respect are the Stanford Later Maturity Publications which have appeared from 1931 onwards under the direction of Prof. Walter R. Miles, and which were aided by a grant from the Carnegie Corporation. A reference to some of these abilities is now necessary.

Sensory and Motor Abilities.

The importance of abilities such as reaction speed and co-ordination of movements in the various industries and sports hardly needs mention. Motor skills are so varied that each has to be studied by itself, and although some evidence for group factors in this field has been obtained, yet in the main it is the specificity of each ability which is striking; and this is not surprising when it is considered that some demand considerable visual acuity, others visual attention, others muscular power, others neuro-muscular speed of reaction, and so forth.

Probably visual acuity is at its maximum in the teens. It is probably one of the first physiological functions to show a very slight deterioration with age. About the age of fifty on the average this deterioration may become sufficiently serious to handicap the individual in occupations where visual requirements are exacting. In industry, of course, there are other factors which affect the issue, such as the efforts of an employer to get cheaper, that is, younger, labour, or the effort of the employee himself to acquire a more responsible position. The more striking fact, according to Miles, is the relatively small, although steady, decrement shown throughout the life-span in tests such as reaction speed or rotary motility. 'Guessed on the basis of what industry has popularly said of the old and also in terms of the derogatory reports made by old people about themselves, the situation has appeared far harsher than the objective data warrant.'

Intellectual Abilities.

Under this heading may be considered tests of memory, manipulations of symbols and of space areas, interpretations of meaning in verbal form and all the so-called higher mental functions which figure in tests of intelligence. Here again the deterioration due to age as such is relatively small. The differences between individuals at the older ages are often quite marked, so that other factors are probably at least as weighty as age in accounting for an individual's actual score. Thus Sorenson found that the mental abilities of adults who participate in schemes of adult education are maintained at a high level over a long span of adult years.

Miles also points out that when speed is the stressed element in an intelligence test for adults, then the decrement due to age is greater than it is when power in unlimited time is stressed. The fact that intelligence tests are usually standardised for children also points to the need of further research when dealing with adults.

Interests.

Here we turn to one of the Stanford Later Maturity Publications—namely, *Change of Interests with Age*, by Prof. Edward K. Strong. It is based on examination of more than two thousand men between the ages of twenty and sixty representing eight occupations. The following quotation gives the author's standpoint: 'If "vocational interest" is defined as "the occupation an individual likes best now," then the conclusion must be reached that vocational interests are very unstable. There are ample data to prove that boys and girls and also older persons change their "first choices" very frequently, and in most cases without apparent rhyme or reason. But if "vocational interest" is defined as "the sum total of all interests that bear in any way upon an occupational career," then we find surprising stability, certainly among adults, and, as far as we have been able to judge, also among young men of college age and presumably among still younger people.'

That is to say, just as we do not probe an individual's intelligence by one test but by as many as we can afford time for, so it should be with interest.

The slight differences found between men of twenty-five and fifty-five years of age seem to indicate that interests are not particularly affected by years of activity in a given occupation, and that therefore interests are responsible for choice of occupation rather than a resultant of it.

Older men are no more catholic in their interests than younger men, but their likes and dislikes are not identical with those of younger men. Thus the older men are not so interested in situations involving physical hazards, or in anything which interferes with established habits. This factor appears to be of great significance for both employer and employee. Many an employer is unsuccessful not so much for lack of abilities, but owing to a disinclination to introduce a change, and the old employee often becomes unemployed not on account of inability, but because he has no desire to change his methods when changes are deemed essential by the management.

I now turn to the extraordinarily interesting book of Prof. Charlotte Bühler, *Der Menschliche Lebenslauf als Psychologisches Problem*, which was published in 1933. The investigations were aided by a grant from the Rockefeller Foundation. The course of man's life is studied by the aid of 200 published biographies of poets, writers, inventors, scientists, statesmen, musicians, painters, theologians, business men, financiers, actors, singers, sportsmen, and philosophers. For comparison, fifty life-histories were obtained from the Old People's Homes in Vienna.

Life is regarded from several aspects : as a biological phenomenon, as a series of events and experiences, and from the standpoint of work produced. Its normal structure—ascent, culmination, and decline—is discussed. It is impossible to do justice to this pioneer study in a brief sketch, and I will only single out what appears to be the importance of age in athletic records. Here, then, Prof. Bühler has at hand the severe tests of the athletic field as substitutes for psychological tests in order to ascertain when various motor abilities are at their maxima in the case of the best athletes. On analysing the best lists for the year 1930 the following were the results :

	Individual Sports.	Age.		*Group Sports.*	Age.
A.	Sprint run	23·5	A.	Boxing	21·9
	Long jump	23·5		Wrestling	22·3
	Throwing the javelin	24·2		Football	23·8
B.	Medium run	24·3	B.	Jiu-jitsu	26·0
	Hurdles	24·5		Hockey	26·4
	High jump	24·8		Tennis	28·5
	Pole vault	25·4			
	Putting the weight	25·4			
C.	Long run	25·6	C.	Polo	up to 50
	Rowing	26·5		Riding	up to 50
	Throwing the discus	26·9		Trotting	up to 50
	Weight lifting	30·5			
	Throwing the hammer	31·0			

It is characteristic of Group A that the activities demand a maximum expenditure of energy per second. Economy of effort plays no part here.

In Group B there is demanded economy of effort and a proper distribution of it. As for Group C, in addition to the greatest economy of effort, enormous demands are made on technique which only comes after long experience.

As two typically British sports are not included in the table—namely, cricket and golf—I have attempted to get corresponding figures for batsmen, bowlers, and golfers. Taking the season of 1934, the names of eighty-three batsmen who exceeded a thousand runs in first-class cricket appear. The median age is 30 years (the quartiles being 27 and 33 and the extremes 19 and 47). Then the bowling averages were analysed. The median age is again 30 years (the quartiles being 26 and 34 and the extremes 20 and 50).

Taking the names of the forty golfers who headed the Open Championship list in 1934, the median age is about 35 years (the quartiles being 29 and 39 and the extremes 24 and 45).

Taking a still higher standard, it appears that batsmen who have exceeded three thousand runs in a season show a median age of 34·5 years (the quartiles being 30 and 39 and the extremes 27 and 44).

And, in golf, the thirty-seven open champions since 1894 show a median age of 31 years (the quartiles being 28 and 37 and the extremes 23 and 44).

Applications to Education and Industry.

Not only do psychological investigations show in a clear light how widely adults of a particular age differ from each other, but they also show that age is not the main cause of most of the differences. Even in a test of reaction speed the average man of eighty is only 50 per cent. slower than the average man in his prime, and even the latter is less speedy than some men of eighty.

Industrial accidents also decrease with increasing age owing to the greater experience and caution of the older workers. Not so, however, with pedestrian accidents. Very high, according to Dr. Ford, would appear to be the rate of fatalities for those over sixty-five years of age in an American city. Further research may determine the relative effectiveness of such factors as decrease in muscular agility, increase in weight and consequent decrease in speed of movement, preservation of traffic habits from days when cars were not a hazard, impairment of sensory acuity, absent-mindedness, and a variety of senile effects on mentality.

In industry it is necessary to investigate how far the handicaps of the older workers are due to their own physiological, mental, or vocational disabilities and how far to the age prejudice of employers, as there are degrees of disability sufficiently serious to necessitate special legislation for the purpose of extending retirement pensions. Again, in organising schemes of adult education, it is important to know the capacities and mental characteristics, whether native or acquired, of the individual pupils. Ancient customs and opinions which had little scientific backing have in the past made it difficult for many of the unemployed to embark on any training for a new career. But the verdict of psychology is that such training is possible. The human organism cannot with impunity be thrown on the scrap-heap like a cheap car. In the long run it will successfully resist such treatment. In self-preservation one of its reactions is to turn to schemes of adult education. It is only in exceptional circumstances, when the fight becomes too unequal, that a whole community sinks into listless apathy as at Marienthal.

But the main motive for adult education is not self-preservation; rather is it an enhanced idea of the self as an enduring entity, as a personality conscious of powers unexercised and unrealised, striving steadily towards its own goals. However excellent primary education may be, there must remain many lessons which an adult can only learn when the need arises. The gardener cannot train his tree while yet a seedling: he must wait till its branches begin to shoot, and he tends it until it ceases to grow. At present, however, the salvaging of adults of mature age has not been systematically taken in hand, partly owing to the pressing need of finding employment for adolescents. Here, again, age as a variable has to be taken into consideration. What should be the age allowance for scholarship candidates for secondary schools or for the universities? What should be the school-leaving age? Is the break from school to industry too abrupt? There are indications of stagnation, if not actual retrogression, to be found in the duller half of the child population for the years immediately following this break if extent of vocabulary and richness of concepts be taken as criteria. It is true that vocabulary and concepts cannot be divorced from real life, but the question here is whether such individuals have made sufficient initial progress before the break to enable them later on effectively to discharge their responsibilities as citizens in the modern world.

Theoretical Implications.

A most important development in modern psychology is the search for innate, basic, unitary traits of personality. There is accumulative evidence in favour of the existence of a number of unitary traits or factors, and it has been found convenient to denote them provisionally by letters of the alphabet, analogous to a practice of physics and other sciences. This does not in the least imply that their functional interpretation is necessarily less clear than that of concepts such as introversion and the like. It is true that polysyllabic words have sometimes only to undergo a very cursory censorship, but this practice leads to abuses of the language mechanism which may retard individual cerebral evolution. Besides, the less popular use of letters to denote new concepts is not likely to proceed indefinitely, if only for the fact that the introduction of such a letter is preceded by many thousand hours of laborious work.

Closely connected with the study of traits is the difficult question of the effectiveness of past experiences. Spearman's researches show that retentivity is independent of *g*, and there is evidence that the old tend to deteriorate in tests of immediate memory. How far is the balance redressed when the extent and variety of all their previous experiences as well as their integration are taken into account? It is hardly necessary to illustrate the dire effects of lack of experience. Thus the brilliant young debater is often pulverised by one who is dull but elderly. My second example is a very intelligent person who has been totally blind from birth. I found that the subject had no idea at all of the size of the sun as it appeared in the sky. The subject imagined that most stars had five points, but that some had six or even eight, and that a rainbow had the shape of a tied bow, and so forth. Manifestly all knowing, even in the case of the gifted, must start from experiencing.

Now that the method of factorial analysis is becoming increasingly effective, not only in the case of cognitive abilities, but also with regard to personality in all its aspects, it becomes necessary to study age as one of the 'primordial potencies' more systematically. Not only during childhood and adolescence, but throughout the life-span. This will determine the relative importance of the various traits at different stages of life, and this in turn will lead to a fuller psychological interpretation of the unitary traits themselves.

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SECTION K.—BOTANY.

SOME ASPECTS OF PLANT PATHOLOGY

ADDRESS BY

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PRESIDENT OF THE SECTION.

SINCE the Aberdeen meeting of the British Association botany in Britain has suffered the loss of Prof. O. V. Darbishire, Prof. R. A. Robertson and Dr. R. C. Knight. Prof. Darbishire in particular was a staunch supporter of the British Association and those of us who attended the Bristol meeting in 1930 will remember the lively interest he took in the affairs of Section K. Prof. Darbishire is well known for his researches on Lichens, and he made notable contributions to their physiology, morphology and systematics. Of great kindliness of heart he was always eager to help others, and I recall with gratitude the large measure of assistance he gave me when I was revising Scott's *Flowerless Plants* a few years ago. Without request he generously placed at my disposal several hitherto unpublished figures illustrating the morphology of *Xanthoria parietina*. Prof. Robertson had only recently retired from his long tenure as head of the botanical department of St. Andrews University where he had designed and organised new laboratories. Dr. R. C. Knight, unfortunately cut off in the prime of life, was a brilliant investigator at the East Malling Research Station, where he had made important contributions to our knowledge of the physiology of fruit trees. In a wider field botanists mourned the death earlier this year of Prof. Hugo de Vries whose researches have had a profound influence on plant physiology and genetics. His career will always be a landmark in the history of botany.

During the meeting of the British Association held in Norwich in 1868 I may remind you that Sir J. D. Hooker, then Director of the Royal Botanic Gardens, Kew, was the President of the Association and that the Rev. M. J. Berkeley, often referred to as the Father of British Mycology, was the President of Section D which then comprised both Botany and Zoology.

Norwich, the metropolis of East Anglia, is a particularly appropriate place for a gathering of botanists, partly because of the great interest taken in our subject by the Norfolk and Norwich Naturalists' Society and the Norfolk Research Committee, and partly because of the varied character of the vegetation in the vicinity. Much important work has already been done on the vegetation of these interesting tracts of country. I need only recall the pioneer work on the vegetation of Blakeney Point by Prof. Oliver, Prof. Salisbury and their colleagues, the botanical survey of Scolt Head by Messrs. Deighton and Clapham—now being greatly extended by Dr. V. J. Chapman, the accounts of the vegetation of the Holme Salt Marsh by members of the Cambridge Botany School, the investigations on the vegetation of the Norfolk Broads by Miss Pallas—again being studied by Dr. Godwin and Mr. Turner, and the researches on the plant communities of Breckland by Mr. E. P. Farrow, an area which I hope will always remain a happy hunting-ground for the botanist and which Dr. A. S. Watt has been investigating in great detail for some years. In addition, East Anglia is floristically one of the most interesting parts of the British Isles, as is evident from Prof. Salisbury's classical monograph, *The East Anglian Flora*, published through the great enlightenment of the Norfolk and Norwich Naturalists' Society. The same Society sponsored the *Flora of Norfolk* in 1914, which was edited by Mr. W. A. Nicholson and which contained an especially interesting chapter on Physiography and Plant Distribution by Mr. W. H. Burrell.

Norfolk has been the home of many famous botanists. Sir Thomas Browne, who had great interests in botany, natural history and horticulture, lived in Norwich for many years before his death in 1682. Sir J. E. Smith, who founded the Linnean Society in 1788, was a native of Norwich. Sir W. J. Hooker was born in Norwich. The Rev. Kirby Tanner, who published a Flora of Norfolk in 1866, died at Norwich in 1887. Another renowned Norfolk botanist and mycologist was Dr. M. C. Cooke who was born at Horning and lived in the county until the age of twenty. His range of botanical interests was widespread, but he is chiefly remembered as an outstanding authority on the Fungi. His *Illustrations of British Fungi* and *Mycographia* are still indispensable to mycologists. One of the most eminent Norfolk naturalists was Dr. C. B. Plowright of King's Lynn, a physician with many scientific interests, who in the latter half of the nineteenth century made innumerable contributions to our knowledge of the Fungi, especially of the life-histories of the Rusts. His work culminated in the publication in 1889 of the *Monograph of the British Uredineæ and Ustilagineæ*, which for many years was the standard book on these groups. It is of interest to know that Dr. Plowright's son-in-law, Mr. T. Petch, the well-known tropical mycologist, is spending his retirement at North Wootton, near King's Lynn, where he is still making important contributions to mycology, especially as regards entomogenous fungi. Mr. H. J. Howard, of the Norwich Museum, is one of the chief authorities on the Mycetozoa, Mr. E. A. Ellis of the same Museum is an ardent botanist who has recently published a valuable list of the Rust Fungi of Norfolk, and Dr. G. Edward Deacon of Brundall is an assiduous student of the Fungi who has contributed to our knowledge of the *Botrytis* disease of roses and who has been of great assistance to myself in providing material of certain other rose diseases under investigation at Cambridge.

I propose now to deal with some aspects of plant pathology which I hope may be of interest to general botanists. Perhaps, too, it is not inappropriate that this address at Norwich should deal with the subject of disease in plants, for Norfolk farmers were among the first agriculturists to become convinced that barberrry bushes had some influence in the establishment of 'Mildew' in wheat, or 'Black Rust' as it is now called. For instance, Marshall writing in 1781 in *The Rural Economy of Norfolk* says 'the idea that the barberry plant has a pernicious quality (or rather a mysterious power) of blighting wheat which grows near it, whether the idea be erroneous or founded on fact, is nowhere more strongly rooted than among the Norfolk farmers.' Fundamentally, plant pathology is a branch of botany, and I hope that the tradition which has grown up in this country of training plant pathologists first to be all-round botanists will always be maintained. Later on, of course, they should become familiar with the practices and economics of crop production, but unless they have been inculcated with an adequate knowledge of botanical principles and are well acquainted with botanical technique they will always be handicapped as investigators of the problems of disease in plants.

Mycologists and plant pathologists have frequently been the scientific pioneers in the development of the extensive Departments of Agriculture which are now universally present in tropical countries. Tropical agriculture is often chiefly applied botany, for it is usually much more concerned with plant than with animal production. The first problems of crop production in the tropics which clamoured for attention were those of epidemic disease, and the early mycological investigations shewed that it was just as essential for crop plants to be studied by scientific experts in the tropics as in temperate countries. Credit is due to these mycological pioneers for the confidence they won as to the merits of the application of science to the improvement of crop production in the tropics. Nowadays, of course, botanists of many kinds are employed in the tropical Departments of Agriculture.

Some notable advances have been made in recent years in the control of plant diseases. First and foremost, the discovery by Biffen [1] that susceptibility and resistance of wheat varieties to Yellow Rust (*Puccinia glumarum*) were inherited in Mendelian fashion gave a great impetus to plant breeders, often working in association with plant pathologists, to synthesise new varieties of crop plants which would be resistant to specific diseases and which at the same time would retain the valuable commercial qualities of the older varieties. In addition, selections of resistant forms from amongst mixed populations and the independent propagation of these resistant types have also led to marked improvement in crop production through reduction of disease. Such genetical and selection methods have led to great advances in the control of certain wilt diseases, Black Rust of wheat in North America, and the serious leaf-curl virus disease of cotton in the Sudan. The skill of the geneticist indeed may be the only hope for the maintenance of certain kinds of cultivated plants as, for example, Antirrhinums, which were devastated in this country last summer by *Puccinia Antirrhini*. Direct control of this Rust appears to be impossible at present, and until new resistant races of this popular plant have been built up the outlook for its continued cultivation in this country is a dismal one. Fortunately, some progress in this respect has already been made in the United States. It is sometimes claimed that the work of the plant pathologist will pass wholly into the hands of the plant breeder in the course of time.

[1] *Jour. Agric. Sci.*, **2**, p. 109 (1907).

I do not subscribe to this view. While full of admiration for the achievements of the geneticists in disease-control, I think there will always be an extensive field for plant pathologists in the elucidation of the problems of disease in plants, which must precede control, and in direct attack on many diseases. The plant breeder is sometimes faced with almost insuperable difficulties, for there is often complete or almost complete linkage between susceptibility to a specific disease and high quality, which is extremely difficult to break. This is notably true of potatoes, in which the best varieties are almost invariably susceptible to Blight (*Phytophthora infestans*). In passing, however, it may be mentioned that Dr. Salaman and Miss O'Connor have recently achieved some desirable syntheses between domestic potatoes and species of *Solanum* which are immune to Blight, and that these productions shew considerable promise for the future. Again, many crop plants are liable to severe attack by several different diseases, and since susceptibility and resistance are often transmitted independently for each specific disease the work of the geneticist becomes well nigh endless. With arborescent plants breeding for disease-resistance is necessarily slow even when possible, and the time can hardly be visualised when the services of the pathologist will not be required for the control of the diseases of woody plants ; for example, it is difficult to conceive of the breeding of a strain of the rubber tree (*Hevea brasiliensis*) which will not be liable to attack by the root and bark diseases that commonly afflict it. Furthermore, disease-resistance, although of great genetical significance, is not usually unmodifiable under diverse environmental conditions. A variety bred for resistance in one locality may become susceptible if transferred to a different environment. It must be remembered also that parasitic organisms are liable to evolutionary change just as their hosts are, and one cannot postulate therefore that their parasitic proclivities will remain constant over long periods of time. There is evidence that new physiologic forms of parasitic fungi arise both by hybridisation and by mutation, and this capacity of micro-organisms to change must always be borne in mind by geneticists and plant pathologists. Lastly, it is sometimes hardly worth while to try to build up disease-resistant varieties, for completely efficacious treatment of the disease in question by simple mycological means may be already available. Bunt in wheat, for instance, can be entirely eliminated in most countries by fungicidal treatment of the grain before sowing, so it is scarcely worth while for the plant breeder to labour in this field.

Another advance in the control of plant diseases lies in the greater attention now paid to plant sanitation or plant hygiene. Such preventive treatment, following the same lines as in medical and veterinary sanitation, aims at the abolition of the sources of infection wherever possible. The efficacy of plant sanitation is best seen in intensive cropping in fruit plantations and under glass. For instance, by preventing the fungus *Stereum purpureum* from sporing within and on the confines of fruit plantations the risk of Silver-leaf disease is appreciably reduced.

The elimination of certain seed-borne parasitic diseases by fungicidal treatment of the seed before sowing without impeding germination, the control of some epidemic diseases by spraying the shoot system with fungicides, and the protection of wounds in woody plants against parasitic invasion have all received much attention in recent years and have met with a considerable degree of success.

More care is now paid than formerly to growing plants under the best environmental conditions with a view to diminution of parasitic attack, including modifications of cultural practice which tend to favour the host at the expense of the parasite. The ecological study of disease in plants, as I may term it, is only in its infancy, but it promises to be one of the most fruitful aspects of pathological investigation in the future. Environmental conditions often determine whether a disease will become serious or not. In the Malayan rubber plantations for instance Pink Disease, caused by *Corticium salmonicolor*, is only severe in the regions of highest rainfall. Reinking [1a] has summarised our knowledge of the relationships which often exist between certain types of soil and *Fusarium* wilt diseases. He points out that the wilt disease of bananas caused by *F. cubense* is much more severe in Central America on sandy than on clay soils. The study of the temperature-relationships of parasitic fungi which infect their hosts below soil level has already yielded results of the highest value, notably at the University of Wisconsin under the leadership of Prof. L. R. Jones. For instance, Walker and Jones [2] have shewn that at soil temperatures of 29° C. and above *Urocystis Cepulæ*, the cause of the smut disease of onions, cannot cause infection because the spores do not germinate normally ; at such temperatures, however, the host grows well. It is in connection with the action of weak parasites, especially root parasites, that attention to the well-being of the host will prove to be of the greatest consequence. Claims are occasionally made that by growing plants in the best environment pathogenic organisms will be reduced to impotence. Such claims, however, cannot be justified in general. Although there may be some truth in this belief with regard to certain weak parasites, it is not true in connection with the incidence of obligate parasites such as Downy Mildews and Rusts. Fungi of this kind generally thrive best when their hosts are in a vigorous state. The same considerations apply to many virus diseases. The 'Spotted Wilt' virus, for instance, is at least as severe in its many hosts grown under good conditions as when they are enfeebled. It is not implied that the incidence of virus diseases is entirely unrelated to the condition of their hosts ; Spencer [3] has shewn that tobacco plants which made the most rapid growth were somewhat less susceptible to certain mosaic viruses than plants in which growth was retarded by excess nitrogen. It is maintained, however, that plants grown under normal nutritive conditions shew no particular resistance to appropriate virus diseases.

Of greater academic interest to botanists are the mutual relations between parasitic micro-organisms and their hosts. The province of the plant pathologist is particularly intriguing in this respect, for he has to study a complex of two organisms in relation to environmental conditions. The pioneers of plant parasitology such as the brothers Tulasne, de Bary,

[1a] *Zentralbl. f. Bakt.*, II, **91**, p. 243 (1935).
[2] *Jour. Agric. Res.*, **22**, p. 235 (1921).
[3] *Phytopathology*, **25**, p. 178 (1935).

Brefeld and Marshall Ward outlined some of the main features of the relations between parasitic fungi and their hosts, but the physiological interpretation of fungal parasitism has made greater strides in recent years, as was pointed out by Prof. V. H. Blackman in his presidential address to this Section in 1924. In particular, the mode of initiation of infection by fungus and bacterial parasites has been elucidated in no small degree, and the reactions of resistant varieties to attempted invasion by parasitic organisms have been interpreted to a considerable extent.

Before dealing with some of the wider aspects of modern research in plant pathology I will mention a few recent investigations which have had repercussions in the field of pure botany. Craigie,[4] in charge of the Dominion of Canada Rust Research Laboratory, in carrying out an intensive study of *Puccinia graminis*, discoveted that it was heterothallic and that its spermatia, hitherto believed to be functionless, were accessory ' fertilising ' agents. Drayton,[5] another Canadian plant pathologist, has discovered peculiar sexual arrangements in the genus *Sclerotinia* during his investigation of *S. Gladioli*, the cause of a serious disease of Gladiolus, and has demonstrated for this species at least that the microconidia are essential for fertilisation, although they were formerly thought to be of no importance in the life-cycle. In connection with the grafting of high-yielding strains of rubber trees on to seedling stocks in Malaya some failures occurred which led Sharples and Gunnery,[6] pathologists of the Rubber Research Institute there, to investigate the processes involved in the union of stock and scion, and their results are probably the most complete which have been published concerning the manner in which this union is established. A few years ago Tetley [7] compared, from the embryonic condition onwards, the development of plum leaves, silvered through the influence of *Stereum purpureum*, with that of healthy leaves, and she has added considerably to our knowledge of leaf development as an outcome of these investigations. Again, in connection with an intensive study of Silver-leaf disease my colleagues and myself [8] devised a method of injecting plum stems with non-living extracts of *Stereum purpureum* by means of which silvering of the foliage was induced without the intervention of the living fungus. This method of injection has obvious applications in certain physiological researches and has already been used in a modified form by Thomas and Roach [9] in investigations on the nutrition of fruit trees. These are a few of many illustrations which might be given of the intimate relationships between plant pathology and other branches of botany.

With regard to the wider aspects of recent researches in plant pathology I will first deal briefly with progress which has been made in the study of the epidemiology of certain parasitic diseases, i.e. the study of the distribution in space and time of the causative micro-organisms which develop epidemically under favourable conditions. The rapid onslaught of a parasitic disease on a cultivated crop is a striking phenomenon, and the

[4] *Phytopathology*, **21**, p. 1001 (1931).
[5] *Mycologia*, **26**, p. 46 (1934).
[6] *Ann. Bot.*, **47**, p. 827 (1933).
[7] *Ann. Bot.*, **46**, p. 633 (1932).
[8] *Jour. Pomology and Hort. Sci.*, **5**, p. 61 (1926). *New Phytologist*, **30**, p. 128 (1931).
[9] *Jour. Pomology and Hort. Sci.*, **12**, p. 151 (1934).

manner in which this comes about has only been explained for some of the most serious diseases during the last few years. To explain how a fungus epidemic disease arises it is necessary to know what is the source of the abundant inoculum and to understand the precise environmental conditions in which infection of the host and rapid spread therein can take place. Not so long ago a sudden outbreak of *Puccinia graminis* in the wheat crop was looked upon as being something akin to magic. This holds no longer, for researches in countries where this fungus is rife have explained almost completely how such epidemics arise. In countries with mild winters, like the southern United States and Australia, it is now known that *P. graminis* survives from season to season by means of uredospores, so that the intervention of the barberry bush is unnecessary; the same is true under somewhat different conditions for Kenya Colony. In the important wheat belt of North America, where epidemics of *P. graminis* are still severe, there are two serious sources of infection of the crop, as pointed out by Stakman [10]: firstly, æcidiospores from naturalised barberry bushes which have been infected from the teleutospores that survive on the straw of the previous crop notwithstanding the severity of the winter; and secondly, uredospores brought by winds from Mexico and Texas, for by using aeroplanes for trapping spores in the upper air it has been shewn that there is a drift of inoculum northwards. As might be expected from these considerations there is a lag in the time of development of epidemics of *P. graminis* as one proceeds northwards to the limit of wheat cultivation in Canada. One important outcome of these investigations has been the demonstration that spores of parasitic fungi can be distributed by wind in a living condition over a much greater distance than was formerly thought possible. In the plains of northern India the problem of the annual recurrence of *P. graminis* is of a different nature. The barberry plays no part in the life-cycle, but the difficulty there is to account for the over-summering of the fungus owing to the very high temperatures in the plains, which kill the uredospores. Mehta,[11] however, working for several years under great difficulties, has solved the problem. He has shewn that at altitudes of about 4,000 feet along the flank of the Himalayas uredospores on volunteer wheat plants and stubble survive the moderate summer temperatures; by this means the following wheat crop in the hills is infected during November and December, and the uredospore stage is maintained as the temperature does not fall sufficiently low to kill it. In this way a source of inoculum is provided in the hills, which is blown by the prevailing north-westerly winds to the wheat belt in the plains, where infection usually occurs at the end of January or early in February. Mehta has also demonstrated that similar foci of infection occur in the lower reaches of other mountainous regions in India. In Britain the barberry is necessary for the annual recurrence of *P. graminis* as the uredospores do not normally survive the vicissitudes of our winter climate. Unlike the position about a century or so ago, however, this fungus is no longer a menace here, for nowadays it generally attacks the cereal crops too late in the season to do appreciable harm.

[10] *Proc. Fifth Pacific Science Congress*, **4**, p. 3177 (1934).
[11] *Indian Jour. Agric. Sci.*, **3**, p. 939 (1933).

Other cereal rusts, e.g. *Puccinia glumarum* and *P. triticina*, are widespread in Britain in certain seasons. Both these fungi over-winter in England in the uredospore condition, sometimes undergoing prolonged incubation in the host during low temperatures, although more precise information is needed with regard to the duration of such incubation periods. Alternate hosts appear to play no part in the recurrence of *P. triticina* and *P. glumarum* in this country, and in fact no alternate host for the latter is known.

Much attention has recently been paid to the elucidation of the environmental conditions which promote epidemic outbreaks of potato Blight (*Phytophthora infestans*) and the Downy Mildew of the vine (*Plasmopara viticola*). By careful study of weather conditions warning can now be given in some countries as to the appropriate times for spraying these crops with protective fungicides.

The storage rots of citrus fruits, bananas and apples have now been intensively studied, and some interesting correlations have been traced between the distribution of the causative fungi in the plantations, including the prevalence of their spores in the air, and the rots which subsequently develop; this has been the subject of special investigation in apples by Horne [12] and Carter.[13] In this connection a somewhat similar occurrence in another mycological field may be mentioned. Mould growths occasionally develop on meat kept in cold storage for long periods, rendering the meat unsightly. There is evidence that unhygienic conditions in the abattoirs promote these mould growths. Such fungi develop readily on plant debris and animal excreta, so that if the air surrounding the carcases is heavily laden with spores the meat will become dusted with them. The spores subsequently germinate and produce unsightly growths unless appropriately low temperatures are constantly maintained.

In no branch of mycology has there been greater activity during the last decade than in the determination of physiologic or biologic forms of parasitic fungi, especially the Rusts and the Powdery Mildews. In general, these physiologic forms cannot be differentiated by morphological criteria, but only by their host relationships. In *Puccinia graminis* for instance more than one hundred clearly defined forms have been identified on wheat alone. The plant pathologist has now to visualise therefore the occurrence, within many species of fungi, of large complexes of forms which differ in their parasitic proclivities, and thereby the task of the plant breeder in producing resistant varieties of cultivated plants is sometimes greatly complicated. In the determination of these physiologic forms of parasitic fungi their reactions on a range of differential host varieties are studied under known environmental conditions. In work of this kind it is essential that the host varieties should be genetically pure and that the inoculation tests should be carried out on plants at the same stage of development within precise limits of temperature, light, humidity and mineral nutrition, for variations in these respects may cause profound disturbances in the infection picture.

[12] *Rep. Food Investigation Board*, 1932, p. 285. *Proc. Roy. Soc.*, *B*, **117**, p. 154 (1935).
[13] *Trans. Brit. Myc. Soc.*, **19**, p. 145 (1935).

Thanks to the researches of Stakman and Levine[14] in the United States, Newton and Johnson[15] in Canada, Waterhouse[16] in Australia, Macdonald[17] in Kenya, Mehta[18] in India, and Verwoerd[19] in South Africa much is now known about the physiologic forms of *Puccinia graminis* on wheat. Johnston and Mains[20] in the United States, Scheibe[21] in Germany and Mehta[22] in India have described many forms of *Puccinia triticina*, Gassner and Straib[23] in Germany have shewn that *Puccinia glumarum* consists of a complex of forms, and so on with many other fungi which are obligate parasites. Work has been proceeding recently at Cambridge concerning the physiologic forms of *Puccinia triticina*, *P. glumarum* and *P. coronata* which occur in Britain. With *P. triticina* and *P. glumarum* several forms have been determined which have not hitherto been described on the Continent of Europe or elsewhere notwithstanding the great attention which has been paid to these fungi. This is a somewhat surprising result and points perhaps to independent mutational changes here.

An interesting question of nomenclature has arisen out of Gassner and Straib's investigations on *Puccinia glumarum*. Many years ago Eriksson,[24] who was the pioneer investigator of specialised parasitism in the Cereal Rusts, divided *P. glumarum* into *P. glumarum Tritici*, *P. glumarum Hordei*, *P. glumarum Secalis*, etc., thinking that each trinomial indicated a distinct physiologic form. More recently it has been held that *P. glumarum Tritici*, for example, comprises a number of forms, all of which were thought to be confined to wheat. Gassner and Straib,[25] however, have now shewn that this trinomial nomenclature is invalid, for some forms of *P. glumarum* will readily infect wheat, barley and rye provided that the variety range of each cereal is sufficiently extensive. Whether the same considerations apply to the nomenclature of *Puccinia graminis* is not yet known. Here there are *P. graminis Tritici*, *P. graminis Avenæ*, *P. graminis Secalis*, etc., each containing many forms. Certain forms of *P. graminis Tritici* and *P. graminis Secalis* are known to infect some barley varieties, and Mehta[26] shewed that *P. graminis Secalis* in England would infect a variety of wheat called Red Sudan. Logically it might be desirable to drop the trinomial nomenclature for *P. graminis*, but owing to the immense number of physiologic forms of this fungus it will probably be found convenient to retain it.

In other types of parasitic fungi, including species of *Fusarium* which infect the underground parts of their hosts, distinct physiologic forms or

[14] *Minnesota Agr. Exp. Sta., Tech. Bull.* 8 (1922).
[15] *Dept. Agric. Canada, Bull. No.* 160, *N.S.*, (1932).
[16] *Proc. Linn. Soc. of New South Wales*, **54**, p. 615 (1929).
[17] *Trans. Brit. Myc. Soc.*, **18**, p. 218 (1933).
[18] *Indian Jour. Agric. Sci.*, **3**, p. 939 (1933).
[19] *S. African Jour. Science*, **28**, p. 274 (1931).
[20] *U.S. Dept. Agric., Tech. Bull. No.* 313 (1932).
[21] *Arb. a. d. Biolog. Reichsanst.*, **18**, p. 55 (1930).
[22] *loc. cit.*
[23] *Arb. a. d. Biolog. Reichsanst.*, **21**, p. 121 (1934).
[24] *Ber. d. deut. bot. Ges.*, **12**, p. 292 (1894).
[25] *loc. cit.*
[26] *Trans. Brit. Myc. Soc.*, **8**, p. 142 (1923).

strains are known which differ in pathogenicity. In *Fusarium cubense*, the cause of the devastating Panama or Wilt disease of bananas in the West Indies and Central America, Hansford[27] has shewn that some strains, morphologically indistinguishable from *F. cubense*, are non-pathogenic to the banana. *Botrytis cinerea* comprises innumerable small genetic units which differ appreciably in morphological characters and to some extent in pathogenicity, as demonstrated by Brierley.[28] As research extends and as these forms hitherto included in *Botrytis cinerea* become more clearly differentiated by morphological and cultural criteria some of them are elevated to the rank of distinct species.

How have these innumerable minor forms of parasitic fungi arisen? Doubtless hybridization between genetically different strains of fungi which reproduce themselves sexually has played an important part in their evolution, as has been demonstrated for *Puccinia graminis* in North America and Australia. But how did these inherently different strains of sexually reproducing fungi arise? They may, of course, be the outcome of sexual interactions in the distant past, but this does not entirely account for their abundance at the present time. Although evolution may proceed mainly by the interactions of dissimilar gametes, as claimed by some authorities, there is abundant evidence in the fungi that evolution has occurred to a considerable extent by gene mutation. Sexual processes rarely occur in the life-cycle of *Puccinia triticina* and its sexual stage probably does not exist in this country. *Puccinia glumarum* is now probably entirely asexual. Yet in both these fungi there are many physiologic forms. It seems likely, therefore, that evolution in such fungi as regards pathogenicity has proceeded by changes of a mutational character. Mutants in fungi commonly arise as regards colour and other cultural characteristics without the intervention of sexual processes, so it is not surprising if changes in pathogenicity occur in the same manner. Some such changes have been observed under experimental conditions. For instance, Miss F. M. Roberts[29] in her investigation of the British physiologic forms of *Puccinia triticina* has found that one form, which had been stable during a long succession of uredospore generations, suddenly gave rise to a form which differed markedly in pathogenicity from the parental stock. Such a change can only be accounted for by mutation, for the original culture was started from a single spore so that any question of an admixture of forms can be ruled out.

It may be asked whether these physiologic forms of fungi are stable entities. There is no doubt that in general they are, apart from occasional alterations through hybridisation and gene mutation. Although these forms are usually constant in their parasitism it would be rash to be too dogmatic about the matter. Miss Roberts has discovered one form of *Puccinia triticina* which seems to be genetically unstable in its behaviour on the differential host varieties: under constant environmental conditions it apparently varies in pathogenicity at different times.

The prevailing opinion of the general stability of physiologic forms of

[27] *Kew Bulletin*, p. 257 (1926).
[28] *Ann. App. Biol.*, **18**, p. 420 (1931).
[29] Cambridge Ph.D. thesis, 1935 (not yet published).

parasitic fungi as regards their host relationships may be contrasted with the views of Marshall Ward [30] who believed in their 'educability' to live upon hosts which they did not normally attack. As an outcome of his researches on the Brown Rust of brome grasses he believed that certain host species and varieties enabled a particular physiologic form of the fungus to pass from one group of species of the genus *Bromus* to another. His hypothesis of the existence of 'bridging hosts' has not, however, been substantiated by later work, and the evidence now available tends to invalidate the conception that fungi can be easily 'educated' to attack new hosts. In N. America barley is readily affected by a form of *Puccinia graminis Tritici* which attacks wheat strongly and rye feebly, and also by a form of *P. graminis Secalis* which attacks rye but not wheat. It might be thought, therefore, that barley would act as a 'bridging host' and would enable the form of *P. graminis Secalis* to pass from rye to wheat. Stakman and others,[31] however, have shewn that even if the form from rye is cultivated constantly on barley for many uredospore generations it does not become capable of attacking wheat. Since Marshall Ward enunciated his hypothesis of 'bridging hosts' the technique for the investigation of physiologic forms has been much improved. Nowadays it is considered necessary to establish cultures from single spores because of the known occurrence in nature of mixtures of forms, sometimes even in the same spore pustule, and special precautions are taken to prevent contamination of the stock cultures. Mr. P. W. Brian has been carrying out at Cambridge a re-investigation of the host relationships of the Brown Rust of brome grasses by modern methods. The results which he has obtained so far do not support Marshall Ward's conception of 'bridging hosts.' The latter's results appear to be explicable on the basis of the existence of more physiologic forms than had then been identified and by the possible intermixture of different forms in the spores used for inoculation. Marshall Ward's hypothesis of the 'educability' of parasitic fungi is nevertheless a fascinating one and evidence for it may yet be forthcoming.

One of the most striking features of heterœcious fungus parasites is the contrast between their frequent extreme specialisation to one or a few particular hosts during one phase of the life-cycle and their ability to live upon entirely unrelated hosts at different stages in the life-cycle. Heterœcism is, of course, a common feature of parasitism in general, but we have no precise clue as to its origin even though the biological advantages of this mode of life are evident. It is remarkable, for instance, that *Puccinia Pruni-spinosæ* occurs only on certain species of *Prunus* during one part of its life-cycle and only on a few species of *Anemone* during another. On the other hand a rust fungus may have a wide range of hosts during one phase of its life, although this may perhaps be wholly or partly due to the existence of different physiologic forms, and a single unrelated host for the remainder of its life. Further information is needed as to whether an apparently wide host range for one phase in the life-history of such fungi is often due to a multiplicity of physiologic forms: probably it is not, for in *Puccinia glumarum* certain forms thrive both on wheat and barley.

[30] *Annales Mycologici*, **1**, p. 132 (1903).
[31] *Jour. Agr. Res.*, **15**, p. 221 (1918).

The extreme dissimilarity in systematic relationship between the teleutospore and æcidiospore hosts in the heterœcious Rusts is very striking. The metabolism of the dissimilar hosts is probably vastly different, yet the fungus flourishes during both its alternating phases. The divergence between the teleutospore and æcidiospore hosts cannot be wholly bound up with the usual stomatal infection of the former and cuticular penetration of the latter, for unless there are important metabolic differences between the two phases of the fungus it is difficult to understand why the æcidiospores do not infect, by way of the stomata, the host on which they are produced since they infect the alternate host in this manner. It may be thought that change of host is correlated with an alteration of the fungus from the haploid to the diploid condition, or *vice versa*, but so far as the sexual processes of the few heterœcious Ascomycetes are understood this does not apply, nor does the correlation hold good for the heterœcious worms among animal parasites. If we try to understand heterœcism on a genic basis we may perhaps suppose that in a heterœcious fungus there are two genes or sets of genes controlling metabolism which become separately active during the different phases of the life-cycle. It is easier to visualise heterœcism arising suddenly by a large change than to conceive of its evolution by a succession of minute variations. In connection with heterœcism in the Rust Fungi further information is required as to what happens when æcidiospores and sporidia are placed on the hosts from which they have been derived and also on other plants which play no part in the perpetuation of these fungi, comparable with the knowledge which is available about the behaviour of uredospores on inappropriate hosts. Gibson [32] shewed some years ago that uredospores germinated normally on inappropriate hosts and formed appressoria over the stomata and vesicles below the stomata, from which hyphæ grew out ; these, however, were unable to establish haustoria in the mesophyll cells and speedily died. Mrs. Hanes [33] has recently shewn that on inappropriate hosts which are fairly closely related to the proper ones the behaviour of the germinating uredospores is sometimes of another kind. In the cereal rusts, for instance, if uredospores are placed on leaves of the wrong cereal the initiation of infection is normal, but at a slightly later stage there is sometimes a violent reaction between parasite and host which leads to the death of the mesophyll cells involved ; the fungus then makes no further progress in the tissues. Such behaviour is comparable with the well-known hypersensitiveness of resistant host varieties to specific rust fungi.

With the Powdery Mildews (Erysiphaceae) Corner [34] has shewn that on inappropriate hosts the early stages of penetration are the same as on the proper host, i.e. the cuticle is pierced mechanically by a stylar process which in its passage through the cellulose part of the wall is preceded by a local swelling of the latter, the papilla. The penetration process, however, usually develops no further in the inappropriate host and is probably killed by toxic substances in the ' host ' cell.

In contrast to the extreme specialisation of obligately parasitic fungi to

[32] *New Phytologist*, **3,** p. 184 (1904).
[33] Cambridge Ph.D. thesis, 1933 (not yet published).
[34] *New Phytologist*, **34,** p. 180 (1935).

their hosts, many fungi which invade the host tissues through wounds and which can live also in a purely saprophytic manner generally shew no pronounced degree of specialisation to particular hosts. *Stereum purpureum* from a birch stump, for instance, can attack a wide range of living trees such as plum, apple and laburnum, and *Polyporus squamosus* can invade many kinds of broad-leaved trees. Apart from *Stereum purpureum* and a few other species there is little precise information yet available concerning the initiation of infection by fungi which obtain entry into the host through exposures of the wood. We do not know exactly, for example, how such common fungi as *Polyporus squamosus* and *P. betulinus* infect living trees. With *Stereum purpureum* Moore and I [35] have shewn that prior to infection the spores are usually sucked a considerable distance into the vessels, where their germ tubes are in less danger of desiccation than on the exposed surface. In this connection it is of interest that the spores of most of these wound parasites are much narrower than the diameter of the vessels in the wood of their hosts. Experiments with many such fungi indicate that under certain conditions the spores are readily drawn into the vessels, and this is probably an important factor in the initiation of attack by fungi of this class. Again, *S. purpureum* much more readily invades fresh wounds in the wood than those which have remained under the influence of the host's response to wounding and the action of other micro-organisms.[36] This fungus can also infect new wounds with greater facility at some periods of the year than at others, probably in correlation with the varying metabolic condition of the tree. Whether such factors operate in connection with other fungi which infect their hosts through exposures of the wood is not known. In large trees the heart wood differs greatly from the sap wood, especially in containing no living cells. It is known in a general way that some fungi, e.g. *Polyporus squamosus*, attack the heart wood more vigorously than the sap wood, whereas others spread chiefly in the sap wood, but further information is required concerning the influence of these two classes of woody tissues on the initiation of invasion by fungi. There is also a wide field for further research on the early stages of infection of plant tissues by other classes of fungi which live sometimes as saprophytes and sometimes as parasites. Thanks to Marshall Ward,[37] Blackman and Welsford,[38] Brown [39] and others we now have an almost complete picture of the initiation of parasitism by *Botrytis cinerea* and allied fungi in which the secretion of toxic enzymic substances plays the principal rôle. It is perhaps in the initiation of attack that the most interesting features of fungal parasitism are shewn. This is exemplified in Green's [40] recent investigations on the rots of oranges caused by *Penicillium digitatum* and *P. italicum*, mould fungi which are familiar to everyone. In addition to infection through wounds these fungi can infect perfectly sound fruits under certain conditions, although the outer yellow

[35] *Proc. Cambridge Philosophical Soc. (Biolog. Sci.)*, **1**, p. 56 (1923).
[36] *Jour. Pomology and Hort. Sci.*, **5**, p. 61 (1926).
[37] *Ann. Bot.*, **2**, p. 319 (1888).
[38] *Ann. Bot.*, **30**, p. 389 (1916).
[39] *Ann. Bot.*, **29**, p. 313 (1915).
[40] *Jour. Pomology and Hort. Sci.*, **10**, p. 184 (1932).

rind is very resistant to invasion. If these moulds are grown in orange juice they produce substances, perhaps enzymic, which cause the pectic decomposition of the outer rind, thereby destroying its resistance to attack. In this way the spread of rotting from one mouldy orange to sound fruits in contact with it can be accounted for. On the other hand, if these fungi are grown on the usual synthetic media they are incapable of producing this resistance-destroying system, as Green terms it. This is an interesting illustration of the fact that the biochemistry of micro-organisms varies considerably according to the nature of the substratum on which they grow.

Another branch of plant pathology which is receiving much attention at the present time and which will probably assume greater importance in the future is the influence of one micro-organism on another in the establishment of disease. In ecology generally the factors of competition and the influence of one plant on another have long been held to be of supreme importance. The effect of such interactions is now receiving attention from plant pathologists, and the judicial consideration of factors of this kind will lead to a better ecological interpretation of the incidence of disease in plants. Fawcett [41] has already stressed the importance of this aspect of plant pathology.

The effects of associations of micro-organisms in culture are often profound. A mixed culture of two organisms can often produce a result which neither of them alone can induce. Such an effect has been termed 'synergism' by Holman and Meekison.[42] One organism may change the substratum so that it becomes suitable for the growth of the other, but the interactions of the two associates on the original medium are sometimes of a more intricate nature. For associations of bacteria the literature has been reviewed by Buchanan and Fulmer,[43] and this has been done to some extent for fungi by Harder,[44] Porter [45] and Machacek.[46] The sequence of fungi on natural substrata is related to such associations. On a tree log, for instance, a succession of different fungi usually develops in orderly sequence over a period, one species apparently preparing the way for another. An analysis of the factors which determine such a succession would be of great interest. The effects of combinations of specific yeasts and bacteria are illustrated by the fermentation processes induced by the ginger-beer plant and by kephir grains. The influences of micro-organisms on one another in culture may be very diverse: instead of producing an effect which neither alone can bring about, one organism may greatly stimulate the activity of the other or may completely inhibit it, or the two organisms may be entirely indifferent to one another. In Nature associations of diverse micro-organisms are the rule rather than the exception, so it is important for the microbiologist and the plant pathologist to study these complexes.

[41] *Phytopathology,* **21,** p. 545 (1931).
[42] *Jour. Infectious Diseases,* **39,** p. 145 (1926).
[43] *Physiology and Biochemistry of Bacteria,* vol. iii (1930).
[44] *Naturw. Zeitschr. Landw. Forstw.,* **9,** p. 129 (1911).
[45] *Amer. Jour. Bot.,* **11,** p. 168 (1924).
[46] *Macdonald College, McGill University, Tech. Bull. No.* 7 (1928).

In the domain of plant pathology I will first mention some examples in which a host, attacked by one fungus, is thereby rendered more susceptible to a second fungus. If a variety of wheat normally resistant to *Puccinia glumarum* is attacked by bunt (*Tilletia Caries*) it becomes susceptible to the rust, the effect of the bunt mycelium being apparently to break down the resistance to the rust. Again, Johnston [47] and Roberts [48] have shewn that if a variety of wheat normally resistant to *Puccinia triticina* is affected by *Erysiphe graminis* it becomes susceptible to the rust in the immediate vicinity of the patches of mildew. Fawcett [49] has indicated that combined inoculations of *Diplodia natalensis* and *Colletotrichum glœosporioides* into slight wounds in the bark of citrus trees produced a much greater effect than did either organism applied alone. In another series of experiments on citrus trees he [50] found that inoculations of *Phytophthora citrophthora* combined with a *Fusarium* led to the formation of more rapidly enlarging lesions than did inoculations with the *Phytophthora* alone ; the *Fusarium* introduced by itself did not spread at all, so that in this instance an innocuous organism facilitated the progress of the parasite.

In a bacterial disease of cocksfoot grass (*Dactylis glomerata*) my colleague Dr. Dowson [51] has found, as Smith [52] had previously indicated, that the predominant yellow bacterium (*Bacterium Rathayi*) is constantly associated with a white bacterium : inoculations with the slime containing both organisms reproduce the disease but all inoculations with the yellow bacterium alone have failed.

In recent investigations on virus diseases of plants, Kenneth Smith [53] and others have demonstrated that the symptom expression of a complex or association of two viruses in certain hosts is quite different from that of either virus acting alone. Viruses profoundly modify the metabolism of the plants they infect and a promising line of enquiry is the influence which they have on the incidence of specific fungus and bacterial diseases. In this connection Prof. Murphy of Dublin informs me that the potato variety Champion, which is the early days of its cultivation in Ireland was very resistant to *Phytophthora* Blight and is now very susceptible, has, in his opinion, lost its resistance through more or less universal mosaic infection. This opinion is borne out by the investigations of Davidson,[54] who has shewn that virus-free stocks of this variety are still markedly resistant to Blight.

On the other hand, the effect of micro-organisms on one another is frequently one of antagonism. Two organisms may mutually inhibit the development of each other, or one may be greatly impeded in its growth by the other. In the latter case one organism may exercise some toxic influence on the other or it may utilise the available food material so rapidly as to starve the second organism. Factors of this kind may perhaps

[47] *Phytopathology*, **24**, p. 1045 (1934).
[48] Cambridge Ph.D. thesis, 1935 (not yet published).
[49] *Florida Agric. Exp. Sta., Annual Report*, 1912.
[50] *Jour. Agr. Res.*, **24**, 191 (1923).
[51] *Ann. App. Biol.*, **22**, p. 23 (1935).
[52] *Bacteria in Relation to Plant Diseases*, vol. iii, p. 155 (1914).
[53] *Proc. Roy. Soc., B*, **109**, p. 251 (1931).
[54] *Econ. Proc. Roy. Dublin Soc.*, **2**, p. 319 (1928).

play an important part in the specificity of saprophytism exhibited by certain fungi. The first fungus to appear on a newly exposed oak stump is commonly *Stereum hirsutum* whereas on a birch stump *S. purpureum* takes this position. In the laboratory these fungi can be grown in culture both on oak and on birch wood. Both fungi are widespread and their spores are probably equally abundant in the air so that their chances of alighting on oak and birch stumps are similar. Allowing that oak wood is initially slightly more favourable for the growth of *S. hirsutum* than for *S. purpureum*, at a later stage the permeation of the wood already by *S. hirsutum* probably prevents the development of *S. purpureum*. As previously indicated the occupation of exposed wood in plum trees by comparatively harmless micro-organisms tends to prevent subsequent invasion by the dangerous *Stereum purpureum*.

In plant pathology there is now a large mass of data concerning the inhibiting effect sometimes evident of one organism on another. In many instances the inhibiting organism is purely saprophytic, but more rarely two pathogenic organisms inhibit each other. Fawcett and Lee [55] record that on inoculating the fungus *Dothiorella gregaria* and the bacterium *Pseudomonas juglandis* together into walnut branches no lesions were formed, although *D. gregaria* is parasitic on the branches and *P. juglandis* causes a blight of the leaves and young stems ; here the bacterium inhibited the pathogenicity of the fungus in the branches. Of particular interest and of great importance is the antagonism shewn by certain saprophytes to pathogenic fungi which invade the underground parts of their hosts : indeed it is not too much to say that a new chapter in soil microbiology has been opened with the recognition of this factor of biological antagonism. In 1924 Porter [56] shewed that inhibition of infection of wheat seedlings by *Helminthosporium* resulted when a certain bacterium as well as the fungus was introduced into the surrounding soil, and that there was considerable delay in the infection of flax seedlings by *Fusarium Lini* when the same bacterium was included in the soil. The manner in which such inhibition is brought about is unknown, but perhaps the bacterium in its growth produces some substance which is toxic to the fungus. In 1923 Millard [57] demonstrated that *Actinomyces scabies*, a commonly occurring soil organism which causes potato Scab, could be prevented from attacking potatoes by incorporating large quantities of green manure in the soil. Millard and Taylor [58] subsequently shewed that when another, purely saprophytic, species of *Actinomyces*, *A. præcox*, was incorporated in the soil with *A. scabies* the latter was suppressed. They suggest, therefore, that in green manuring for the control of potato Scab saprophytic species of *Actinomyces*, and perhaps also soil bacteria, are favoured to such an extent in competition with *A. scabies* that the latter is inhibited. More recent work on the antagonism of other soil micro-organisms to infection by pathogenic fungi in the soil has been ably reviewed by Garrett,[59] but

[55] *Citrus Diseases and their Control*, p. 38 (1926).
[56] *Amer. Jour. Bot.*, **11**, p. 168 (1924).
[57] *Ann. App. Biol.*, **10**, p. 70 (1923).
[58] *Ann. App. Biol.*, **14**, p. 202 (1927).
[59] *Biolog. Reviews*, **9**, p. 351 (1934).

there are some features of these investigations to which I would like to refer. Simmonds[60] in Canada first directed attention to the rapid deterioration of inocula of fungi which cause foot-rot of cereals when added to unsterilised soil, an effect which was attributed by Broadfoot[61] to the antagonism of other micro-organisms in the soil. Henry[62] shewed that the growth of *Helminthosporium sativum*, one of the fungi causing foot-rot of wheat, in sterilised soil might be completely suppressed by adding small quantities of unsterilised soil or by simultaneous inoculation of the sterilised soil with certain other fungi and bacteria. In a later paper Henry[63] has elucidated some puzzling results concerning the effect of temperature on the pathogenicity of some of these foot-rotting fungi. Since the optimum temperature for the growth of wheat seedlings is about 15° C. and that for the growth of the foot-rotting fungi ranges from 24° C. to 30° C., it might be thought that there would be a greater incidence of foot-rot at 24° C. than at 15° C. The reverse effect, however, is sometimes seen. Henry explains the decrease in infection by *Ophiobolus graminis* with rise of temperature in unsterilised soil as being due to the antagonism of other soil micro-organisms to the pathogen, which is not operative at the lower temperature. In sterilised soil there is the expected increase in infection by this fungus with rise of temperature to about 24° C., and Garrett[64] has found that in a naturally occurring sand in South Australia, which is practically devoid of micro-organisms, *O. graminis* is most pathogenic at 24° C.

Further work will doubtless elucidate the nature of this antagonism to pathogenic fungi in the soil, which is exhibited by other constituents of the micro-flora. It may be that saprophytic organisms sometimes starve out the pathogenic fungus, but another explanation is that the saprophytes secrete toxins which kill the pathogen. One example of antagonism has been elucidated by Weindling[65] in the latter manner. He has shewn that the saprophytic fungus *Trichoderma lignorum* secretes a lethal principle which destroys the hyphae of *Rhizoctonia Solani*, one of the common causes of the ' damping off ' of seedling plants. By adding *Trichoderma* spores to *Rhizoctonia*-infested soil under conditions which favour the secretion of the toxic principle he has been able to control this disease in citrus seedlings. Weindling's results concerning the toxic influence of *T. lignorum* on certain pathogenic fungi in the soil have been confirmed by Allen and Haenseler.[66] Pathogenic fungi which live in the soil are notoriously difficult to control. When more is known about the antagonism of other micro-organisms to them it may be possible to devise methods of biological control, such, for example, as altering soil conditions in such a way as to favour the antagonistic action of other members of the micro-flora. Some interesting data on this subject have been presented

[60] *Report of Dominion Botanist, Canada,* 1927, p. 98.
[61] *Report of Dominion Botanist, Canada,* 1930, p. 92.
[62] *Canadian Jour. Res.,* **4,** p. 69 (1931).
[63] *Canadian Jour. Res.,* **7,** p. 198 (1932).
[64] *Jour. Agric. South Australia,* **37,** p. 664 (1934).
[65] *Phytopathology,* **22,** p. 837 (1932).
[66] *Phytopathology,* **25,** p. 244 (1935).

by King, Hope and Eaton,[66a] who have found in Arizona that the application of organic manures to soil infested by the cotton root-rot fungus (*Phymatotrichum omnivorum*) greatly reduces the disease. They consider that the organic manures so stimulate other soil organisms as to bring about conditions unfavourable for the root-rot fungus. The fungi causing foot-rot of cereals are very diverse, and further study of biological antagonism may throw light upon the reasons why this disease is chiefly caused by *Fusarium culmorum* in England, by *Ophiobolus graminis* in South Australia, by *Helminthosporium sativum* in New South Wales, and by *O. graminis*, *H. sativum*, *Gibberella Saubinetii* and *Fusarium spp.* respectively in different parts of Canada and the United States.

Much attention is being paid at present to the fungus root diseases of perennial tropical crops such as rubber, tea, cocoa and oil-palms. The plantations are often established in land previously under high forest in which these pathogenic fungi are indigenous, but in which root diseases never assume alarming proportions. When the jungle is felled, however, and a rubber plantation for instance is made, the balance of nature is upset, with the result that fungi such as *Fomes lignosus* and *Ganoderma pseudoferreum* spread underground rapidly by means of rhizomorphs and become a potential menace to the plantation. Considerable progress has already been made towards a proper ecological interpretation of this class of root diseases, and I should like to pay a tribute to the work accomplished by tropical mycologists in this respect, especially in Malaya, Ceylon, the Gold Coast and the West Indies.

Certain important bacterial diseases of plants have been intensively studied in recent years, especially as regards their incidence in relation to environmental conditions. When I was a student there was considerable scepticism as to whether bacteria were ever pathogenic to plants, but it is now universally acknowledged that many serious plant diseases are caused by these organisms. I can refer to only a few investigations in this field. Stoughton [67] has made a special experimental study of the environmental conditions requisite for infection by *Bacterium malvacearum*, which causes the ‘ black-arm ’ or ‘ angular leaf spot ’ disease of cotton in the Sudan, Uganda and other countries, and Massey [68] and Hansford and others [69] have made notable contributions to our knowledge of the epidemiology of this disease in the field. Riker and his colleagues [70] in the United States have thrown further light on the Crown Gall disease of numerous plants caused by *Bacterium tumefaciens*, and have clearly distinguished the galls produced by it from the overgrowths which are sometimes the response to wounding. Wormald [71] has shewn that one of the most serious diseases of plum trees in this country is caused by *Bacterium mors-prunorum*. Day [72] has brought forward evidence that the ‘ watermark ’ disease of the cricket-bat willow in the eastern counties of England

[66a] *Jour. Agr. Res.*, **49**, p. 1093 (1934).
[67] *Ann. App. Biol.*, **20**, p. 590 (1933).
[68] *Empire Cotton Growing Review*, **11**, p. 188 (1924).
[69] *Ann. App. Biol.*, **20**, p. 404 (1933).
[70] *Jour. Agr. Res.*, **48**, pp. 887 and 913 (1934).
[71] *Jour. Pomology and Hort. Sci.*, **9**, p. 239 (1931).
[72] *Oxford Forestry Memoirs*, No. 3, 1924.

is caused by a bacterium, and Dr. Dowson is carrying out further investigations on this disease, an account of which will be given during the present meeting.

Time does not permit me to deal with the important advances which have been made recently in our knowledge of the innumerable diseases of plants caused by viruses—some of which are of great importance—and of the properties of the viruses themselves, but Dr. Kenneth Smith, one of the most successful workers in this field, will discuss some of the more notable of these advances during the meeting. I will only add that these remarkable ultra-microscopic agents of disease should be of interest to all biologists for they may belong to a borderline territory between the living and the non-living.

During the early development of plant pathology little attention was paid to the study of disease in plants of a functional kind, *i.e.* to disease not induced by parasitic agency. For a long time information about this class of diseases was fragmentary and vague, and in some respects this statement is still true. In certain ways non-parasitic diseases of plants are more difficult to investigate than those due to parasites, and not much progress can be made with the elucidation of some of them until more is known about normal plant physiology. Some notable advances have been made, however, in the understanding of certain diseases of this class, and some of these investigations have resulted in important contributions to plant physiology. This is especially true of diseases which are caused by insufficiency of elements in the soil that had not hitherto been suspected of being of importance in plant nutrition. Warrington [73] and Brenchley [74] startled the botanical world some years ago by demonstrating that boron was an essential element in the proper nutrition of certain green plants. Since then Brandenburg [75] has suggested that boron-deficiency in the soil is the cause of the serious 'heart-rot' disease of sugar beet and mangolds. Another element having the property—formerly unsuspected—of exercising an important rôle in the nutrition of some plants is manganese. It has long been known that oats did not thrive on certain soils unless salts of manganese were added. On such land the oats were stunted in growth, the leaves were affected by grey blotches, and the plants died prematurely, the disease being known as 'grey leaf' or 'grey-speck.' Small amounts of manganese sulphate applied to the soil enabled a healthy crop to be grown. Samuel and Piper [76] have shewn by careful experiments that minute quantities of manganese must be available in the soil to allow of the normal nutrition of oats and certain other plants. Such a disease as that of 'grey leaf' of oats is now known as a 'manganese deficiency' disease. Another interesting example of the importance of nutritional factors in the maintenance of well-being in crop plants is afforded by the researches of Storey and Leach [77] on a grave disease of tea bushes in Nyasaland, which causes chlorosis and rapid death. They have demonstrated that this disease is

[73] *Ann. Bot.*, **37**, p. 629 (1923).
[74] *Ann. Bot.*, **41**, p. 167 (1927).
[75] *Phytopath. Zeitschrift*, **3**, p. 499 (1931).
[76] *Ann. App. Biol.*, **16**, p. 493 (1929).
[77] *Ann. App. Biol.*, **20**, p. 23 (1933).

due to insufficiency of available sulphur in the soil; it can be speedily remedied by the application of sulphur or salts containing sulphur. Several of the functional diseases of apples in storage, some of which are caused by respiratory disturbances, have been investigated by plant physiologists at the Low Temperature Research Station, Cambridge, and by pathologists in the United States and Australia. I will refer briefly to one of these troubles. For many years large losses had been incurred in the importation of apples from the Antipodes into this country, owing to the disease known as ' brown heart,' which is characterised by a brown discoloration of the flesh between the skin and the core. Kidd and West [78] shewed that this condition was brought about by disturbances in the respiration of the cells of the apple owing to the accumulation of a high percentage of carbon dioxide in the atmosphere surrounding the fruit in the holds of the ships. Nowadays greater care is taken than formerly to ensure adequate ventilation in the holds of ships carrying cargoes of apples, with the result that ' brown heart ' has been practically eliminated. Another kind of plant injury that is receiving renewed attention is that caused by frost. In this connection I have time only to refer to the damage sustained by the larch tree in Britain by late spring and early autumn frosts. Day and Peace [79] claim, I think justifiably, that much of the canker or blister disease of the larch tree, generally believed to be due to a species of *Dasyscypha*, is primarily caused by such frosts, which kill groups of active cambium cells. There is still an enormous field for research on the functional disorders of plants not caused by parasitic organisms, and it is particularly in this branch of the study of disease in plants that the help of the physiologist is required.

Plant pathology is a subject with wide ramifications and many-sided interests. It is an important connecting link between botany and crop husbandry, and the economic importance of the study of plant diseases is self-evident. From the academic standpoint research in plant pathology is becoming more and more closely associated with physiology, and it is clear that future advances in the understanding of disease in plants will become more and more dependent upon the use of analytical methods similar to those employed by the physiologist. In this address I have tried to shew that plant pathology has a contribution to make to our knowledge of botany in general and that many pathological investigations are of interest to the pure botanist. Furthermore, just as researches in medical science have added greatly to our comprehension of the attributes of protoplasm so does plant pathology provide an instrument for increasing our knowledge of general biological principles.

[78] *Dept. Sci. and Indust. Res., Food Investig. Bd., Spec. Rep. No.* 12, 1923.
[79] *Oxford Forestry Memoirs, No.* 16, 1934.

SECTION L.—EDUCATIONAL SCIENCE.

EDUCATION AND FREEDOM

ADDRESS BY

A. W. PICKARD-CAMBRIDGE, D.Litt., LL.D., F.B.A.,

PRESIDENT OF THE SECTION.

It has not been unusual at the meetings of the British Association to discuss questions which have a peculiar practical interest and I venture to

British Association, Norwich, 1935.

SECTION K: PRESIDENT'S ADDRESS: CORRIGENDUM.

Page 170, line 21. *For* Tanner *read* Trimmer.

P.T.O.

the individual to the State, not only in his external life and action, but also, so far as education and propaganda can achieve it, in thought and will. In all three countries the methods adopted have been essentially the same—the ruthless exercise of force, the extermination of persons who seemed likely to be irreconcileable, and thereafter the continuing threat of death, imprisonment and loss of goods, the employment of espionage in its most inhuman and revolting forms, creating distrust between members of the same family and between friends who seemed inseparably united, and the enforcement of methods of education and psychological manipulation calculated to mould impressionable minds into one and the same rigid and uniform shape, and to permit no independence of judgment or of action. The suppression of truth and the propagation of convenient falsehoods have been regular elements in the system. Any due to insufficiency of available sulphur in the soil; it can be speedily remedied by the application of sulphur or salts containing sulphur. Several of the functional diseases of apples in storage, some of which are caused by respiratory disturbances, have been investigated by plant physiologists at the Low Temperature Research Station, Cambridge, and by pathologists in the United States and Australia. I will refer briefly to one of these troubles. For many years large losses had been incurred in the importation of apples from the Antipodes into this country, owing to the disease known as 'brown heart,' which is characterised by a brown discoloration of the flesh between the skin and the core. Kidd and West [78] shewed that this condition was brought about by disturbances in the respiration of the cells of the apple owing to the accumulation of a high percentage of carbon dioxide in the atmosphere surrounding the fruit in the holds of the ships. Nowadays greater care is taken than formerly to ensure adequate ventilation in the holds of ships carrying cargoes of apples, with the result that 'brown heart' has been practically eliminated. Another kind of plant injury that is receiving renewed

British Association, Norwich, 1935.

SECTION L: PRESIDENT'S ADDRESS: NOTE.

Page 190. Mr. Wells has informed me that the paragraph which refers to his book "The Shape of Things to Come" misrepresents it. I am sorry if this is so, though after re-reading the book I cannot see that the paragraph misdescribes what is to be found there. But I am content that our readers should judge for themselves, and I am therefore anxious that his disclaimer should be known to them.—A. W. P.-C.

P.T.O.

of botany in general and that many pathological investigations are of interest to the pure botanist. Furthermore, just as researches in medical science have added greatly to our comprehension of the attributes of protoplasm so does plant pathology provide an instrument for increasing our knowledge of general biological principles.

[78] *Dept. Sci. and Indust. Res., Food Investig. Bd., Spec. Rep. No.* 12, 1923.
[79] *Oxford Forestry Memoirs, No.* 16, 1934.

SECTION L.—EDUCATIONAL SCIENCE.

EDUCATION AND FREEDOM

ADDRESS BY

A. W. PICKARD-CAMBRIDGE, D.Litt., LL.D., F.B.A.,

PRESIDENT OF THE SECTION.

It has not been unusual at the meetings of the British Association to discuss questions which have a peculiar practical interest and I venture to offer some observations on the connection between education and freedom, in the belief that the subject is one of critical importance to-day and that it is essential that those who are concerned with education should determine their attitude to it.

No one with any power of discernment can have failed to note two opposite tendencies at work in the present day: the one, a tendency antagonistic, both in intention and in fact, to freedom; the other, a tendency to lay claim to freedom in ways which it is not always possible to defend. Of the second of these tendencies I do not intend to say much to-day, though I shall refer to it incidentally later on. It is seen in a number of educational theories which would so far as possible exclude discipline from life in the supposed interests of free development; and also in a certain impatience with all forms of authority, of which those who are associated with young people have been more conscious in recent years than (for instance) before the war. But the other tendency we can see writ large in the recent history and present condition of nations and also reflected in the smaller letters of individual mentalities. In Germany, Italy and Russia we are watching the complete subordination of the individual to the State, not only in his external life and action, but also, so far as education and propaganda can achieve it, in thought and will. In all three countries the methods adopted have been essentially the same—the ruthless exercise of force, the extermination of persons who seemed likely to be irreconcileable, and thereafter the continuing threat of death, imprisonment and loss of goods, the employment of espionage in its most inhuman and revolting forms, creating distrust between members of the same family and between friends who seemed inseparably united, and the enforcement of methods of education and psychological manipulation calculated to mould impressionable minds into one and the same rigid and uniform shape, and to permit no independence of judgment or of action. The suppression of truth and the propagation of convenient falsehoods have been regular elements in the system. Any thinking which runs counter to the ideas promulgated by the ruler is sternly discouraged. The individual exists simply to carry out those ideas, and it will be bad for him if he does not do it.

Now if such phenomena were only presented to us by foreign peoples, they would even then merit our very serious attention; but he would be very blind who did not see the same tendency at work among ourselves. We call ourselves a Democracy, and the essence of democracy is that it rests upon the free expression of individual thought; but the rigidity of organisation in our political parties has increased during the present century to an ominous degree, and with it the application of what is called 'party discipline,' depriving the individual of all freedom of action and speech, whatever freedom of thought he may privately retain. Some of those who listen to me would not, I feel sure, have to look far to find not merely parliaments or municipal councils, but even education committees, in which the vote of every member of a party, on questions imperatively demanding free and open discussion and not suggesting a division by parties at all, is determined by a previous party meeting, so that, whatever the discussion may bring forth, he dare not vote otherwise, on pain of being drummed out of his party; and the spectacle of the management of (e.g.) higher education in some great city or county by such rigidly organised majorities, most of whose members may never have received any higher education themselves, and may have little or no knowledge of schools or of teaching, and yet may not deviate an inch from the course marked out for them by their organisers, whatever considerations may be urged by persons of experience and independent judgment, is a spectacle in which comedy and tragedy are about equally blended.

It is at least equally serious, that some of the constructors of the imaginary Utopias which have been most popular with the younger generation in the last few years clearly envisage and apparently approve of political and educational systems based upon the complete elimination of individuality. Mr. Aldous Huxley's *Brave New World* and Mr. Wells' delineation of *The Shape of Things to Come* both assume that it is possible to organise individual freedom out of existence; and the means suggested to supplement certain catastrophes, which occur conveniently and give the imaginary State-builders a *tabula rasa*, are violence at the beginning and the ruthless crushing out of opposition at all stages. Even if the motives of the Government are benevolent to the utmost degree (and no one will deny Mr. Wells' State-builders this merit) the governed have no voice in their own lives. 'Democracy,' says Mr. Wells, 'asks people what they want; what is required is to *tell* them what they want, and see that they get it.' His new government, he tells us, was meant 'to rule not only this planet, but the human will'; and education was devised accordingly. It is open, of course, to any of us to treat such works as nothing more than rather unconvincing pieces of fiction; but the fact that they have found a definite response from a great number of young people at the impressionable age of University studentship gives them a significance which intrinsically they may hardly merit.

For the events of our own times have shown that there is more than imagination in these pictures; that it *is* possible in fact so to educate and to govern as to eliminate freedom of thought and life, to make human beings efficient members of an all-embracing organisation, cogs in a machine, and to convince a large number of them that that is the best life for them ; and it is certain that the idea of such an organisation has for many persons a great attractiveness, and that they are prepared to believe that it is worth the price. It is easy, but it is not of much service, to argue that the cause of these phenomena in modern States is fear, generated by war and the expectation of war, leading men to transfer to times of peace a rigidity of organisation which is only necessary or even excusable in the presence of war itself ; that in all the three foreign countries which have been mentioned military aims and preparations are intimately interwoven with the new political systems, and that if security can be achieved on a large scale without war, freedom will again lift her head. Or it may be urged that judgment on these new systems is premature, since none has lasted a generation, and the second generation has often been the end of violently imposed governments. We may also suspect that many of those who in our own country are disposed to uphold systems of this kind as an ideal, almost unconsciously think of themselves as the organisers, and not as the organised, and that the realisation of their notions might incidentally involve them in some unpleasant surprises. Yet it is none the less a fact that a large number of quite serious persons are definitely prepared to find their ideal in a state of society in which the freedom of the individual is to play a far smaller part than is consistent with any kind of democracy, and to fashion education so as to create and perpetuate such a state.

Now if this view is accepted, if it is definitely decided that freedom is not worth keeping, the consequences in the field of education will obviously be accepted also—the strict control of all that is to be taught, and of the method of teaching it ; the exercise of thorough-going espionage upon teachers and pupils, and the encouragement in both ranks of the giving of information against colleagues and companions ; the supervision of every part of the individual life, so that there may be no loophole anywhere for the intrusion of counter-influences, and no opportunity for the expression of free thought. There may be those who feel that such a state is what ought to be ; and I do not now propose to argue with them ; but what I have to say to-day is based upon the opposite assumption, that individual freedom, subject to such a minimum of restriction and organisation as is necessary for life as a member of a community, is the indispensable condition of a good and even a tolerable human existence, and that just as the educational systems of coercive States, real or imaginary, are directed to the maintenance of the systems of government and life which have given rise to them, so the educational system of a democratic State, which is based on the principle of freedom, should be directed towards the maintenance of that freedom, and the encouragement of its responsible use. I am convinced that my old masters, Plato and Aristotle, were right in thinking that it *is* the business of education to bring up young citizens in what they call the 'spirit of the polity' (τὸ ἦθος τῆς πολιτείας), and that it makes all the difference, whether the polity is one in which thought as well as life is subject to strict prescription by authority, or one in which the actions of the State and the life of the community are the result of free discussion between those whose minds are trained to be free and encouraged to express themselves freely. As the principle of the direction of education in accordance with the 'spirit of the State' must necessarily result, in the authoritarian State, in training citizens *not* to think, so education in the spirit of a polity of free men and women must above all train them to think freely and accurately, and to desire to carry the results of their thinking into action. As the former type of State will try to produce a standardised and unresisting mentality, the latter will allow the utmost variety and will look for the good life of the community to the clash in rational discussion of the most diverse views, brought to judgment before the bar of a public opinion in the formation of which all alike may take their part.

The freedom of which I am speaking has two aspects. It includes, in the first place, the power of the individual to realise the good, as he understands it, in his own life; and in the second place, the power to take an equal share with any other citizen in determining the action of the community of which he is a member, and in bringing about the realisation of good in the community as a whole, or, in other words, in the lives of others as well as himself. In both aspects freedom depends in part upon the individual's own capacity, in part upon the political and social structure and behaviour of the community, i.e. upon the will of others.

So far as the individual life is concerned, I do not think that much argument is needed to show that the freedom which serious persons desire, and the freedom which is desirable, is just freedom to realise whatever is regarded as good—as possessing value; the power to act in accordance with a deliberately chosen ideal of good, in whatever sphere of action. (It is an illustration of this that the determinist, who thinks that human actions are determined by something other than human free will, usually alleges his theory as the reason (or excuse) why he or others cannot do *good*.) So far as the community is concerned, the ideal State and community will be a democracy in which every individual is free to realise the highest values, physical, moral and spiritual; and the realisation of some of these is only possible if he can enter into freely determined mutual relations with others, participating fully in the life of the community, communicating his share of good to it, receiving his share of good from it. The community and the State will recognise fully the value of the individual personality, and will acquiesce in no condition which makes any individual merely a means to the well-being of others, or to the stability of the organised community, for the sake of which in authoritarian States, real or Utopian, individuality is sternly suppressed. Doubtless such an ideal community is far in advance of anything that has so far been realised; but it is the ideal at which democracy aims and which is implicit in most of the social reforms effected or demanded in our own day; and, so far as I can judge, it is the one political ideal which is worth working for. Ever since the authoritarian State and the authoritarian Church of the Middle Ages had to yield most of their power to a steadily broadening political freedom and a growing liberty of thought, the principle which has been implicit in all political progress in the Western world has been that of the inviolability of the individual personality, and the imperative obligation to ensure the freedom and security of the individual under a reign of law resting upon the consent of those who obey it and who co-operate for those common ends which all feel to be also their own—like players in an orchestra, each making his own contribution and playing his own part, and yet sharing fully in the combined result, the perfection of the whole. The whole trend of what is called progress has been an advance from a condition in which the individual has been under domination or cruelly hindered by his environment to one in which he has been at liberty to express himself, to act upon his own understanding, and give his co-operation by his own free consent. It is to this end that men have striven for and to a great extent attained equality before the law; safety of person and life; freedom from arbitrary arrest and espionage and tolerable material conditions of existence; and to this end, in so far as it is not yet secured, reformers are striving, when they seek to remove adverse conditions of every kind. It is a reversal of all that has been accounted progress hitherto, when liberty is denied and overthrown by force as in some continental countries, or when the faint-hearted, or those who would avoid the responsibilities which freedom carries with it, take refuge in submission to the authority of a person or an organisation without considering whether they can rationally do so. For my own part, I can only express complete agreement with the sentence which sums up the spirit of Sir Percy Nunn's well-known text-book (*Education: its Data and First Principles*, p. 4): 'Nothing good enters into the human world, except in and through the free activities of men and women, and educational practice must be shaped to accord with that truth.'

But the desired freedom of the individual has to encounter obstacles of more than one kind, and it is in a great measure with these that education has to deal. The obstacles are partly in himself, partly in the community. It is obvious at once that no one, as he is, is completely free. It is indeed the assumption of almost all educational theory and practice that everyone has some degree of freedom to accept or reject the good, in whatever sphere; to act or refuse to act in accordance with an ideal; to use what education may give him well or ill—just as it is the working assumption of the Law Courts, and indeed of everyone in his actual dealings with others, and in his judgments on their conduct and his own. If the assumption were not true, a great deal of our conscious experience would have to be explained away; and if it were not made, the whole of the practical life of men in communities would have to be reorganised from top to bottom. At least the burden of proof may be laid upon those who deny it; and (though this is not the place, nor would the time suffice, to argue the matter) the conventional objections raised by the determinist against the reality of human freedom have become much more unconvincing than they used to be found by some philosophers. Nevertheless, it remains undoubtedly true that no one's freedom to realise good in any sphere is complete. It is agreed that everyone is greatly hampered by the effects of heredity, which, whatever the mechanism, seem to be mental as well as physical; by the influence of body upon mind; by the tendencies imparted by early environment and habituation, largely unconscious, yet so powerful as often to fill the wellwisher and the educator with a feeling not far from despair ; and by the results of his own actions. Yet it is probably a fair summary of what may be inferred from common experience, that each individual has at any moment a certain balance or reserve of freedom, i.e. of power to act in the way which he recognises to be good—a balance or reserve which he can increase or diminish by every individual act, every exercise of will, so far as he *is* free. Therein lies (as all moralists have seen) the importance of each single action ; for it is in the determination of single actions that increased freedom must be won. By constant action in one direction, habits are formed which it is very difficult to break. By repeated choice of the higher as against the lower values, the choice of these becomes easier ; freedom is increased. Accordingly, one purpose at least of education is to set what seem to be the higher values before the immature mind in such forms as it can understand, and to encourage the habit of choosing them. About most of these higher values there is really very little doubt, and in such forms as kindness, unselfishness, truthfulness, fair play, thoroughness, neatness and other elementary kinds of beauty, they are as accessible to young minds as to old.

Further, the importance of discipline depends upon the fact that without it—without a certain external compulsion at times—the immature personality may not discover that it *has* the freedom to choose something other (and, as it will afterwards recognise, something better) than that which immediately appeals to it. The youthful mind has, as Aristotle puts it, the power of rational deliberation and choice, but has it in an imperfectly developed form, and so the practice of it has to be artificially stimulated by some more mature personality which has authority. Discipline, correction and guidance reveal the power of choice—of doing what you do not want to do ; and in time self-discipline follows and freedom increases in proportion—freedom, that is, to pursue and realise ends or values deliberately chosen, because they are recognised as good. No one can possibly be less free than one who has always been allowed to do what he likes ; he will never have discovered that he can do anything else. To deprive the young, in the name, forsooth, of freedom, of all benefit from the experience of earlier generations—to put *no* values before them as good—is not, in fact, to increase, but to restrict their freedom by denying them the conditions of a fair choice. The young mind has neither the information nor the training to decide everything for itself. But it *is* the object of education and of discipline that it may ultimately have these, and may do some things no longer because they are imposed by authority, but because they are recognised to be good, and other things, it may be, because the ideas suggested by authority have now been revised and modified by the growing reason. And if the discipline and guidance are accompanied so soon and so far as is possible, by reasons which will not only suggest why it is that such and such acts and habits are good and so cause the discipline to be willingly accepted, but will, above all, help to form the habit of reasoning and of considering what *is* good or bad, the result, so far from hampering freedom, will be to elicit and enhance it.

There is no time this morning to discuss the many ways in which those who are responsible for the education of the young may supplement or counteract the influence of the home (which in this matter is inevitably the most important) in the presentation of values for choice, or, in other words, of standards of good and bad, fair and ugly. Many of these ways are familiar and obvious ; the most powerful no doubt are wise suggestion and example ; but it is clear that not only in the general life of the school as a society, but also in the choice of literature, in the study of characters both in literature and history, and in the presentation, in however simple a form, of the working in history of cause and effect, an immense opportunity is open to the teacher, though how far that opportunity is diminished at least in Secondary Schools (happily, much less in Primary) by the cramping influence of examinations is a very grave question, to which I shall return. Further, I am convinced that the tendency for many years to relegate the study of the Bible to a place of almost complete unimportance in the curriculum has been a fatal mistake, though here again it is the Secondary rather than the Primary Schools that are most guilty. Almost all the principles which distinguish the most progressive modern civilisation from the barbarism to which some apparently desire to return are those which are found in the New Testament and which as a mere matter of history have found their way into civilisation from that source ; and it is significant that both in Germany and Russia the consciousness of this has been so strong that the suppression of freedom has been closely combined with an attack upon the Christian religion. If it is urged that the young ought to be left free to make up their own minds about religious matters, I reply that they have at least the right to be given the chance to do so by being supplied with the materials for the decision, as is done in regard to every other matter which is of importance ; otherwise they *have* no real freedom of choice ; and it is at least reassuring that in our Training Colleges and in the Training Departments of Universities, and still more in the minds of the future teachers themselves, more attention is now being given to the best ways of teaching a subject which both for the understanding of human nature and society and for its bearing on practical life is far more important than any other.[1] But in what I propose to say about training in thinking generally, training in thinking about values will be implicitly considered, and to this we may now proceed.

For education has much more to do in the cause of freedom than the

[1] Sir Percy Nunn (*op. cit.*, p. 98) wisely insists that ' the old pedagogic arts, which represent not merely the blunders of the past but also the successes won during centuries of sincere and patient effort, can never become obsolete ' and that suggestion on the part of the teacher (which is one of the most effective forms of guidance) ' is not by nature a foe to spontaneity, but a necessary instrument in the process by which a man becomes truly the captain of his own soul.' The young scholar will assuredly be exposed to the strong influence of suggestion exercised by his companions ; and to rule out suggestion, and even something more, by older and wiser personalities would be merely silly. Even the most rigid applicants of the principles of Mme Montessori (whose influence for good upon educational practice is unquestioned) admit a very large measure of guidance and suggestion, and restrict the imperfectly developed freedom of the very young by a careful limitation of the possibilities of choice and of going seriously wrong.

encouragement of a habit of discriminating between good and evil, or better and worse, and the suggestion of the lines of such discrimination. For before life is far advanced, the simple problems and issues of early days are merged in far more complicated issues, requiring the utmost clarity of thinking ; and not only does the true discrimination between values itself become more difficult, but a knowledge of facts, a power of analysing them and appreciating their bearing, and therewith an understanding of the particular conditions in which the realisation of ideals of good has to be attempted, become essential ; in short, a clearness of perception and judgment without which the best intentions may end in disaster ; for it is difficult to set limits to the harm which may be done in the world by the muddle-headedness of good people.

For effective thinking two conditions are necessary : first, that the materials with which thought has to deal shall be as far as possible true, or, in other words, that truth about facts shall be accessible ; secondly, that the mind itself shall have been trained to work accurately and honestly ; and if freedom in political and private life is to be preserved, those who educate others must put them in the way of obtaining truth about facts and of distinguishing truth from falsehood in what is presented to them and in their own reasoning. It would take a very brave man to deny the immensity of the obstacles. Even in a country as free as our own, the temptations to accept opinion manufactured by others, not always for the best ends, are enormous. The leaders of parties, of trade unions, of organisations of all kinds, tend more and more to dictate what their followers shall accept without question, and it is much easier to accept it than to work out patiently the reasons for and against. Even more plausible and easily accepted is what a man is told by the newspaper which he habitually reads ; and there are few newspapers which any one has a right to trust as aids to right opinion and action, and very few which can be trusted to tell the truth and nothing but the truth in the presentation of facts. The effect of selection and suppression and of headlines beyond which many will not penetrate may be to create impressions which are almost wholly false ; and when nearly every newspaper is the organ of a party or of a proprietor whose aim is to make money or to damage a particular statesman or group of statesmen, when the paper which would succeed as a commercial speculation dare not say what would be unpopular with its particular clientèle, how is the citizen, young or old, to obtain the materials for sound judgment ? Until some means can be devised whereby full and accurate reports of important matters are placed within reach of all (perhaps by a free service of State), to expect a sane and dispassionate public opinion is to demand bricks without straw. Yet some preparatory work may be done on the lines which are followed, at least in a few schools, in which in some upper forms present-day problems are discussed, or the news of the week presented, in ways which encourage older boys and girls at least to think about them, to be aware of the two or more sides that each question presents, to realise the duty which lies upon them, or will shortly lie upon them as citizens, to get the best information and to form their opinion with a high sense of responsibility and a disregard of the interest of class or self. They can be led to realise that democracy is less a system of equal rights than a system of equal responsibilities ; and even the common life of the school can teach them how much one clear and decided mind can do in shaping the opinion of its own circle. In many ways the school may encourage independence and sincerity of thought, and afford some antidote to the malignant influence of a very large part of the popular press. It is constantly repeated that any man has a right to his opinion ; and this is true if it *is* his opinion. But it is not true, if it is some other person's opinion, accepted without thought ; nor even if it is his own, but formed without reflection and deliberate impartiality. The foundation of habits of impartial and critical judgment *can* be laid at school, and if they are not laid there, the odds are heavily against their being laid anywhere else.[2]

The teaching of history is an obvious instance of the opportunity which education affords for the formation of habits of careful judgment. As in all other matters, there must be an impartial presentation of facts and issues, and, if possible, opportunity of discussion of a kind suited to the age of the pupils. In this connection it is rather alarming to hear of a great Education Authority proposing to review and revise the text books of history to be used in its schools in the interests of the political party which is dominant at the moment. (The other explanations offered are too transparent to deceive anyone.) The same thing has happened before now in America, a deliberate attempt being made to impart an anti-British bias ; and it is happening now in Germany. Now it is quite possible that many of the current text books are biased, consciously or unconsciously, in a particular direction, and that the bias needs correction ; but you cannot correct it merely by substituting the opposite bias, but only by a fresh and impartial estimation of evidence : this is a task which requires the trained skill of the historian, and its fulfilment is frustrated if the conclusions are dictated beforehand. The task of the teacher is to encourage his pupils to think by the presentation of evidence or of opposite points of view ; the desire of the politician is to prevent them from thinking, so that they may swallow his particular notions without question ; and it is this which must be resisted at all costs.[3]

[2] It would be easy to apply this contention especially to the particular case of international affairs, about which it is urgently necessary that an intelligent future voter should, in the present state of the world, have an elementary knowledge. In this matter I agree wholly with a writer from whom I more often differ, Prof. H. Laski, when he writes that 'our educational systems are at no point adapted to confer upon the masses that knowledge even of the larger aspects of international affairs without which reason is powerless' (*The State in Theory and Practice*, p. 267). A little superficial teaching about the League of Nations is in a great number of schools the utmost that is attempted. Even in Adult Education of all kinds, very little attention is given to international relations.

[3] The fear that the discussion of recent history and contemporary events in schools may result in one-sided propaganda is, I think, in the main mistaken. Of course there is a small number of teachers who are strong party-politicians, and they are obviously not the persons for this work, for although strong party-spirit is apt to evoke as much opposition as support, they are not likely to produce a spirit of fair-minded consideration for both sides. But teachers whose aim is that which I have tried to describe are likely to be able to discipline themselves to fairness.

In other ways, the dangers of dependent, unventuresome and even servile mentality may be partly met by the school. Young people are much more likely to *think* for themselves, if, subject to the necessary framework of school discipline which is scarcely felt so long as it is wisely controlled, they *do things* for themselves. This is well understood in the older Public Schools, but I confess that in a great number of Secondary Schools—and Secondary Schools are of special importance, because from them should come the leaders of opinion in nearly all those smaller circles in which, much more than on platforms, public opinion is made as well as most of the future teachers of the mass of the people—I should like to see a good deal more room for independence and self-government. It is bad enough, though perhaps almost inevitable, that everyone now plays the same games, which he takes over ready-made, but it is worse that even for the purpose of these, the organisation is largely in the hands of masters or mistresses; and the same thing is often true of the School Societies. It is impossible to train young people in the free use of judgment without letting them exercise it freely in their own affairs and (with slight and obvious limitations) make their own mistakes, and grow in the power of judging how to act and of understanding the characters one of another; for in a free State, the power to choose persons is as important as the power to choose between policies, and there is no place so good as a school for learning either to lead or to choose and follow a leader. In schools in which the leaders are not chosen but imposed, this lesson is not learned; and there must be hundreds of such schools, in which prefects, captains, debaters, readers of papers are all appointed from above, and in which even the prefect is little but a keeper of order in passages, and the captain does merely what he is told.[4]

The fact that the standard games are provided with such completeness of arrangement that the individual has merely to take his place in the organisation would matter less if the forms of amusement available, apart from the school, gave more scope for individuality; but no one can deny the effect of the mechanised drama, which is the almost universal recreation on certain days in the week, in producing a standard mentality (one might almost say a uniformity of bad taste) and in confining interest to monotonously narrow lines; and the fact that the interest in sport of which our countrymen boast takes for nine-tenths of them the form not of healthy personal activity but of massed attendance at the performances, provided for them by no effort of their own, of two teams of hired entertainers or of a few trained dogs, is not indicative or productive of an active intelligence. If education is to counter this, it must encourage those occupations of leisure in which the individual can exercise his own free choice and express himself—the performance (not merely the hearing)

[4] I have learned something about these things, not only from frequent visits to schools, but also from interviewing for some years a large number of candidates for admission to my own University, and it is with a thrill of delight which comes only too rarely that I hear of schools which seem to have caught something of the spirit which animated (for example) Newbury in the headmastership of Mr. Sharwood Smith.

of music and drama, the practice of handicrafts, of arts, of gardening, of all kinds of performances which are personal, not mechanical. It must set before the young the infinitely various ways of spending time worthily; and must encourage an attitude towards books and reading which few of our examination-ridden youth attain.[5] For all these things are the activities of free minds, not of those which accept unthinkingly everything which is superficially attractive and is therefore accepted by crowds. Without some such influence from education, we can expect only passive minds, barren of ideas, and unable to rise by freedom of thinking to meet the perpetually changing needs of the world in which they are called upon to live. Moreover, unless our young citizens become accustomed to activities worthy of free minds, before the great increase of leisure which is commonly predicted is upon us, we are likely then to see nothing but greater crowds thronging the picture palaces, dance halls, race-courses and football grounds, and degenerating as those must whose only interest is in exciting and profitless kinds of pleasure.

As I have spoken of examinations, I had better say explicitly that I rank examinations, not in themselves, but as they are treated in most schools at the present time, among the worst enemies to education in freedom of thought and independence of judgment. Examinations can be, and should be, invaluable aids to education; but it is a condition of this that they should be only an incident in the work of the school, testing at convenient points the work of both teachers and pupils, and really, and not merely by profession, following and not directing the curriculum. Their usefulness is undoubted in training the young mind to do what it will continually have to do afterwards—viz. to bring whatever knowledge and resource it may have to bear on a particular point at a given moment, and in this both intellectual and moral qualities are involved. But where the whole work of the school is planned to cover or lead up to the syllabus of some particular examination; where every subject is studied at a rush in order to work into the pupils' minds what are virtually prescribed answers to questions which may almost be said to be prescribed—so narrow is the range from which they can be drawn; where the teacher does not dare to encourage his pupils to think; where he cannot go at his own pace and cover in his own way the ground which he can effectively cover, for fear of the effect on the statistics by which the Local Education Authority, knowing little of education, judges the efficiency of his school and his own fitness for promotion, or by which the employer, knowing even less, judges the suitability of individuals for purposes never contemplated by the examination authorities—there examinations are a very mischievous thing. Examining bodies may do their best, as those of which I know anything honestly and untiringly do, to consult the teachers in schools and keep closely in touch with their curriculum, so as to keep the examination requirements well within it, and leave ample margin for generous methods of teaching and for work altogether outside the examina-

[5] It is painful to think of the thousands of boys and girls whose books are taken away from them so soon as the examination, in preparation for which they were used, is over.

tion syllabus; and any one who knows anything about the teachers of the present day will recognise that thousands of them would gladly train their pupils' minds, and not merely prepare them for examinations; but no one who has seen much, at any rate of Secondary Schools, and has heard on every Speech-day the predominant emphasis on the results of examinations, and the proofs which every school confidently produces that its averages are above those of the whole country, can doubt that the attitude towards examinations which is forced upon schools is wholly wrong; and I have no doubt that herein lies the chief obstacle to an education which should produce men and women of alert and independent minds, proof against ready-made answers to any problem, adaptable and originative, and with the powers of vision and of criticism with which nature has endowed them unblurred and ready for use. It would take too long to-day to enter upon a discussion of the remedies, which might in fact involve a very large reconstruction of our whole educational system. The thing most essential is to distinguish examinations as an aid to education from examinations as a test of fitness for purposes external to the school. As it is, the attempt to combine the two aims has had a sufficiently long trial, and has proved a most unhappy failure.[6] The external purpose has virtually eclipsed the internal. I should certainly not abolish examinations, even external examinations—which may be of great use to a school if they are based on the actual and freely arranged work of the school; but there should be no issue of certificates of any kind, nor any publication of results beyond the school itself. Scholarships and positions outside the school might be awarded for the most part upon special examinations involving no specially prepared work, and much more weight might be given to school records (in schools much more thoroughly and regularly inspected than at present); and the activities of Local Education Authorities might be restricted, so far as possible, to the non-educational aspects of school life and work. I cannot develop these suggestions to-day, and I make them in the full assurance that they will never be put into practice. But unless the habit of working and teaching for examinations before everything else is abjured, I see little hope of the type of education which alone can save democracy, and bring up a race of free men and women.

There are other reforms which are urgently needed, if our present system of education is to be brought nearer to the fulfilment of such an end. The prolonging of the time of education is obviously one, provided that the education is of the type which liberates and trains the mind, and does not merely rivet its fetters more tightly.[7] A great reduction in the size of classes in most subjects is another; not necessarily in all subjects, nor for all purposes; but such a reduction as will give the individual member of the class a chance, and will enable a teacher to encourage a

[6] Of course so long as the present system continues, it will be the work of the examining bodies to diminish the mischief done by it as far as they can, and so far as I can judge they are doing this very conscientiously.

[7] The fact that in Russia education is compulsory up to the age of eighteen is not without significance.

pupil who has a line of his own to follow it up, and to see that every pupil is mentally active and not merely receptive. Young people have not indeed enough experience to prescribe or to conduct their own studies to the extent imagined by some enthusiasts ; but they have minds which should not be allowed to be inert or be driven along precisely the same route as twenty-nine or thirty-nine other minds, and the smaller the class the less the risk of this. Even under the present adverse conditions, the teacher must be asking himself (as the best teachers do even now) during every minute of his work, 'Am I leading this or that boy or girl not merely to absorb but to think ?' And the continuous effort involved in this may carry with it the need of an increase in the number of teachers, and perhaps some changes in their training.

It has been impossible to speak to-day of the application of the principles which I have been inculcating to University work and to the various forms of Adult Education. The more examination-ridden University education is, the less it fits men and women for freedom ; but a discussion of the methods of University instruction would need much more than another hour, and in any case, unless the foundations of freedom are laid at school, the University has a very unpromising task. The contribution which Adult Education might make is very well discussed by my friends, Mr. J. S. Fulton and Mr. C. R. Morris, in Chapter IX of their recently published book, entitled '*In Defence of Democracy*,' and to this I must be content to refer.

The suggestions which I have made as regards educational practice have nothing new in them, but I have deliberately chosen familiar instances to illustrate my main contention ; these matters are continually in the minds of those who take education seriously, and there is indeed a danger that we may get too used to hearing about continued education, small classes, reform of examinations and the rest. My object has been to assert that these are no matters merely of theory or of finance or of administrative or political convenience, but of vital and immediate urgency, if we are not unconsciously to bring up a race which, with its mind stunted, its capacity for freedom undeveloped, will be the easy prey of the politician, the journalist and the dictator ; and that if a free democracy is to continue, we must educate for it, for in many respects our present educational system is better calculated to produce a servile and passive mentality than to elicit an activity of mind and an independence worthy of free men and women.

It is evident that these suggestions postulate a great increase in expenditure upon education. Such expenditure is the premium by which the life of a people of free men and women must be assured, and whatever may be the incidental consequences of spending money upon this instead of upon other objects, I am convinced that it will be abundantly rewarded. We have reached a point in the history of Western civilisation when the forces which make for the enslavement or the inertness of mind and spirit are active as they have not been for centuries. It is therefore incumbent upon us to test our educational institutions and methods at every point by their tendency to produce or to hinder freedom of mind, to cut out all that makes for the standardisation of individualities or is hostile to ultimate independence of judgment, at the same time so setting before the young the higher values, which make for good life and good citizenship, that they may have the chance of freely making them their own. If we can do this, we may yet see the development of a type of humanity richer in freedom, self-discipline, courage and vision than any which the world has yet known.

SECTION M.—AGRICULTURE.

THE FINANCIAL AND ECONOMIC RESULTS OF STATE CONTROL IN AGRICULTURE

ADDRESS BY

J. A. VENN, LITT.D., F.S.A., J.P.

PRESIDENT OF THE SECTION.

THE changing practices, derived from scientific progress, observable in post-War British agriculture, have upon recent occasions been described and discussed by this section of the Association. It seems, therefore, not inappropriate now to draw attention to some other aspects of the industry which can claim to be fundamental in any appraisement of our rural complex and have also special relevance when we meet in such a centre as Norwich. I refer in particular to its financial and social economy as well as, more generally, to its present-day bearing upon other human activities, all of which have, as a direct result of State action, suffered great changes. And here, may I explain that in the title of this address the term 'Control' has designedly been substituted for the arguably more correct 'Intervention' or the defensible 'Assistance,' for none can aver that the policies and activities of those engaged in primary production are now as spontaneous and untrammelled as they would be had not successive Administrations, in order to counter exigencies of varying magnitude, visited agriculture, as Zeus visited Danäe, in 'a shower of gold'—I borrow the simile of a well-known politician.

History and economics are frequently indissoluble. This is so in the present instance, and, although, prior to an examination of the extraordinary changes brought about by the recent extension of State influence, I do not ask you retrospectively to accompany me in a study of the recognised mediæval methods of controlling trade or of regulating prices and wages (some of which survived into the nineteenth century), yet I must, in order to illustrate the magnitude of the change that has taken place in the national outlook upon this subject, first crave permission to effect comparison between the State's reactions to the situation confronting it at the present time and in two other comparatively modern periods of depression. I refer, of course, to (*a*) the two disastrous decades that followed upon the Peace of 1815, and (*b*) the eighties and the nineties of last century. Significantly, it is only during such times of stress—whether engendered by war or by monetary causes—that what is still the greatest industry of these islands (in its capitalisation, the numbers of its employees, and the value of its output) receives any appreciable measure of recognition, for, if we exclude what is familiarly designated ' Education and Research '—a euphemism for the semi-official dissemination of scientific knowledge amongst practising agriculturists—international peace and domestic prosperity have ever tended to be accompanied by apathy and neglect of rural interests.

It is a trite, and familiar, saying that ' History repeats itself,' but, in the years that followed the Napoleonic war, the legislative attempts of our forebears to counter falling prices (including a National debt multiplied, as is ours now, tenfold), unemployment, social unrest, and many other evils only too familiar to us were, *mutatis mutandis*, and up to a point in time, remarkably similar to those which we ourselves put forward a hundred years later. It was, indeed, to the historian, a cause of surprise that, in the years 1918–1922, the administrators concerned did not appear to be acquainted with the sequence of events three generations earlier; much unnecessary friction and heartburning, many a miscalculation, involving either ultimate repeal of legislation or excessive expenditure of public funds might, it seemed then, with a little knowledge of economic history, have been avoided. Thus, the Agriculture Act of 1920, conceived in the mistaken view that a world shortage of wheat was imminent, and guaranteeing, therefore, to home producers abnormally high prices for a considerable number of years—which, it was feared, might also be productive of further wars—had its counterpart in the equally abortive Corn Law of 1815, the aim of which was also to remunerate under peace conditions British farmers and land-owners upon a war-time scale of values. Upon both occasions the officially unforeseen, or ignored, superabundance of supplies—derived in the one case from home-produced sources, in the other from the ends of the earth—frustrated man's efforts to perpetuate artificial prices. Listen to an impatient leader-writer of *The Times* in January 1826, who wrote: ' What the nation pants for, is a sensible fall of prices. *Bread must be had cheap.* Rents must be sacrificed to the lives of the people. It is monstrous impudence to talk about the ruin of the *farmers* from a lowering in the price of produce. The farmers want nothing better than low prices, if they can but get their lands at proportionate rents. . . . The paper currency has been pushed to madness, as a temporary help to the manufacturing interest against the monopoly of corn. Leave the loaf of bread to find its own value. It is horrible to tell a starving family, " You shall have no food but at a price beyond your means of procuring it." ' In our own post-war experience the loaf found ' its own value ' more quickly, and the Press could soon point out that it cost but a fraction of the corresponding price on the Continent, thereby suggesting in effect that it might be too cheap. Incidentally, the policy of the now unfortunately defunct Empire Marketing Board and of Ottawa's resolutions were, in the 1815 Act, also forestalled, for thereby the effective order of preference was the familiar one of (1) home produced, (2) Canadian, and (3) foreign (*viz.* European) wheat.

Again, up to 1836 (with the exception of London, where the custom had ceased in 1822) Justices of the Peace, sitting in special Assize, determined the retail price of the loaf, allowing certain margins of profit to miller and baker. Their findings were thus promulgated to our grandparents: 'The Assize of Bread for this town was reduced three farthings in the quartern loaf wheaten, the price of which is now eightpence three farthings' (*Cambridge Chronicle*, March 1822). We ourselves may correspondingly read in our morning newspaper such edicts as the following: 'The London millers announce that the current price of standard-grade flour in the Home Counties is now 27*s*. per 280 lbs.' The principle is the same, but, as in many other cases, we have witnessed a substitution of independent and unbiased bodies by combinations of almost monopolistic trade interests.

In the legislation of 1918 and 1925, which prevented any material increase in the level of tithe payments, there is ample evidence that the popular agitation which had been successful in securing the passage of the Commutation Act of 1836 was still alive, and it is almost certain that, exactly a century later, there will be placed upon the Statute-book another far-reaching measure to regulate or to modify the incidence of this charge. In passing, may I point out that if nowadays, in order to control tithe disputants, extraneous police detachments are sent to Kent, in the early nineteenth century troops were being despatched to that same county, where 'the disturbances [on the part of the agricultural labourers] have now attained to almost alarming magnitude. Each day brings fresh accounts of violence and outrage, and fear and excitement everywhere prevail' (*The Times*).

Yet again, the Reform Act of 1832 had its correspondingly expanded successor in our Representation of the People Act; both, by enlarging the field of responsibility, reflect the same psychological reaction to times of stress. The legal treatment of the rural workless had, after twenty years of misery and even of bloodshed, been mercifully metamorphosed by the 1834 Poor Law Amendment Act, the principles of which survived until a few years ago when, once again, the recurrent twin problems of unemployment and the inequitable distribution of the resultant charges forced the State to recast the whole system in various Acts of Parliament, ranging from reconstitution of Local Government to extended provision for social insurance.

This chronological analogy could be further extended by effecting comparison between the crude Protective duties current for a generation after 1815 and their ostensibly revenue-producing successors of recent years. Sugar-beet may illustrate the continuity of international agrarian history, for, although the Germans could claim priority in this field, it was as a result of our blockade of France that the crop was first subsidised and commercially developed by that country; while the former nation's submarine threat led to our adoption of a like policy in the Great War.

It is, indeed, only when one turns to the human element—and then especially in its capacity as an employee—that this remarkable series of analogies breaks down, for a century ago the evils associated with the prevalent system of rural employment are epitomised in such words as 'Tolpuddle,' 'Swing,' and in many another place—or family-name, while the then customary and legal relationship subsisting between landlord and tenant would scarcely be credited by the present-day representatives of either body. Listen to 'The Thunderer's' views upon the first stirring of agrarian Trades Unionism. 'The public, we believe, are not aware of one subject with which the Cabinet has been occupied at its recent meetings; and when they come to hear it, those who watch political symptoms will confess that one of a more truly portentous character has seldom offered itself to the attention of this or any other Government: we mean *the spirit which has for some time directed the combinations of the working classes* against their employers. If this spirit proceeds as it threatens, we give it as our well-weighed opinion, that neither lawful authority nor private property (as for commerce and manufactures, they are out of the question) will be worth as much as five years' purchase from the date at which we are writing' (September 30, 1825). Here we do indeed find an altered outlook, for the Agricultural Wages Boards, the logical corollary of Trades Unionism, have eventually been supported by all political parties.

Can I better illustrate the changes wrought by the passage of those five-score years than by enumerating some of those infractions of the law for which participants in agriculture could then and can now suffer fine or imprisonment? *Then*, these penalties faced the worker who, with two or three of his fellows, 'combined' for the purpose of seeking an increase in his rate of remuneration; *now*, punishment awaits the employer who fails to pay an independently determined minimum wage. *Then*, retailers who sold bread above the standard price fell foul of the law; *now*, producers vending commodities (e.g. milk) below a stated price suffer collectively administered financial retribution, as also do those who dare to raise more than an arbitrary acreage of certain crops (e.g. potatoes), whilst only a predetermined minority has effective access to some others (viz. hops). Take other fields for comparison. *Then*, forestalling and regrating, although absolved from any legal stigma, were still looked upon askance as potential dangers to trade; *now*, their practice forms, in effect, the recognised livelihood of large sections of the community. *Then*, landlords were omnipotent; *now*, fortified by Agricultural Holdings Acts innumerable, the tenant can virtually dictate his terms to a subservient owner. In the 1820's and the 1830's the tenant-farmer, as well as the landowner, staggered under the weight of National taxation, while together they had also to meet special duties upon a multiplicity of capital and productive goods—*e.g.* cart- and saddle-horses, gigs and traps, the malt they produced—and they had also to contribute, without any special concessions, to the unmodified demands of the rate-collector at a time when, even in rural areas, local taxation could exceed 20*s*. or 30*s*. in the pound, and they were, literally, tithed in kind. *Now*, as I shall hope to demonstrate later, the emasculated charges that remain can be laughed at by those men's great-grandsons. To illustrate, however, in passing, to what a small extent the vast remission of taxation is appreciated by these interests, I recall how, a few years ago, a meeting of East Anglian farmers passed with acclamation a resolution protesting against the weight of taxation that then crushed their industry. Their surprise was great when informed that it had been originally adopted in the same county exactly a century earlier.

When summarising the results of the policy followed during the post-Napoleonic war era, it is significant to observe that its cost to the Exchequer was negligible, for, rocklike, it rested on the axioms that consumers should pay to the utmost (in order that tenants and landlords might be re-established in secure positions) and that workers must, for the sins and omissions of statesmen, unavoidably suffer in full the blasts of an economic hurricane. A hundred years ago there emerged no measures aiming at the rehabilitation of agriculture that could incommode the taxpayer, and, if we exclude the reliefs granted to the rural poor, none affected the ratepayer. Nor, in consequence, did any real change in the practical side of the industry reveal itself. War-expanded cereal acreages were, for the time being, required to meet the Malthus-defying trend of population; and here, in this county, on Lord Leicester's and other reclaimed marshes, the bullock, where once the bittern had boomed, could, it was claimed, still batten, but not necessarily with profit to its owner. The inevitable emergence of Free Trade was, as a result of the hostility engendered by the Act of 1815 and its successors of the twenties, possibly antedated by a decade.

Such, from the landowner's and the farmer's standpoints, were then the results of two decades of European war. The worker, thanks to a compulsory and biased system of enclosure and also to the loss of extraneous sources of family income—attributable to what is popularly known as the Industrial Revolution—found his resources permanently crippled and his, often hereditary, association with the land dissolved. The Nation, whilst recognising no obligation as resting upon itself, could, during the next generation, watch with equanimity the astonishing march of bricks and mortar across the northern face of England's green and pleasant land—and also, incidentally, outwards from London across its brown and fertile arable fields. By an almost unbelievable piece of parsimony the only official connection between the State and agriculture had been severed when the old Board of Agriculture, formed under stress of war and in recognition of Arthur Young's unique services, failed by little more than two years to survive his retirement in 1820. Its resurrection, oddly enough, occurred during a time of high farming, and when depression was a thing of the past, with the establishment, in 1865, of a branch of the Privy Council charged with the control of animal diseases.

The vast changes in a century revealed by such a synthesis must, if the causes are sought, be placed in two categories. On the one hand, those improvements in the relationship of master and man, that strengthening of the position of the tenant at the expense of the landlord, the great amelioration in the social life of all those who labour on the land—these are attributable to a steady and continuous readjustment of standards, without regard to any fluctuations in the state of agriculture itself, which have equally affected other industries and the rest of the community, and have not resulted from any *ad hoc* expenditure upon the countryside. On the other hand, all changes improving the financial stability of the industry, reliefs of a fiscal character, all complementary economic adjustments, synchronous with each successful attempt to improve the material and technical equipment of the farmer, can be progressively correlated with recovery from the two last periods of depression, and obviously indicate a growing sense of responsibility, not perhaps invariably altruistic in character, towards an undertaking which had been for too long the Nation's creditor.

The first of what may be termed the two modern agricultural (and general) depressions that followed upon a generation-long period of unexpected prosperity, due to monetary causes which more than countered the incidence of Free Trade and its accompanying policy of *laissez faire*, I need not describe to this audience, for the effects produced in the eighties and nineties, especially upon the arable districts, are familiar to all and remembered by many. The predominant cause was a world disparity between the demand for, and the supply of, gold which had brought about an average fall in commodity prices of 40 per cent.; subsidiary causes were the rapid growth of overseas competition and a series of climatic vicissitudes. On that occasion, despite the recommendations of numerous witnesses before the Royal Commission of 1894, which ranged from suggestions for the adoption of bimetallism to the re-introduction of import duties, it is noteworthy that remedial measures were practically confined to reliefs from taxation. The rates on agricultural land, representing at that time only some 2*s*. to 2*s*. 6*d*. per acre, or less than 2 per cent. of outgoings, were halved by the Agricultural Rates Act of 1896; payment of tithe was legally shifted from tenant to landlord, and the maximum incidence of Land Tax was reduced from 4*s*. to 1*s*. in the pound. The total cost of the first and last of these measures was less than one and a half million pounds per annum, for the Treasury had agreed to meet only the then existing half share of the produce of rates on farmed land (£1,320,000) so that thereafter the taxpayer could with equanimity view the rising poundage—not so other contributors. The Nation, as represented by its publicly uttered or published opinion, and the administration were content to leave the trinity of British agriculturists to find its own solution. True, the housing, education, and health of rural workers were now the subject of State intervention, but these were matters of general application and represented no special solicitude towards agriculture. Hours and conditions of labour remained, in this industry, unregulated. The farm was not yet a factory; still less was it a controlled unit of production. It is perhaps a legitimate claim to make that the initiation, in 1866, of seemingly so unimportant a matter as the collection of agricultural statistics formed the real foundation-stone of that structure—a Ministry—which was progressively to foster, and to direct, the farmer. Certainly, for the first time, there was thereafter available basic information relating to the then position and the future potentialities of British agriculture.

Although no farmer of the nineties would have dreamed of giving vent to the apocryphal cry of his grandfather 'What we want is another war,' yet, had he but known it, nothing but such a catastrophe would have moved any administration to succour his industry. Actual hostilities, with their terrible aftermath of general unemployment, overtaxation, debt, deflation, and psychological *sequelæ*, are clearly pre-requisites to any determined efforts to help our paramount industry. But, in the nineties, no foreigner threatened us, our secondary products were freely exchanged for an abundance of cheap food obtained from the ends of the earth, few statesmen worried over the loss of some millions of acres of arable land or the emigration of a few hundred thousand agricultural workers. Left to fight, by their own resources, an economic blizzard, the farmers spontaneously developed such new forms of their industry as the long-distance milk trade and the production of fruit, vegetables and other foodstuffs of a luxury character which the growing wealth of the country could command ; the meat trade, at first a standby when cereal prices sagged, was latterly well-nigh overwhelmed by overseas competition. Providentially, foresight and determination at home were supplemented abroad by application of the cyanide process to the extraction of gold and the proved ability of native races to endure life at a depth of more than a mile below the earth's surface when winning this economic prophylactic. World-prices moved responsively upwards, carrying with them those of British agricultural products, and recovery was well on its way by 1908.

At that time, too, the State tentatively assumed certain additional responsibilities ; by strengthening the powers of the Board of Agriculture ; by legislating—it must be admitted, abortively, in the first instance—for the provision of small-holdings ; and in certain other ways that would now be dismissed as parochial, but which were, at the time in question, the subject of astonished comment. Again, however, the cost was low—in keeping, indeed, with canons sacred to Gladstonian finance—and it might, for instance, be claimed that technical instruction to the farmer owes its inception to an unexpected windfall of ' whisky-money ' rather than to any pre-determined Government policy of succour. So passed away, almost imperceptibly, the second great period of rural depression in these Islands, and it did so without affecting either the National outlook or the National purse.

Any commentary upon the years 1914–19, with their story of rigid control applied to every feature of the industry, is fortunately not called for, nor am I here concerned with the gigantic cost of that control to the State, for my real objective is the third great period of agricultural depression—that which, starting in 1922, is, with most of its problems, still facing us. As I have already stressed its causatory and fundamental resemblance to that regnant from 1815 to 1830, I can pass on to analyse and to evaluate the remedial measures that have emerged, for, in contradistinction to previous experience, we may now claim that peace hath her subsidies no less diverse than war. The thirteen years in question can be divided into two distinct periods—the first productive of direct subsidies, grants-in-aid and reliefs from taxation; the second marked by an entirely new development, i.e. the attempted control both of home production and of importation, accompanied by the re-establishment, after eighty-six years, of fiscal duties.

I might perhaps at this stage be expected to assess the weight of this depression and to effect comparison between it and its two predecessors.

For various reasons, however, I do not regard this as incumbent upon me, but will confine myself to the following brief statements. British agriculture does not form one industry, but is, in reality, composed of many, and depression has rarely weighed with equal severity upon all of them simultaneously ; in general, the arable districts have suffered longest and heaviest, and in proportion to the weight of their soil—none more so than East Anglia ; war profits carried many farmers well into the lean years ; it was only in 1931 that agricultural bankruptcies equalled the level attained in the nineties (when at most one in five hundred farmers failed annually) ; new products, and the expansion of the more remunerative older ones, frequently brought help where it was most needed ; the economic situation of the landowner has declined even more than that of the tenant ; while, justifiably, the standard of living of the worker is now greatly superior to what it was in 1914.

In approaching my main thesis I propose, before attempting to estimate the results accruing from the policy each represents, to enumerate, and, as far as possible, to assess the total cost to the State of the various reliefs and disbursements of an eleemosynary character that these post-war years have witnessed. I do not apologise for this, as I feel confident that a large majority even of the agricultural community does not appreciate the weight or the diversity of these aids.

First must be placed the direct, recurrent and non-recurrent, grants. Chronologically, in the forefront of the former comes the Corn Production Acts (Repeal) Act, which, in 1921, resulted in the payment of over eighteen million pounds to the growers of wheat and oats in Great Britain. By this means some three-quarters of all the occupiers of agricultural land received £3 and £4 per acre respectively, or an average of about £80 per head, for the crops in question raised that year. Additionally, a further million pounds was deflected to the furtherance of rural education and research.

The subsidising of sugar and molasses derived from home-grown beet —nowadays a much discussed product—will, with the perfectly legitimate inclusion of the concurrent Excise remissions, during the eleven years of its existence have cost the taxpayer slightly over £47,000,000. At this stage, I will say nothing in regard to the proportionate distribution of that vast sum between farmer and factory, nor will I comment upon the very debatable economic repercussions affecting sugar refiners, foreign cane and beet producers, British shipping interests, or home road and rail services. The benefits derived from the introduction of this crop into our farming economy have been undeniably great, but the spectacle of two hemispheres subsidised to compete for an over-stocked market is a remarkable one.

The redemption of a solemn war-time undertaking to settle ex-Service applicants upon small-holdings caused the expenditure, through the medium of the County Councils, of £15,250,000. The precise cost to the State of establishing the 17,000 persons in question is extraordinarily difficult to assess, but I am indebted to friends at the Ministry of Agriculture for the following information. Some nine-tenths of the sum was advanced by the Public Works Loan Commissioners, and the high rate of interest on post-war borrowings, coupled with an excessive cost of equipment, accounts for the resultant excess of annual expenditure over annual income. This long-term commitment will, by the final year, 2003, have aggregated some £40,000,000. As the Ministry is in reality paying interest, but not the charges upon the loan, the overall average annual deficiency payment will be £565,000, equivalent to £34 for each small-holder. At the present time the charge is some £800,000 per annum—in 1950 it will be £700,000. The weight of such protracted liabilities, both from the national and the personal aspect, is apt to be overlooked, and, remembering the economic hardships to be faced, it is perhaps fortunate that less than half the would-be settlers waited for land.

The Forestry Commission will, under two separate programmes, have expended in fifteen years just under £6,000,000. This is, in effect, a variant form of long-term subvention that will shortly begin to yield substantial returns as the Commission's properties become commercially remunerative.

The cattle and milk subsidies officially represent in part contingent liabilities which are to form claims upon any levies that may hereafter be collected upon imported meat and upon the future resources of the Milk Marketing Board. Even, however, if we accept as certain such repayments, there remain non-returnable State contributions, amounting in the year 1934–5 to £1,600,000, designed to improve the quality of milk, to provide for its sale at reduced rates to schools, and to assist in the production of manufactured grades. During twelve months ending last June, £2,924,000 had been spent on the beef subsidy, which now averages £330,000 a month.

The various post-war measures by which credit has been made more freely available to the industry have caused what would, in normal times, have been regarded as heavy expenditure. Under the Agricultural Credits Act of 1928, a State subscription of £10,000 per annum was guaranteed to the Agricultural Mortgage Corporation, and this piece of legislation, together with the previous Trade Facilities Act, has led to the granting of loans exceeding a million in amount.

While it was implicit in the Wheat (Quota) Act that no expense should fall upon the Exchequer, the corollary of an enhanced price for British wheat now calls for annual payments exceeding £7,000,000, and it is clear that the 'deficiency payments' themselves have, up to now, been worth to the producer somewhat in excess of £4 per acre of wheat. If the whole charge is deflected to the wheat-eater—which it is claimed is demonstrably not the case—the extra expenditure per household must be in the neighbourhood of 15*s.* per annum, or, say, 3½*d.* per week.

It is with the greatest diffidence and hesitation that I countenance the possibility of combining under one head these recurrent or terminally fixed payments, for they vary so greatly in their characteristics and in the relative exactitude with which they can be assessed, but I may hazard the suggestion that, to the *taxpayer*, their gross weight, exclusive, of course, of the 'wheat deficiency payments,' has during the last fifteen years exceeded £90,000,000, or an average of £6,000,000 per annum—say, 5*s.* for every acre of crops and grass in England and Wales : a very disproportionate share has, however, rightly been deflected to the arable districts. As will be indicated shortly, the actual sums expended in recent years, due to the incidence of meat and milk grants and the expansion in beet acreage, have been twice, or even two and a half times, this over-all average.

Next come the annual State disbursements of ever-widening range, made through the medium of official and semi-official bodies, that represent an aggregate sum which would, in pre-war years, have elicited astonishment. Owing to the number of different heads under which the relevant votes fall, it is extremely difficult to determine the total sum thus expended, but at the present time it clearly exceeds £2,500,000 per annum, and ranges from capital grants for building extensions to the establishment of teaching posts and the provision of a complete system of agricultural scholarships, while, too, whether directed to the Outer Isles of Scotland or to the English countryside, it ameliorates the life of the peasant.

The addition of the last-mentioned item will, in such a year as the last, bring the grand total of current *payments*—again exclusive of 'wheat deficiency grants'—to over £15,500,000 per annum, which large sum it must, however, be admitted, represents barely 2 per cent of the nation's Budget. In 1913–14 the amount corresponding to the above-mentioned £2,500,000 was £900,000, which, like it, was expended through the Board of Agriculture, the Scottish Department of Agriculture, and the Development Commission. Drawn from a budgetary expenditure of less than £200,000,000, this figure is not only widely disparate to that recorded above, but, fantastically, apart from the de-rating contribution, it represented the then total National outlay upon the industry.

In view of the fact that grants-in-aid may, from the standpoint of recipients, be very different from that of the taxpayer, it will naturally be asked what proportion of the above financial assistance has reached those actually engaged in farming operations. The answer would appear to be as follows. The whole of the wheat and oats subsidy of 1921 was received by cultivators, as are now the 'deficiency payments' under the Wheat Quota Act, which, with scarcely any loss, balance the 'quota' charges on flour. The sugar-beet subvention presents an extremely difficult problem, which the Greene Committee of Inquiry avoided answering beyond saying that, in 1934–35, its *cost* was equal to £17 an acre. While boldly venturing into this controversial field, I should perhaps first refer to the suggestion, sometimes made, that, with an average net cost of production—always extremely elusive to determine—of some £13 or £14 per acre and cash receipts of £19 per acre (on a beet price of £2 per ton), the factories would, in the event of the subsidy being withdrawn, increase their contribution to the price from £2 to £4 per acre and that therefore, the gross value of this assistance can be reckoned as high as £15 per acre. A second possible method of evaluation rests upon the assumption that the difference between the cost of production and the average return of £19 represents the subsidy's value. Such a differential would be some £5 or £6 per acre (including the value of by-products) which, of course, excludes any advantage derived by the worker owing to enhanced wages. Yet another theory, strongly Protectionist in character, insists that, in effect, the home producer is not being subsidised at all until his rates of benefit exceed those provided for his most favoured Imperial competitors; this basis would give a value of £6 per acre. To me it seems plausible to hazard the suggestion that, despite various difficulties associated with rates of exchange, the fairest method is to attempt to locate the difference between the average of world beet prices and of those ruling domestically. I arrive thus at a present-day world value of 25*s.* per ton, compared with 40*s.* for the internal price, which gives a difference of 15*s.*, or, with a yield of 9·5 tons, of £7 per acre. This, then, is the figure I propose to use in connection with certain tabular statements that follow. Incidentally, all the methods enumerated above, except the first, give results that correspond closely with the widely spread empirical belief that one-third of the gross State expenditure has reached the farmer and his employees.

It is obvious that, in the case of beef, the 5*s.* per live cwt, or average sum of approximately £2 10*s.* per beast, represents a clear addition to the impossibly low prices that would otherwise have been secured; the failure to occur of an anticipated rise in prices led, incorrectly, to the claim that middlemen had absorbed these grants. Admittedly, the consumer is paying more for his milk, and the distributor is enjoying no smaller margin, while in this trade the producer can point to a guaranteed outlet rather than to substantially enhanced prices as the principal result. Sums devoted to afforestation, the provision of small-holdings, and, to a certain extent, sugar-beet, have percolated to many grades of cultivators —actual or potential—but a small proportion has doubtless remained with owners, who find land values improved thereby, while certain ancillary trades, e.g. transport and building construction, have been provided with augmented outlets. Few of the grants have failed to provide additional employment or at least to prevent diminution in the numbers of wage-earners.

When one turns to investigate the truly remarkable reliefs from the 'burdens'—both statutory and non-statutory—which have been implemented during the last ten or twelve years, one finds tax- rate- and tithe-payer all affected. By the Agricultural Rates Act of 1923, which halved the contribution of agricultural land (already, under the provisions of the 1896 Act, reduced by fifty per cent.), the Exchequer thereafter handed over to the local authorities of Great Britain an annual sum exceeding £3,800,000; this, of course, was in addition to the £1,320,000 per annum falling due under the Act of 1896. In 1925 the derating of agricultural buildings necessitated a further contribution, amounting to £700,000 per annum. In 1928 the remaining quarter of local taxation falling upon land, representing £4,132,000, was remitted. The occupiers of agricultural land and buildings in England and Wales alone have, by these means, been relieved of payments which would, in recent years, prior to the readjustment of the Block Grant system, have amounted to about £16,000,000 per annum, equivalent to an average of 12*s.* per acre; rather more than half (£9,000,000) of this sum must have come from the pockets of the taxpayer, the bulk of the remainder being charged upon non-agricultural ratepayers. It may be recorded that this relief represents some £40 per 'average' holding, or £50 per occupier per annum. Similar remissions and reliefs have been accorded in Ireland where, in the case of the Free State, it has been calculated that payments from farmers have been reduced by £2,000,000 per annum; in Scotland £800,000 has been remitted to landlords and £150,000 to tenants.

Even taking into consideration the recent slight fall in the poundage of local rates, it is true to say that, in the aggregate, reliefs from rating must, in Great Britain, represent some £15,000,000 per annum. Whatever theory may postulate, or particular interests suggest, there is now no evidence, any more than was the case on previous occasions, that, as rates were remitted agricultural rents rose, so the full concessions have been enjoyed by their intended beneficiaries.

Rightly classified as a 'productive industry' under the general derating scheme, agriculture secured yet a further concession, assessed at £800,000 per annum, in the shape of preferential rates for rail transport applicable to certain types of produce.

Finally, in approaching the vexed and even hazardous topic of tithe, all interests will perhaps allow me to state that, by the legislation of 1918 and 1925, landowners have been relieved of payments which, had this charge been permitted to pursue the course dictated by the then existing legislation, would up to date have involved them in an additional contribution of £11,000,000. As the whole subject is, as it were *sub judice*, I will only throw out the suggestion that, had some form of sliding scale, indicative of variations in the purchasing power of money, been retained in the last Act, the difficulties experienced by both owners and payers might have been much reduced. The 'pegging' of tithe has, of course, relieved only those farmers falling within the category of owner-occupiers.

Having now enumerated the principal *ad hoc* payments and remissions secured by British agriculture, and attempted to indicate their ultimate distribution as well as their cost to the nation, it is only reasonable that I should refer to certain factors, State-dictated, that figure upon the other side of the rural balance-sheet. The first of these was the re-establishment of the statutory Wages Boards, which, by raising rates of remuneration above the level existing prior to 1924 (under the voluntary system of Conciliation Committees) to the extent of slightly over 6*s.* per week, have caused an addition of £10,250,000 to the annual cost of labour in England and Wales (itself representing one-third of all outgoings) which in turn is equivalent to some 8*s.* per acre over-all and may, in the arable districts, easily exceed 12*s.* per acre. Real wages, due to a steady fall in the cost of living, synchronously advanced. Secondly, our, as it proved to be, premature return to the Gold Standard in 1925, by raising the value of the sovereign some 5 per cent., also, for a period, militated to the extent of another 10*s.* per acre against the farmers' returns; it is fair, however, to point out that in its incidence it was not peculiar to the industry under discussion.

Ignoring for the moment any consideration of the financial advantages derived from import duties or from the avowedly price-raising quantitative control of home produced and imported commodities, it is now possible to strike a general balance based on the principal, and still effective, of all the foregoing items in their reaction upon the *producer*. At levels current now or in 1934–5, it reads, for Great Britain, approximately as follows :

	Credit	*Debit*
'Wheat deficiency payments'	£7,180,000 [1]	
Sugar-beet subsidy (calculated at £7 per acre)	£2,820,000 [2]	
Meat subsidy	£3,300,000 [3]	
Milk grants	£1,600,000 [4]	
Smallholdings and allotments	£900,000	
Afforestation	£450,000	
Ministry of Agriculture, Scottish Department and Development Commission	£2,500,000	
Local taxation reliefs	£15,000,000	
Wages Boards		£10,250,000
Net Gain	£23,500,000	

(1) Cereal year ending September 1934 (official estimate for 1934–5 = £6,865,000)
(2) Year ending March 1935.
(3) Calculated for year ending September 1935 : future commitments estimated at £4,000,000 per annum.
(4) Year ending March 1935 : exclusive of officially returnable advances.

In reviewing these figures, it must be remembered that the official index-number applicable to agricultural commodities produced at home now stands at only some few points above the 1911–13 parity, while, with labour costing double what it did in 1914, and the price of many requisites increased by 50–70 per cent, the weighted average cost of production lies in the region of 50 per cent above the 1911–13 level. The margin to be bridged, therefore, exeeds several times over the credit balance revealed above, which, in round figures, may be taken as equivalent to some 15*s*. an acre.

While taking care not to impinge seriously upon the more practical aspects of the question to be dealt with by other speakers, it will perhaps be appropriate if I illustrate by local example, derived from such a typical arable area as Norfolk, the results of State assistance. This is the soil which, in ancient times, according to that great Norwich medico-antiquary, Sir Thomas Browne, protected certain 'minor monuments from the drums and trumpets of three conquests.' It has subsequently had to endure a similar number of economic assaults upon its own productivity.

Here, in 1934, the 990,000 acres of farmed land derived, in round figures, the following major pecuniary advantages : 'wheat deficiency payments' (calculated on the Wheat Commission's official basis of 3*s*. 11·074*d*. per cwt.), £436,000 or £3 15*s*. for every acre grown ; rating reliefs (at 13*s*. in the pound on agricultural land and buildings), £650,000 ; the sugar-beet subsidy brought into the county some £1,617,000 of which, dare I say, utilising my previous basis of £7 per acre, £666,000, therefore, reached the producer ? The meat subsidy, together with the grants directed towards education, small-holdings, afforestation, and so forth, must have amounted to at least £200,000, or 4*s*. per acre. We arrive, then, at a total of £1,952,000 or, say, £2 for every acre in agricultural utilisation. From this must be deducted £596,000, or 12*s*. per acre, as a result of the increased rates of remuneration ordained by the Wages Board, leaving a nett gain of £1 8*s*. It is a curious coincidence that sugar-beet benefits and wage increments should so nearly cancel one another out, for it has been repeatedly claimed by East Anglian farmers that the former were entirely absorbed by the imposed higher cost of labour.

When it is borne in mind that the over-all per-acre value of our soil products is barely £8, and that it may cost £7 10*s*. to raise an acre of wheat, £4 10*s*. in the case of seeds hay, and £30 in that of potatoes, the advantages derived are, if not striking, at least appreciable. Statistically, the resultant changes in Norfolk agriculture are not unexpected. Wheat is now back to its pre-war acreage, while (regulated) potatoes and the fruit areas have increased ; the other, and unsubsidised, cereals have declined, while sugar-beet has largely supplanted turnips and mangolds. Milch cattle are now more than 50 per cent. above their pre-war numbers, the sheep population is only two-thirds of what it was, but pigs, beneficiaries under the new régime, have practically doubled. The arable land has not been reduced disproportionately to the national loss attributable to the demands of a more mobile and discriminating urban population. It is probable that increased mechanisation, as much as financially dictated staff reductions, has been responsible for the withdrawal of some two thousand whole-time male employees during these fourteen post-war years.

Norfolk may, indeed, be taken as illustrative of the recent post-war tendencies exhibited by the country as a whole, and frequently unappreciated by the man in the (urban) street. They are as follows : a slight increase in the physical output of the soil, a decline in arable area, which would undoubtedly have been much larger but for the grants-in-aid directed to specific crops ; a marked transference from the production of feeding-stuffs to that of sale crops ; a reduction in the number of workers, accompanied by a greater output per person employed ; and a redistribution between the different classes of livestock, which still account for three-quarters of the total agricultural output expressed in terms of money. Nationally, there has occurred a very marked augmentation in the consumption of Imperial as opposed to non-Imperial supplies, together with an increase in the *per caput* consumption of the more expensive foods.

Of the expenditure which has brought about these results, land-owners, have, directly, received little, and their position has, owing to permanently enhanced costs of maintenance and repairs, continued to deteriorate. Tenant-farmers have, by it, been enabled partly to bridge the gap that would otherwise have rendered them impotent to function as producers.

The economic betterment of rural workers can best be measured by recording that their weekly wages now stand at some 75 per cent. above the pre-war level, while the cost of living index-number remains in the region of 40. Remembering the immovable attitude of the administration, and also the public apathy of forty to fifty years ago, and knowing the terrible situation that faced their predecessors yet a century earlier, the present representatives of what is justly one of the most famous agricultural counties in England, must surely feel encouraged by these tangible signs of support to continue their efforts to escape from the darkness of depression into the light of returning prosperity.

Let us now leave the subject of direct financial impacts and benefits, resultant upon State action, to be weighed according to individual opinion, and consider the repercussions attributable to higher policy which involve economic and fiscal adjustments often extraneous in character. The precursors of marketing reform on the grand scale emerged in the shape of the Horticultural Produce Act of 1926 and the ' Rings ' Act of 1927 (both of which attempted to strengthen the position of the farmer in regard to the sale of his produce), extension of the C.O.D. system, and the setting up of the ' National Mark '—all these supplemented the Empire Marketing Board's policy of concentration upon the business functions of the producer. The cost of that Board during its short life (at first a million per annum, subsequently reduced to half that figure) was small compared with the incipient value of its work, which clearly paved the way for the far more ambitious operations of the Agricultural Marketing Acts. By the latter legislation our internal policy was completely altered, and over-riding powers were conferred upon proved majorities to transfer, withhold, process, or otherwise dispose of, ' regulated products ' in order to control output, with the economic *suggestio falsi* that, if fully successful, such a price-raising system would merely readjust profit margins between farmers and intermediaries without raising prices to consumers. When, however, it became apparent that unrestricted supplies from overseas were effectively paralysing the original (1931) Marketing Act, its successor was passed which gave to the Board of Trade full powers quantitatively to control imports of any agricultural commodities already subject to the provisions of the former Act.

The delicate ' gentlemen's ' (but, not necessarily, economists') agreements, soon sought with the Scandinavian group of countries, and with certain South American producers, in the hope that their exports might be cut down to the required figures—generally expressed as percentages (*circa* 60–90) of some basic year or average of years—were not always easy to conclude. Trade agreements or Ottawa pledges will have prevented, in the case of certain articles—e.g. milk, meat and dairy produce—the introduction until this, or even the next, winter of such undertakings with some foreign Countries and with several of our own Dominions and and Dependencies. With import duties also imposed, in 1932, upon a majority of agricultural and horticultural commodities, including one on foreign wheat at 2*s*. per 480 lb., and 10 per cent. *ad valorem* on foreign flour, our Free Trade principles, zealously guarded since 1846, were jettisoned and ' the people's food ' was taxed indeed.

It is extremely difficult to estimate in terms of money the net results of a 'planned' agriculture at home, combined with reduced non-Imperial imports, but, during the second reading of the 1933 Marketing Act, the Minister of Agriculture claimed that, as a result of past policy, 'We shall be able to show that we have secured a rise of 20–30 per cent. in wholesale prices without a rise of more than 1 or 2 per cent. in retail prices.' On the other hand, the Ministry's official *Agricultural Statistics*, 1933, Part II, p. 99, reads as follows: 'In the first six months of 1933 the monthly numbers were between 11 and 15 points lower than the year before. Later, however, there was a recovery, and in the last quarter of the year the index was 7 points or more higher than in the corresponding months of the previous year, while a margin of 6 to 7 points was maintained throughout the first quarter of 1934.' The figures in question, of course, refer to commodities sold off farms (valued at £222,000,000 in 1932–1933) and are, therefore, wholesale. During the last year they have averaged some 7 to 8 per cent. above the level of 1932 and 1933. This, for Great Britain, is equivalent to an aggregate rise of £15,000,000 to £17,000,000 in producers' receipts as compared with Mr. Elliot's implied rise of £44,000,000 to £66,000,000. If we feel justified in ascribing the whole of the officially recorded increase to the influence of the Marketing Acts and their supplementary legislation, this is the sum that must be added to the grand total (£23,500,000) of subsidies and reliefs previously enumerated, for the new policy is supplementary to the old—based upon long-term grants—which of course continues side by side with it. We thus arrive at a figure approaching £40,000,000 as representing the cumulative annual benefits derived from the three policies, *viz.*, grants, remissions, and augmented prices. The new method is far more potent than the old, and, although it is arguable to what extent, if any, middlemen's returns have been affected, it concerns most intimately the consumer. The direct taxpayer, it should be emphasised, has thereby gained a measure of respite at the expense of the indirect.

Including these price- and quantitative control devices, the home market is now in possession of an almost complete battery of economic weapons. So far, that is to say during the last three years, the result has been seen in this relatively small rise in the (wholesale) price of its products, accompanied by a considerable increase in the proportions of Empire, at the expense of foreign, consignments. This has been accomplished at the cost of a growing dependence upon outside direction and some expansion in the numbers of persons ancillary to the industry. Forms to be completed, contracts to be signed, instructions to be obeyed, inspections to be suffered—these are the penalties of a planned and a regimented industry.

In the case of potatoes, some hundreds of transgressors were last Spring summoned to appear before the management of their Board on charges of failing to make returns of stocks, for selling products below the size fixed by the regulations, or for rendering inaccurate acreage returns; fines up to £20 were inflicted. The demand for potatoes as human food is, to a certain degree, elastic, and the Boards have it in their power, by withdrawing small varieties, to raise the price of those in other categories;

acreage restrictions should then prevent any tendency to overproduction. So far, potato prices, whilst not soaring, have substantiated economic theory, while heavy duties on imported ' earlies ' have buttressed the whole structure.

The milk industry has perforce become accustomed to receiving, through eleven ' pools,' payments calculated in pence per gallon to two places of decimals, and varying with the status of the producer, the season, the locality, and the intended utilisation of individual consignments; many producers and a larger proportion of consumers remain in ignorance of the destination and of the source respectively of a commodity whose production and handling are vital to health. Significantly, no provisions for limiting output have at present been imposed, and the Board's energies have mainly been devoted to increasing the consumption of fresh milk at the expense of that unremuneratively disposed of for manufacturing purposes; the average price secured by producers rose last year by about a penny a gallon, but has since declined by perhaps a halfpenny.

Producers responded too well when first invited to contract for the supply of high-grade bacon pigs, and, if prices were to be maintained, limitation of supplies was essential. When faced with markedly higher retail prices consumers became restive, there was evidence that demand was shifting to alternative commodities, and simultaneously the European exporter expressed open dissatisfaction with his reduced opportunities. In these circumstances, the change of policy announced last June and July met with complete agrarian approval. Levies raised on foreign bacon are now to be used to maintain, or to augment, the price of pigs at home and, incidentally, a tariff on imported beef will in due course operate in a similar manner. It thus looks certain that the movement of these substantial economic straws indicates a general change in direction of the political or administrative winds.

Certain branches of the industry, such as fruit, vegetables, and poultry, have rejected regulating schemes, preferring, presumably, to trust, in conjunction with specially granted fiscal protection, to those insular advantages that they possess.

British agriculturists, having witnessed for long the evils of neglect and *laissez faire*, would have been foolish to refuse, at any rate for a time, this form of assistance on the ground that it involved certain sacrifices on their own part, and, when looking around at other occupations, including those of their fellows in many different countries, were wise to accept compulsory co-operation. For, as with armaments, so with industry, it appears unfortunately at the moment to be the accepted rule, *si vis pacem bellum para*—if the primary producer wants enhanced prices and thereafter stability, he must seek both by outbidding in tariffs, subsidies, and exchange restrictions, the aims of foreign countries. Agriculture will assuredly be the last industry spontaneously to support the reintroducton of Free Trade.

The passage of a hundred years has witnessed a vast change in the treatment of social and economic problems, and nowhere is this more marked than in agriculture, where consideration has ousted severity and preferential treatment superseded *laissez faire*. We see agriculturists throughout the world, white, yellow, brown, black, faced with the twin problems of apparent overproduction and under consumption. If analysed, however, the former generally appears to be due, in the main, not to technical improvements such as mechanisation, combined with higher rates of yield, but to State maintenance of artificially augmented crop areas by means of devices, often meretricious in character, designed to bolster up sub-marginal producers or those attracted to the industry by the lure of war-time price levels. Equally, we observe many secondary industries in this and other countries struggling against reduced prices and augmented costs of production. Everywhere we see nationalism, elevated upon a pedestal, temporarily defying, with the aid of every device known to the wit of man, economic and financial vicissitudes, which in turn clog the transference of men, money, commodities and services. We see European states fostering their peasantry by every artifice in order to secure agrarian tranquillity, and we see, simultaneously, the United States of America pouring out thousands of millions of dollars to improve the prospects of her more extensively engaged producers. Everywhere the cry is 'More land for the people!' and 'More people for the land!'

Have we in this country not done wisely to pursue, during the latest of three onslaughts, a middle course (in relation to the above examples) on the one hand, not extravagant in money, nor, on the other, by persuading an undue proportion of our population to live on, or by, the land, subversive of ethical standards? Even such a policy as ours represents, however, a complete break with tradition and with outlook in regard to social as well as to economic matters, and it has been accomplished at first by comparatively heavy financial commitments, in turn to be succeeded by the adoption of a 'planned economy' that has called for readjustment in the respective interests of consumers, distributors, overseas producers, and even of other industries, some of which latter are themselves unsheltered from the blasts of world competition. This 'emergency' programme, as it was first termed, has been carried through at the cost of a reduction in the initiative and freedom of producers, by a certain transference from 'dirty boot' farming to the filling of forms, by a progressive dependence upon outside authority, and, psychologically, by the growth of what may tend to become a defeatist attitude. Yet, the appeal *non tali auxilio* has yet to issue in any volume from the lips of rural spokesmen. Up to the change of policy in 1932, the direct cost—even if we include those long-term commitments—had, by post-war standards, not been excessive, but the nation, or, rather, the urban population, has now acquiesced in a policy which more and more affects not merely the producer and the tax-payer but every householder in the land, so that, latterly, a price raising objective has had to sustain criticism and inquiry from a far wider field.

I have refrained from discussing certain factors axiomatic to the new system, such as its effects upon our secondary industries hitherto engaged in exchanging their products for imported foodstuffs; the future trade and financial relationships likely to subsist between ourselves, our own

Dominions and foreign countries, as a result of the restrictions imposed ; and the political and economic risks attaching to any serious increase in the cost of urban living brought about by a virtually monopolistic and dominant rural hegemony. Upon these questions, that are of overwhelming importance and pregnant with danger, each must form his own conclusions. Fundamentally, too, the farmer whose production costs are high now secures recognition that formerly was the reward of his more efficient brethren. Nor can it be denied that this system of regulated production will, as a concomitant to increased profits for those permitted to remain, logically necessitate the exercise of restraint upon every soil product, including those essential to health, raised upon each commercial unit of land, which in turn must bring under review the determination of rent as well as (now) profits and wages. Whether justified on economic grounds, such a procedure would be open to attacks based on other, and wider, considerations, very difficult to counter. Even technically, a quota system has inherent disadvantages which render its stability uncertain and necessitate frequent revisions and adjustments to neutralise fluctuations in different sources of supply and in prices. Home producers prefer import duties to restriction, and we in this country must not forget that the latter method presents to our own kith and kin overseas a virtually insoluble problem in the shape of consequential control of their own individual producers. It is therefore certain that the latest proposals, initiating a movement from quotas to levies, with a modicum of Dominion preference, will meet with approval from both parties. During the last two or three years we have travelled farther than in the whole of the previous century, and, perhaps kindly, ‘ the iniquity of oblivion has scattered her poppy,’ for we are in danger of forgetting to what an extent our rural and national economy has been transformed by official recognition of some of the above-mentioned paradoxes.

Although my rôle has been merely that of expositor, I hope nevertheless that I have been sufficiently provocative to call forth the opinions of others upon these reflections. It is said that ‘ a rolling stone gathers no moss,’ but, may I suggest that, if, in its third descent during a century into the valley of depression, British agriculture gained a protective covering sufficiently effective to shield it from the worst economic shocks, in future this accretion may actually hamper it when progressing over the smoother and level terrain of normality that we hope lies in front of it ? One is left wondering if the present system of ‘ reorganisation ’ will survive any considerable passage of time, or whether, legislation having telescoped chronology, the comparatively near future may not witness, even as subsidies gave way to planned economy, some relaxation from control, some restoration of individual liberty of action, initated, maybe, by nation-wide restoration of the gold standard giving greater freedom to world trade, and accompanied by the abolition of fear and avarice which would increase reciprocally the demand both for manufactured articles and primary commodities. One of the world's dictators has recently uttered the following dictum : ‘ What the situation calls for is the free movement of goods, of people, of capital, and of credit.’ We, in these islands, have more to gain than any other nation by such a consummation.

Looking back on the past history of British agriculture, I am confident of one thing—whether that time be far distant or near at hand, the industry will resume its prosperity—its importance it has never lost—and unborn generations will regard the present epoch as affording one of those many trials through which, during countless generations, it has emerged unscathed but remodelled, this time not despite a policy of *laissez faire*, but as a result of considered action and preferential treatment of an all-embracing character.

REPORTS ON THE STATE OF SCIENCE,

Etc.

SEISMOLOGICAL INVESTIGATIONS.

Fortieth Report of Committee (Dr. F. J. W. Whipple, *Chairman* ; Mr. J. J. Shaw, C.B.E., *Secretary* ; Miss E. F. Bellamy, M.A., Prof. P. G. H. Boswell, O.B.E., F.R.S., Sir Charles Boys, F.R.S., Sir F. W. Dyson, K.B.E., F.R.S., Dr. Wilfred Hall, Mr. J. S. Hughes, Dr. H. Jeffreys, F.R.S., Mr. A. W. Lee, Prof. E. A. Milne, M.B.E., F.R.S., Mr. R. D. Oldham, F.R.S., Prof. H. H. Plaskett, Prof. H. C. Plummer, F.R.S., Prof. A. O. Rankine, O.B.E., F.R.S., Rev. J. P. Rowland, S.J., Mr. D. H. Sadler, Prof. R. A. Sampson, F.R.S., Mr. F. J. Scrase, Dr. H. Shaw, Sir Frank Smith, K.C.B., C.B.E., Sec.R.S., Dr. R. Stoneley, F.R.S., Mr. E. Tillotson, Sir G. T. Walker, C.S.I., F.R.S.).

Personal.—The deaths of two members of the Committee are recorded with deep regret. These were Sir H. Lamb and Prof. H. M. Macdonald, both distinguished for their work in applied mathematics ; both had served on the Committee since 1915. Reference must also be made to the deaths of two former members. Sir Alfred Ewing was one of the group of British scientists who helped to develop the beginnings of instrumental seismology in Japan. As early as 1881 he devised the method, subsequently adopted by Galitzin, of obtaining a long free period for the vertical seismograph, by attaching the spring BELOW the axis of the lever. He was naturally one of the first members of the Committee formed when Davison and Milne joined forces in 1895. He served until 1909. Sir Arthur Schuster, who was a member of the Committee from 1910 to 1931, took great interest in the organisation of international co-operation. It may be recalled that he was chairman of the Committee, appointed in 1904 by the International Association of Academies, to consider the advisability of co-operation in seismological investigations. This Committee recommended[1] that the Associated Academies should take action with their respective governments in favour of joining the International Seismological Association, founded at Strasbourg in 1903. Schuster became an active member of the Permanent Commission of this Association, and presided over the meetings held at Zermatt in 1909, and at Manchester in 1911. To throw light on the question whether microseismic disturbance was related to sea waves, Schuster had apparatus made for counting and so finding the average period of the waves.[2] This apparatus was set up at the lighthouse at South Shields, and was maintained in operation by Mr. H. Morris-Airey. It appears, however, that no detailed comparison with seismographic records was ever carried out. The set of Galitzin

[1] *Cf.* B.A. *Report*, 1905, p. 92.
[2] Assn. Int. de Sismologie, *C.R.*, 1911, p. 69.

seismographs, which were his gift to Eskdalemuir Observatory and which are now in operation at Kew Observatory, may be regarded as a token of Schuster's strong belief that good instruments, well standardised, were a necessary aid to progress in seismology.

Miss E. F. Bellamy and Mr. J. S. Hughes, both of the University Observatory, Oxford, have been co-opted as members of the Committee.

Finance.—The annual grant of £100 from the Caird Fund and the special grant of £50 from the General Fund of the British Association were allocated to the University Observatory, Oxford, for the maintenance of work on the International Seismological Summary. The Committee also voted the sum of £50 from the Gray-Milne Fund for the same purpose. It will be necessary to make like provision for the coming year.

The Committee has authorised the making of a large metal sphere, on which the positions of all seismological stations are to be permanently marked. It is expected that it will be possible to measure epicentral distances on this sphere with an accuracy which has not been attained previously by such simple means.

The memoir by Dr. Jeffreys and Mr. K. E. Bullen, in which the results of their analysis of the travel-times of earthquake waves are set out, has been published by the International Seismological Association. (*Travaux Scientifiques*, Série A., Fasc. 11.) The data on which the memoir depends were derived from the *I.S.S.*, and it was regarded as appropriate that a grant should be given from the Gray-Milne Fund to enable the tabular matter to be printed with the text of the memoir. It will be recalled that standard tables based on the work of Jeffreys and Bullen have already been taken into use in the preparation of the *I.S.S.*

The income of the Gray-Milne Fund is still suffering from the lapse of the dividends due from the Canadian Pacific Railway.

Gray-Milne Trust Account.

	£	*s.*	*d.*		£	*s.*	*d.*
Brought forward . .	294	19	1	International Seismological Summary . .	50	0	0
Trust Income . .	46	14	10	Operation of Seismographs . . .	15	18	8
Bank Interest . .	1	7	10	Milne Library . .	9	15	9
				Fire Insurance . .		15	0
				Printing (Jeffreys and Bullen Memoir) .	63	7	0
				Carried forward . .	203	5	4
	£343	1	9		£343	1	9

Bound Volumes of the Summary.—In accordance with a recommendation of the Committee recipients of the *I.S.S.* were given the choice between quarterly parts, and the bound volume, for the year 1930. The bound volume was chosen by 135 and the parts by 205. The volume, strongly bound in blue cloth, is now on sale (post free £1 1*s.*) and is to be obtained from The Director, University Observatory, Oxford.

A New Catalogue of Earthquakes.—A catalogue of earthquakes, of the years 1925 to 1930 inclusive, has been prepared by Miss Bellamy, and is being published by the British Association.[3] This catalogue is based on

[3] See pp. 230 *seqq.*

the *International Seismological Summary* and is in the same form as that for the years 1918 to 1924, which was due to Prof. Turner, and appeared with the Report for 1928.

In these catalogues the earthquakes are in chronological order. It is hoped that it will also be possible to publish a continuation of Turner's *Index Catalogue of Epicentres* 1913·0–1920·5, in which a geographical arrangement is adopted. This is in course of preparation.

Seismographs.—A second Milne-Shaw seismograph has been supplied by Mr. J. J. Shaw to the Liverpool Observatory and Tidal Institute at Bidston, in order to give the two horizontal components of tilting of the red sandstone of Bidston Hill with the rise and fall of the tide in the Mersey estuary. These investigations are being conducted by Prof. Proudman and Dr. Doodson in their research on tidal phenomena.

A working seismograph has been constructed by Mr. Shaw and erected on the second floor of the Science Museum, South Kensington. The pendulum (370 lbs.) is supported on the main outer wall of the building and records upon smoked paper in order that the public may see the seismograph in operation. The record travels 8 mm. per minute and runs for two days. The instrument is also fitted with a bell-ringing device such that an earthquake will give alarm, but slow tilting of the building, due to temperature, etc., produces no effect.

A Milne-Shaw seismograph is on order and nearing completion for Brisbane. Prof. Alexander Brown reports that the two seismographs provided by the Committee on loan to the University of Cape Town are functioning satisfactorily.

British Earthquakes.—A small earthquake occurred near Inverness on August 16, 1934, at 2.15. The shock was felt over the Highlands and was recorded by the seismographs at the English stations, including the Wood-Anderson at Kew.

Other small disturbances which may have been due to such causes as the collapse of old workings in mines were reported in the newspapers on the following dates :

Llanhilleth, Monmouth . . .	March 2, 1935
Aspley, Nottingham . . .	May 3, 1935
Jersey	July 28, 1935

The Quetta Earthquake.—Last year we were reminded by the devastation on the borders of Bihar and Nepal how liable India is to great earthquakes. This year we have to mourn the loss of some 15,000 lives in an earthquake of almost equal severity at Quetta, on May 31, 1935. Only a few months earlier, Mr. W. D. West, of the Geological Survey of India, in his report on two earthquakes which occurred in 1931, had written : 'At present the majority of buildings in Quetta are about as unsoundly built from an earthquake proof point of view as it is possible for them to be.' It is satisfactory to note that the need for special regulations governing building in the areas liable to earthquakes is appreciated by the local authorities in India. The desirability of the provision of more seismological stations with suitable equipment is emphasised in the latest annual report of the Geological Survey of India, and we should like to lend all possible support to this plea.

Montserrat.—A series of small earthquakes in the West Indian island, Montserrat, has caused material damage and considerable alarm, the disturbances being associated with the emission of large quantities of sulphuretted hydrogen and other gases from vents near to Plymouth, the only town on the island. Mr. F. A. Perret, the American vulcanologist, has been consulted and has equipped a small research station. These occurrences have emphasised the need for more seismological stations in the West Indies.

Microseisms.—Two papers on microseisms by A. W. Lee have been published during the year. At Kew Observatory, as previously at Eskdalemuir, the amplitude and period of the microseisms recorded by the North component seismograph have been measured four times a day. Mr. Lee made similar measurements of the microseisms recorded by the East and Vertical component seismographs during the year 1932. It was found that on the average the amplitudes of the three components were equal. As a result of this investigation it was decided that the vertical movements should be measured and published as from the beginning of 1935.

In the other paper Lee has developed a method of determining the direction from which microseismic waves approach an observatory. The successful application of this method provides a verification of the hypothesis that these waves are of the Rayleigh type, the movement of the ground being such that the earth particles move round ellipses or circles in a vertical plane; the motion is retrograde, being opposite to that of a point on a wheel rolling along the ground in the direction of propagation of the wave. It is found that the microseismic waves generally approach England from N.W. and are associated with storms in the Atlantic.

The International Seismological Summary.

A Note by Mr. J. S. Hughes.

The *International Seismological Summary* for 1930 has been completely distributed, and the first quarter of 1931 is in the Press. The year promises to be an unusually heavy one, partly on account of increase in the number of stations, and partly by increased seismic activity in the early months. The Hawke Bay–New Zealand earthquake of 1931 (Feb. 2) is followed by numerous aftershocks, but owing to the uncertainty of the times from several of the New Zealand recording stations, only the few largest are sufficiently recorded for the purpose of the *Summary*. Other records from New Zealand definitely attributed to aftershocks have been tabulated in full as far as the end of February.

The new tables of Jeffreys and Bullen have now been in use for over a year, and the experience gained of them fulfils the hopes entertained of a more even fit of observation with theory along the whole scale of epicentral distance (as far as 100°). In particular, the few well-recorded earthquakes, for which nearly all the observational material was obtained within 20° of the epicentre, can now be determined with great accuracy. As stated in the Introduction to the *I.S.S.* for 1930, the P phase carries most weight in analysing the observational material and, as a result, the S phase recorded at distances where it is not usually confused with any other phase, sometimes shows systematic errors not easily explained, and much in excess of the probable error of the time curve. On 1931 January 15d. and 16d. two earthquakes occurred at epicentre 16·4° N. 96·3° W., but, whereas for the earlier shock the residuals are nicely balanced both in azimuth and as between P and S, for the latter, although the P is equally good, the S is systematically late by several seconds. This effect is opposite to that where S is read too early and a suitably increased T_0 would make residuals resemble those associated with a shock of slight focal depth. This phenomenon is attributed to Z effect or high focus in the superficial layers of the earth's crust, but it is difficult to believe that a difference of focal depth in so very shallow a stratum should produce so great an effect on the travel time. The two shocks from the same epicentre make it impossible to attribute the discrepancy to peculiarities of internal structure, at least in this case.[4]

The *Seismological Bulletin of the Central Meteorological Bureau of Tokyo*, for 1931, contains readings from many stations in Japan which would not otherwise be received by the *I.S.S.* Several of these readings appertain to large distant earthquakes, but mostly they are records of local shocks obtained with seismographs with short periods. Wherever possible, the epicentre determined at Tokyo is adopted for the *Summary*, but in a few cases it is necessary to modify the position in the light of information from other sources. As one example of the excellence of these readings, it may be mentioned that the table for the shock of 1930 November 25d. 19h. with epicentre 35·1° N. 139·0° E. contains records of thirty-nine Japanese stations, all with $\triangle$ less than 10°.

Further valuable data have begun to appear in 1931 from the group of stations in California, whose headquarters is at Pasadena. They are Haiwee, La Jolla, Mt. Wilson, Riverside, Santa Barbara, and Tinemaha. All their observations are extremely good and their position most fortunate, for, although they exist primarily for carrying out experiments on short wave transmission, they are able to record shocks in those distant parts of the Pacific too far west to give satisfactory readings at places near the Atlantic coast and for which observations to the east and north-east would otherwise be scanty. Pasadena itself, with its large instrumental equipment, often gives several readings for each phase, but when these only differ by one or two seconds the earliest is considered sufficiently representative.

The earthquakes of 1930 July 23d. 0h. and November 21d. 2h. from 41·1° N. 15·4° E. and 40·0° N. 19·5° E. are notable for lists of nearly seventy stations with $\triangle$ not greater than 22°. The epicentres are both given by De Bilt, the latter being quoted from the *Bulletin* of the Russian stations, and is of much greater accuracy than the round figures suggest. Here again we have large positive residuals for S, though in the nearest stations S* or Sg may be recorded instead of S.

1930 December 3d. 18h. epicentre 18·2° N. 96·4° E. is strangely unsatisfactory. Although there are two large groups of observing stations in azimuths round 55° and 320°, consisting of nearly all the best data from Japan and Europe, yet the residuals are scattered indiscriminately over the wide interval between ±8s., which at 70° of $\triangle$ corresponds to a range of apparent errors in distance of about ±1·5°. There has been here some general difficulty in reading the phases, and examination of the traces for Oxford instruments shows marked but not exceptional disturbance by microseisms which in the case of instruments of high magnification might make it impossible to distinguish a P of very small amplitude. As contrast to this, the shocks of 1930 July 2d. and 1930 September 22d. 14h., with origins in the same neighbourhood, show as good a fit as can be wished, both for Japanese and European records. For these dates microseisms are almost entirely absent from the Oxford films and it remains a question whether stations in Japan as well as in Europe were troubled by the microseisms in making their readings of the December 3d. films.

[4] It may be that in the first of these two earthquakes no appreciable compression waves were generated at the focus so that the phase recorded as P was really the phase sP; the latter phase is generated from shearing waves which reach the surface near the epicentre. The interval between sP and S is less than that between P and S.—F. J. W. W.

Transmission Times.

By Dr. Harold Jeffreys.

The paper on 'Transmission Times,' by Mr. K. E. Bullen and myself, has been published by the International Seismological Association, part of the cost being covered by a grant from the Gray-Milne Fund. I have now rediscussed the whole of the data, supplemented by some further earthquakes and special studies. The P times are found to have standard errors of about 0·3 sec. at most distances, rising to about 1 sec. at 105°. S seems also to be well determined between about 25° and 70°; but at shorter and greater distances different earthquakes giving good series of observations give times differing by about 10 secs. when the adjustable constant Z is chosen to fit the times from 25° to 70°. The core reflexions PcP and ScS have been tabulated from Scrase's and Stechschulte's studies of deep-focus earthquakes. On combining these with the observed times of PKP and SKS times of K for all distances in the core have been found. A number of other core phases have been computed. SKKS, where it is best determined from observation, agrees well with the calculated times. The only noteworthy changes from the times given in the Jeffreys-Bullen tables are in SKKS beyond 170°, and in PKP_2, which has to be reduced by about 7 secs.

In a further paper, five deep-focus shocks have been discussed. The effect of focal depth has been calculated and allowed for, so as to reduce the observations to a standard focal depth, namely for a focus at the top of the lower layer. The intervals pP–P, sP–P, and sS–S, when adjusted in this way, give determinations of the times lost in passage through the upper layers. The results are not quite consistent, but what seem to be the best determinations agree with thicknesses of 14 km. and 28 km. for the upper and intermediate layers respectively; the standard error of the sum is about 3 km. It seems probable that this work may lead to a determination of Z for a known focal depth and to crucial tests of the doubtful parts of the S table, but this part of the analysis is not yet complete.

The Long Wave Phase of Earthquakes.

By Dr. R. Stoneley.

The presence of this phase of a seismogram is generally attributed to the passage of elastic waves over the surface of the earth. Two distinct types of wave are known to be theoretically possible: Rayleigh waves, in which the motion of the ground has both vertical and horizontal components but is always in a vertical plane through the line of travel, and Love waves, in which the motion is horizontal and perpendicular to the direction of propagation. The velocity of a surface wave on the earth depends on its period; the first surface waves to appear on a seismogram are the Love waves of very long period, which should, and apparently do, travel faster than the longest Rayleigh waves. Some progress has been made in separating these two types by choosing earthquakes whose surface waves arrive in a N., E., S., or W. azimuth; for instance, if waves arrive in an E. azimuth, a N. component seismograph will record the Love waves and the E. and Z components the Rayleigh waves. In this way the transmission times of waves of different periods can be found. The velocity of travel is not the wave velocity, but the group velocity; the wave velocity can, however, be obtained from this by numerical integration when some assumption has been made about the velocity of a wave of very long period. The integration has been carried out[5] with some of the data that were published by W. Rohrbach. The velocities derived for Love waves across Eurasia fit very closely the theory of the propagation of Love waves in a double superficial layer, and correspond to a continental structure in which about 15 km. of granite rest on some 30 km. of tachylyte, with dunite as the underlying material. The observations of Love waves which have travelled across the floor of the Pacific are consistent with the presence of a layer of granite 10 km. thick, with dunite as the subjacent material, or alternatively with the presence of about 16 km. of diorite over the dunite.

One further difficulty arises in separating the two types of surface wave. Either the transition from ocean to continent, or variations of thickness of the upper layers within a continent or below an ocean floor, will cause, in addition to a scattering of waves, regular refraction and reflection. It is, therefore, not correct to assume that in general these waves travel by a great circle path from epicentre to recording station. This point is further discussed in the paper above cited.

It is desirable to call attention to the intrinsic differences that may occur between different earthquakes. Prof. H. H. Turner found that, for the majority of the earthquakes that he investigated, the observations of L, the onset of the long wave phase, indicated transmission times corresponding to 0·477 minutes per degree, or about 3·9 km./sec. This corresponds to the onset of the Rayleigh waves and may be distinguished as LR. The corresponding onset of the Love waves (or ' Querwellen ') should correspond to about 4·4 km./sec., or 0·42 min./deg. Actually, Turner[6] found that for one earthquake, 1926 October 3d. 19h. the observations of L corresponded to 0·41 min./deg., so that in this earthquake the onset of the Love waves, which may be denoted by LQ, was specially prominent, although for European stations the arrival was in an easterly azimuth, and the E. components, on which the *I.S.S.* was preferentially based, would have been expected to record mainly the Rayleigh waves. Some stations record both LQ and LR ; Simla E., for instance, gives in that earthquake LQ, whereas Simla N. records LR. Evidently, then, the primitive S movement in this earthquake was predominantly of an SH type, and such earthquakes may not be common ; at any rate, the point is worth further investigation, and information may be forthcoming from a study of the body waves. The fact that one of the two L onsets may be found among the ' Additional Readings ' is a justification, if any were needed, for Turner's policy of printing as many readings in the *I.S.S.* as space and financial considerations would allow.

Those who have had experience of the heavy analysis and computation involved in the problem of Rayleigh waves in a heterogeneous medium will welcome a paper[7] in which Dr. Jeffreys applies Rayleigh's Principle to find the velocity of Rayleigh waves. Even in the unfavourable case in which the whole change of properties occurs in a single abrupt transition, the velocity of a wave of any given period can be calculated within a few per cent. ; and the saving of labour is enormous.

Reappointment.

The Committee asks for reappointment, for the continuation of the grant of £100 from the Caird Fund, and for a special grant of £50 for the maintenance of the *International Seismological Summary*.

[5] R. Ast. Soc., *Mon. Not. Geophy. Suppt.*, III, 262 (1935).
[6] *International Seismological Summary*, 1926.
[7] *Geophysical Supplement*, III, 253 (1935).

CATALOGUE OF EARTHQUAKES 1925—1930

(1) In 1928 the late Prof. Turner prepared a 'Catalogue of Earthquakes, 1918–1924,' which was published by the British Association for the Advancement of Science. It was his intention to publish a further Catalogue, and he was engaged upon this, upon his 'Shallow and Deep Earthquake' research, and upon the revision of the tables within a month of his lamented death in Stockholm in 1930. Since then I have endeavoured to fulfil his wish by completing the manuscript of the Catalogue to the end of 1930, being the last year for which the I.S.S. is complete. The Catalogue, therefore, contains the statistical summary of the world's earthquakes for six years, 1925–1930. This Catalogue has been compiled as voluntary work at home, and is offered as a contribution to earthquake science and as a personal memorial of respect to Prof. H. H. Turner.

(2) A characteristic of the period 1925–1930 has been the increase in the number of epicentres determined and the consequent increase in the size of the I.S.S. on which this Catalogue is based. This increase in the number of epicentres is presumably or entirely due to the increase in the number of stations which send good readings to Oxford. Thus when the work was taken over from Shide in 1918 only some 120 stations were available, while by the end of 1930 readings are being received from over 300 stations. The consequent increase in the number of epicentres determined is well shown in the following table, which is self explanatory. It is interesting to note that, apart from 1918, old epicentres form in the mean one-half the total of determined epicentres in each year. The increase of pages in the I.S.S. is due not only to more quakes and records being received, but to more phases being identified and included in the 'Additional Readings' given, at the end of each quake.

	Epicentres.			Ratio.	Pages in
Year.	New.	Old.	Total.	New Old.	I.S.S.
1918	171	201	372	0·85	218
1919	111	212	323	0·52	170
1920	111	223	334	0·50	200
1921	103	155	258	0·67	176
1922	119	191	310	0·62	222
1923	185	359	544	0·52	316
1924	120	350	470	0·34	284
1925	133	347	480	0·38	324
1926	151	461	612	0·33	427
1927	167	495	662	0·34	473
1928	177	418	595	0·42	440
1929	217	385	602	0·56	518
1930	207	446	653	0·46	426
Total ..	1972	4243	6215	Ratio is 0·465	

The increase in the number of quakes and in the number of pages of print appears to be maintained, subject to slight variations from year to year. Though the number of quakes given for 1930 (653) is 51 more than 1929, the number of printed pages is 92 less; this is partly accounted for by the

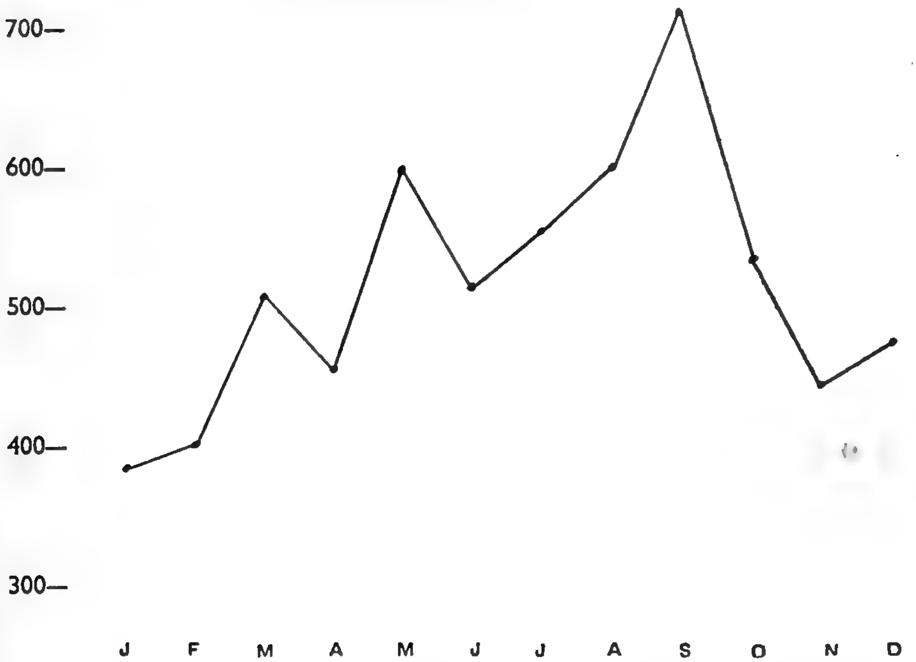

FIG. 1.—Total number of Earthquakes in 1918–30 occurring in various months.

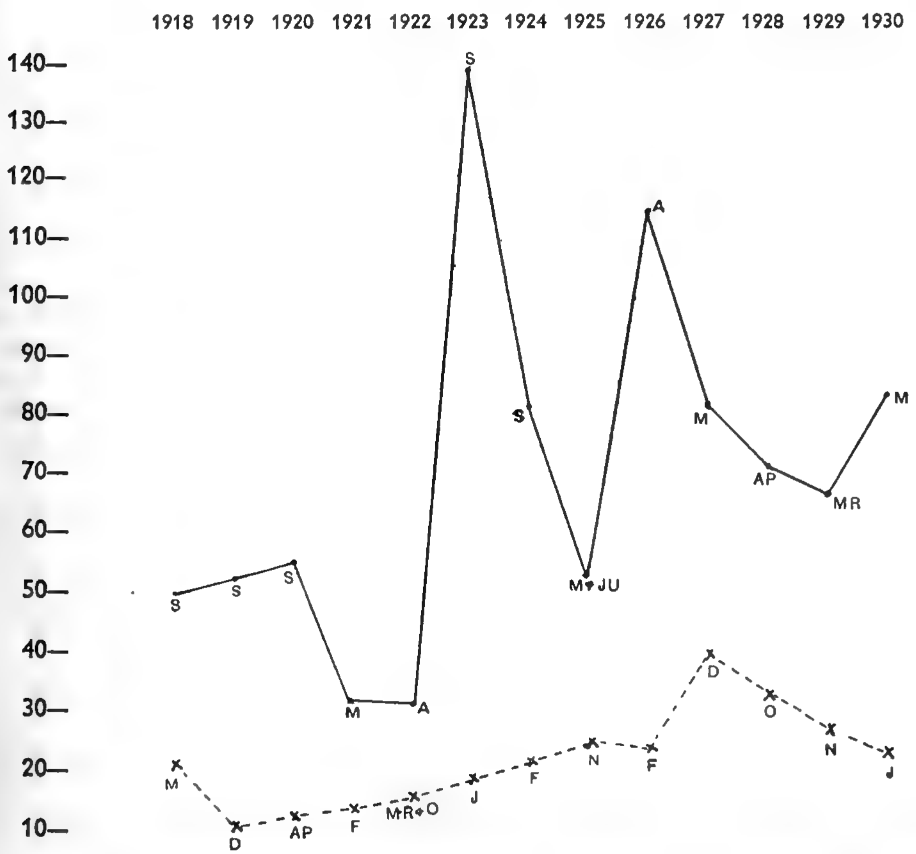

FIG. 2.—Number of Earthquakes occurring in maximum and minimum months.

omission in the tabular part of all stations which recorded only L or M; those giving L waves are mentioned by name at the end of 'Additional Readings': this change was introduced in the Summary for 1930.

(3) The material now available in this and the previous catalogue strongly confirms an earlier suggestion of Prof. Turner on the monthly frequency of earthquakes. A count of the total number of epicentres occurring per month over the whole period 1918–1930 gives a marked maximum in September and some evidence of a secondary maximum in the spring; these two periods account for nine maxima in the thirteen years. Attention is directed to the only other months having a maximum, March, April, June, and August. This is well shown by Fig. 1, for which the abscissa is the month and the ordinate is the total number of earthquakes occurring in that month for the whole period. A related question is how pronounced this maximum is in any given year. This is shown in Fig. 2, where the upper complete line gives the number of earthquakes occurring in the 'Maximum Month,' and the lower broken line the number of earthquakes occurring in the 'Minimum Month,' each as a function of the year. The letters attached to each point denote what months in each of the years 1918 to 1930 are the 'Maximum' and the 'Minimum.' The vertical distance between the two lines is a measure of the departure from a uniform number of earthquakes per month throughout the year, so that 1923, the year of the frequently repeated earthquake in Japan of September 1, was a year with a very pronounced maximum, while 1921, 1922 and 1925 were years with very uniform distribution.

(4) It is necessary to repeat some part of the explanation of the columns in the present Catalogue; the former Catalogue for 1918–1924 gives the explanation and reasons more fully.

The first column is the day of the month, given at the head of each group, with the T_0, of the shock in hours, minutes and seconds of G.M.T. from midnight.

The second and third columns show the latitude (North +, South −) and longitude (East +, West −) of the epicentre.

The fourth column has the number of stations which have given recognisable observations of the shock; this number indicates very roughly which are severe shocks observed at considerable distances, and which are only slight and local. The number in this column really represents the number of stations in the world that have sent records to Oxford and been used in the tabular part. These shocks, for which the preliminary wave P has been observed at a distance of at least 80° from the epicentre, are marked with an asterisk (*). The dagger (†) in column four refers to notes collected at the end. Most of these notes show the cases of anomalous focal depth, expressed in fractions of the earth's radius and measured from the normal focal depth as reference depth.

"The fifth column, headed 'Former Occasions,' is, it is hoped, an addition of some value. It was left an open question for some years whether earthquakes were apt to recur at precisely the same epicentre or merely in proximity to it; and accordingly independent determinations of epicentre were made for successive shocks in the same neighbourhood. But it gradually became apparent that the hypothesis of exact recurrence was often as good as any other, while the convenience of utilising the calculations of $\triangle$ and azimuth already made was considerable. Accordingly the habit of using old epicentres became gradually established; and there is this to be said in favour of it, that those who doubt the validity of the implied hypothesis may be glad to have an easy reference to test cases."

"The sixth column, 'Minor Ents.,' shows the number of observations relegated to the notes in the I.S.S., as cases where there is not sufficient material to give an epicentre. Many of them are records at a single station only, unsupported by any independent observation. On some days there are only sporadic observations of this kind, with no serious shock; but *no day* in the six years is *completely blank*. It will be seen that the number of residual observations of this kind is given, on days when there are also several considerable shocks, against the *last* shock for that day."

Ethel F. Bellamy.

University Observatory, Oxford.
1935, *June* 13.

CATALOGUE OF EARTHQUAKES, 1925–1930.

An asterisk (*) denotes that there are observations of P beyond $\Delta = 80°$; a dagger (†) that there is a note at the end of the Catalogue.

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1925 *January*.			
d. h. m. s.	°	°			
1					15
2 16 40 30	+36·0	− 5·0	3	1924 Dec. 25	
2 23 15 45	+38·8	+ 70·0	11	1924 Sept. 16	15
3 8 18 42	+44·7	+147·6	26	1924 June 30	19
4					6
5 13 45 36	−12·0	− 69·0	*15	1922 Aug. 21	
5 21 42 0	+24·0	−107·0	15	1922 June 12	
5 21 59 15	+24·0	−107·0	15	1925 Jan. 5	16
6					20
7 11 6 42	+42·0	+ 22·5	8	1924 May 16	13
8 2 44 56	+47·2	+ 6·0	14		
8 20 52 0	+36·5	+139·5	5	1924 Oct. 23	9
9 4 35 20	+36·5	+139·5	4	1925 Jan. 8	
9 7 1 30	+36·5	+139·5	6	1925 Jan. 9	
9 10 16 40	+36·5	+139·5	1	1925 Jan. 9	
9 14 25 26	+36·5	+139·5	1	1925 Jan. 9	
9 15 27 56	+36·5	+139·5	9	1925 Jan. 9	
9 16 19 46	+36·5	+139·5	2	1925 Jan. 9	
9 17 38 15	+41·0	+ 44·0	50		15
10					8
11					20
12					8
13					13
14 10 19 0	−11·0	+167·0	15		11
15 2 50 15	+42·0	+ 22·5	6	1925 Jan. 7	
15 16 50 50	0·0	+135·0	12	1921 Oct. 10	17
16					6
17					13
18 12 5 52	+48·8	+153·5	*103	1923 Feb. 16	
18 13 11 42	+12·0	− 91·0	5		

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1925 *February*—contd.			
d. h. m. s.	°	°			
4 10 2 32	− 7·0	+148·0	23	1921 Jan. 6	6
5					11
6 17 11 12	+35·0	+142·0	18	1922 July 2	13
7 8 53 0	+37·2	− 3·6	3	1924 Nov. 28	
7 12 14 56	+36·5	+ 19·7	33	1920 Nov. 28	
7 17 23 50	+48·0	+105·0	10		
7 18 9 50	+ 5·4	+125·2	*12	1923 Aug. 31	
7 18 18 0	+25·0	+121·5	*23	1923 July 2	
7 20 24 48	− 1·0	+117·0	8		19
8					16
9 5 53 30	+16·0	− 90·0	9†	1920 Oct. 8	
9 14 9 48	−22·0	+170·0	*64†	1922 May 12	11
10 3 22 20	+16·0	− 90·0	14	1925 Feb. 9	
10 8 16 54	−22·0	+170·0	11†	1925 Feb. 9	
10 10 38 18	−22·0	+170·0	10	1925 Feb. 10	
10 12 14 45	−22·0	+170·0	11	1925 Feb. 10	
10 21 43 40	−22·0	+170·0	7	1925 Feb. 10	16
11					10
12 6 27 30	+40·0	+ 42·0	3	1924 Sept. 27	15
13 7 12 52	+35·5	+143·5	4	1923 May 31	
13 13 32 35	+11·5	+128·5	5		
13 13 49 15	−29·2	−177·0	*48	1921 May 14	11
14 0 42 18	+37·0	+138·5	4	1924 Oct. 2	4
15 7 48 0	+34·5	+138·0	4	1924 Dec. 21	8
16 17 39 8	−58·0	− 7·0	*54		10
17 14 13 18	−51·7	+173·8	7	1920 May 9	16
18 11 31 18	+ 9·0	+141·0	*8	1919 Mar. 30	16
18 (11 35 50	+69·0	+145·0	8†)		
19					12
20 1 2 20	+46·0	+149·0	*82	1923 Aug. 22	19

19	9	4	40	+34·5	+ 25·0	12	1923 Dec. 31	24
20								25
21	18	11	0	−55·0	− 24·0	*25	1923 May 1	8
22	10	17	42	+36·5	+140·5	5	1923 May 26	9
23	17	1	0	−11·0	−170·0	12	1917 May 18	11
24	8	26	45	+36·5	+140·5	5	1925 Jan. 22	25
25	10	45	48	+36·0	+138·0	6	1923 Sept. 29	13
26	19	2	6	+ 8·7	− 83·0	*55	1918 Apr. 27	28
27	8	17	0	+33·5	+ 27·0	15		17
28	4	5	25	+43·2	+147·2	*90	1924 Dec. 29	
28	10	58	30	+ 8·7	− 83·0	*26	1925 Jan. 26	
28	18	14	40	+52·8	+174·0	23†		
28	18	15	6	+39·0	+155·0	*23		22
29								26
30	17	28	20	+52·8	+174·0	*48†	1925 Jan. 28	15
31	7	5	20	+48·0	+ 21·0	19		
31	17	0	30	+42·5	+149·0	22	1915 June 7	18
				1925 *February.*				
1	5	23	50	+43·2	+147·2	*79	1925 Jan. 28	
1	15	56	48	+15·5	+ 56·5	7		
1	17	14	36	+43·2	+147·2	7	1925 Feb. 1	
1	18	0	15	− 1·0	+126·0	9		
1	19	33	36	+39·0	+ 73·0	4	1922 Dec. 17	
1	21	3	30	+41·0	−127·0	*18	1919 Jan. 31	
1	21	52	40	+50·0	− 6·5	21		38
2	10	53	33	+43·2	+147·2	4	1925 Feb. 1	
2	11	18	36	+43·2	+147·2	11	1925 Feb. 2	
2	11	38	40	+43·2	+147·2	22	1925 Feb. 2	
2	13	29	9	+43·2	+147·2	*74	1925 Feb. 2	
2	14	11	50	+43·2	+147·2	10	1925 Feb. 2	
2	18	44	24	+ 9·5	+ 60·0	8		
2	19	24	50	+43·2	+147·2	13	1925 Feb. 2	
2	19	46	45	+43·2	+147·2	*86	1925 Feb. 2	
2	22	12	45	+43·2	+147·2	22	1925 Feb. 2	28
3	2	27	50	+43·2	+147·2	13	1925 Feb. 2	
3	18	18	42	+ 6·3	+123·2	*20	1922 July 13	12

22								19
23	23	53	36	+60·0	−146·0	*92		8
24								19
25	22	0	40	− 3·5	+146·5	*19	1924 May 27	7
26								7
27								7
28								12
				1925 *March.*				
1	2	19	12	+48·2	− 70·8	*83†		
1	3	57	0	+46·7	+145·8	12	1921 Oct. 12	
1	12	25	26	+22·0	+120·5	*30	1924 Jan. 15	10
2								6
3	0	38	36	+41·0	+ 13·5	4	1920 Apr. 5	9
4								11
5								10
6								7
7	18	14	8	−55·0	− 5·0	*27		10
8	0	51	40	−26·5	−179·0	*13	1924 Apr. 28	
8	11	27	42	+35·0	+ 69·0	18†	1921 May 20	17
9	19	48	54	+41·0	+131·0	5	1923 July 26	26
10								8
11								12
12	1	22	0	+40·0	+ 42·0	8	1925 Feb. 12	
12	11	20	12	+39·0	+ 55·0	6		20
13								11
14	2	13	30	−55·0	− 24·0	12	1925 Jan. 21	
14	14	36	48	+ 6·5	+128·0	5	1924 July 26	10
15	13	46	44	−10·8	+119·5	*14†		
15	15	41	30	−10·8	+119·5	*27†	1925 Mar. 15	
15	17	14	54	+43·8	+ 11·2	11	1924 June 12	37
16	4	28	36	+31·5	+130·0	6	1923 July 13	
16	8	52	54	+31·5	+141·5	6	1922 June 29	
16	10	8	55	−18·0	− 73·0	5†	1922 Sept. 19	
16	14	42	6	+25·0	+100·5	*89†		
16	23	19	24	−27·0	−176·0	18	1924 Nov. 13	

Catalogue of Earthquakes, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1925 *March*—contd.			
d. h. m. s.	°	°			
16 23 50 26	+25·0	+100·5	21	1925 Mar. 16	17
17 15 32 0	+39·0	+ 24·8	21		20
18 14 2 6	− 0·5	+152·0	*23	1921 Oct. 20	12
19 15 37 55	+ 4·8	+ 96·8	*22	1917 Nov. 4	19
20 5 42 48	− 5·0	+109·0	11		
20 12 19 30	+31·0	+133·0	*28		13
21 15 21 40	+48·2	− 70·8	8†	1925 Mar. 1	
21 16 15 20	+34·0	+ 21·0	10	1924 Aug. 8	
21 16 24 30	− 7·0	+148·0	6	1925 Feb. 4	28
22 8 41 50	−18·5	+168·5	*94	1924 July 20	
22 14 5 24	− 1·0	+140·0	*29		27
23					8
24 12 55 0	+24·0	−107·0	7	1925 Jan. 5	13
25 12 3 0	− 6·0	+160·0	* 8†	1924 Apr. 6	9
26 10 25 12	+ 5·4	+125·2	*20†	1925 Feb. 7	15
27 4 16 48	+39·8	+130·3	*13		26
28					13
29 21 12 27	+ 7·5	− 79·0	*76†	1924 July 20	8
30					4
31 1 6 2	+35·5	+141·0	4	1924 Oct. 5	7
		1925 *April*.			
1 17 20 0	−22·0	+172·0	27		11
2 1 29 30	+34·0	+133·0	3	1923 Dec. 12	
2 22 45 36	+21·0	+125·5	8		17
3 10 52 36	+44·5	+ 16·5	4		24
4 23 34 36	+35·5	+ 29·0	6		18
5 3 4 25	+35·5	+ 29·0	35	1925 Apr. 4	
5 3 53 40	+35·5	+ 29·0	17	1925 Apr. 5	
5 21 1 35	−16·0	−171·0	20	1919 July 16	6

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1925 *May*.			
d. h. m. s.	°	°			
1 2 24 40	+44·8	+ 14·7	4	1923 Oct. 18	
1 3 48 50	− 3·0	+143·5	*16	1923 Sept. 22	
1 6 6 55	+34·0	+133·0	4	1925 Apr. 18	
1 8 17 36	+34·0	+133·0	5	1925 May 1	9
2 2 57 0	+34·0	+ 61·5	5		12
3 0 23 42	−14·0	−174·0	8	1924 July 7	
3 17 21 42	+ 2·5	+126·7	*95		
3 22 58 54	−34·0	+ 57·0	*85	1925 Apr. 11	6
4 4 0 24	+ 4·0	+128·0	*18		
4 9 42 10	+ 4·0	+128·0	* 6	1925 May 4	
4 11 28 48	−16·0	+140·0	*29	1924 May 7	8
5 10 6 0	+ 9·5	+123·0	*87	1919 Mar. 23	
5 10 40 0	+ 9·5	+123·0	4	1925 May 5	
5 11 58 33	+ 9·5	+123·0	*25	1925 May 5	
5 12 44 36	+ 9·5	+123·0	3	1925 May 5	
5 16 23 18	+ 9·5	+123·0	6	1925 May 5	
5 18 16 0	+ 9·5	+123·0	10†	1925 May 5	
5 23 21 0	+ 2·5	+126·7	*73	1925 May 3	15
6 4 58 18	+ 2·5	+126·7	*16	1925 May 5	
6 8 10 48	−33·0	+168·0	*17		30
7 0 42 45	+ 2·5	+126·7	5	1925 May 6	
7 12 11 22	+12·0	+126·0	*22		
7 14 33 50	+12·0	+126·0	*39	1925 May 7	54
8					12
9 3 37 42	+ 2·5	+126·7	7	1925 May 7	9
10 3 0 30	+ 2·5	+126·7	6	1925 May 9	3
11					20
12					21
13 8 10 40	+ 2·5	+126·7	11	1925 May 10	
13 22 51 15	+41·0	+ 44·0	15	1925 Jan. 9	
13 23 54 24	+10·5	+ 92·5	*38		19

6					8
7 18 5 36	+ 7·0	+126·0	*66	1924 Dec. 1	18
8					11
9					17
10					6
11 10 41 54	−34·0	+ 57·0	*88		
11 22 27 10	+35·5	+143·5	7	1925 Feb. 13	3
12 19 27 0	+39·0	+ 23·0	28†	1922 June 16	
12 (19 25 35	+35·5	+ 29·0	18)	1925 Apr. 5	6
13					12
14 1 34 10	+12·0	+ 95·0	12	1922 Oct. 17	
14 15 16 51	+44·0	− 20·0	7	1919 Sept. 13	7
15 4 58 48	+35·5	+ 29·0	13	1925 Apr. 12	
15 6 1 45	+35·5	+ 29·0	6	1925 Apr. 15	
15 6 14 30	+35·5	+ 29·0	18	1925 Apr. 15	
15 9 32 45	+45·0	+ 73·0	5		34
16 5 32 15	+27·0	+103·5	11		
16 19 52 30	+22·0	+120·5	*96†	1925 Mar. 1	19
17 5 41 57	+37·0	− 6·5	6		
17 11 4 55	+ 7·0	+126·0	6	1925 Apr. 7	11
18 10 52 44	+34·0	+133·0	4	1925 Apr. 2	24
19 15 46 36	+33·0	+137·5	*41†		
19 20 41 55	+40·0	+141·5	*27	1920 Jan. 6	11
20 2 0 36	+40·0	+141·5	6	1925 Apr. 19	
20 10 20 40	+ 2·1	+127·8	4	1922 Oct. 5	
20 10 28 0	+37·2	+101·4	4	1921 Apr. 12	10
21					13
22 23 10 30	− 1·0	+129·0	*36	1924 May 15	8
23 19 32 30	+ 7·0	+126·0	14	1925 Apr. 17	7
24					10
25 9 18 18	+20·0	+128·0	15		
25 13 17 50	−19·0	+166·0	*28†		15
26 8 24 10	−58·5	+145·5	*43	1924 Apr. 29	11
26 (8 24 22	−55·0	+145·0	*23†)		
27					42
28					17
29 20 3 40	+39·6	+ 27·7	8	1924 Dec. 22	
29 22 26 25	+59·0	−135·5	7	1923 Apr. 25	3
30 10 58 10	−34·0	−175·0	21	1924 May 6	12

14 7 10 48	+36·5	+ 70·5	18†	1921 Nov. 15	
14 15 19 18	+ 6·0	+125·0	*10	1923 Mar. 2	13
15 11 57 0	−25·0	− 71·0	*61		
15 18 25 36	+30·5	+138·5	14†		18
16 2 20 0	−34·0	+ 57·0	*14	1925 May 3	
16 10 27 50	+ 9·0	+155·0	*17		18
17					15
18 7 22 30	− 1·5	+ 66·5	7		
18 16 4 6	+36·1	+137·3	4	1923 Feb. 12	13
19 5 23 35	−34·0	+ 57·0	*80	1925 May 16	9
20 7 53 48	+37·5	+ 19·7	10	1923 Feb. 13	
20 11 4 48	+30·6	+141·8	*47	1919 Mar. 26	
20 22 46 6	− 8·0	+127·5	*20	1924 Feb. 1	16
21					11
22 9 40 10	+30·6	+141·8	*46	1925 May 20	16
23 2 9 40	+35·7	+134·8	*80†		
23 (37 shocks	+35·7	+134·8	64)	1925 May 23	
23 7 34 50	+24·0	+123·0	9	1923 Nov. 25	
23 21 21 42	+24·0	+123·0	7	1925 May 23	24
24 1 24 20	+24·0	+123·0	*36	1925 May 23	
24 5 9 25	+24·0	+123·0	4	1925 May 24	
24 (8 shocks	+35·7	+134·8	21)	1925 May 23	22
25 3 43 0	+12·0	+123·1	*53	1922 Aug. 29	
25 (7 shocks	+12·0	+123·1	7)	1925 May 25	
25 16 22 14	+35·7	+134·8	*43	1925 May 25	
25 (12 shocks	+35·7	+134·8	32)	1925 May 24	3
26 8 20 24	+16·5	− 89·5	*28	1921 Feb. 4	
26 15 37 0	+24·0	+123·0	*38	1925 May 24	
26 (11 shocks	+35·7	+134·8	24)	1925 May 25	
26 (9 shocks	+12·0	+123·1	9)	1925 May 25	9
27 2 29 54	+36·5	+133·0	*54†		
27 20 58 36	+60·0	+175·0	*16†		
27 (5 shocks	+35·7	+134·8	15)	1925 May 26	15
28 3 19 15	+22·0	+ 63·0	7		
28 5 55 10	−34·0	+ 57·0	*64	1925 May 19	
28 (6 shocks	+35·7	+134·8	14)	1925 May 27	26
29 (6 shocks	+35·7	+134·8	11)	1925 May 28	15
30 22 45 0	+43·8	+ 15·7	17	1924 Mar. 1	14
31					15

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1925 *June.*

T₀ (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1					12
2 3 43 50	+41·0	+144·0	11	1924 July 9	
2 5 18 12	+41·0	+144·0	*37	1925 July 2	16
3 4 33 50	+ 3·0	+126·0	*92		9
4 1 13 10	+43·0	−125·0	23	1924 July 1	
4 1 19 40	+27·0	+125·0	5		
4 12 2 55	+43·0	−125·0	*39	1925 June 4	20
5					7
6 3 42 25	−30·0	− 77·0	3		
6 8 51 28	+39·0	+ 22·0	8	1922 Mar. 15	
6 20 45 25	−32·0	− 95·5	8		16
7 23 41 40	+ 3·0	− 80·5	*51†	1924 Oct. 18	8
8					17
9 13 40 20	− 3·5	+142·0	*96	1918 July 3	
9 18 53 45	− 2·0	+128·5	19	1924 Nov. 18	8
10 16 45 10	+35·3	+ 3·5	25	1924 Nov. 6	24
11 15 56 30	− 3·5	+142·0	*30	1925 June 9	8
12 10 58 24	− 3·5	+142·0	*33	1925 June 11	
12 22 53 30	+21·0	− 67·0	13		11
13 20 23 0	−30·0	− 24·0	*26		18
14 0 33 6	+35·7	+134·8	4	1925 May 25	
14 5 38 10	+24·0	+123·0	20	1925 May 26	
14 6 49 30	+24·0	+123·0	8	1925 June 14	
14 13 39 45	+24·0	+123·0	14	1925 June 14	
14 16 0 54	+24·0	+123·0	12	1925 June 14	
14 22 28 6	+17·5	− 83·0	*37		40
15					14
16 14 54 12	+44·5	+ 11·5	7	1922 Aug. 24	26
17					23
18					13
19 7 50 28	−15·0	−172·0	*34	1923 May 15	

1925 *July*—contd.

T₀ (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
3 16 37 45	+34·0	−119·0	7	1925 June 30	
3 18 20 55	+34·0	−119·0	11	1925 July 3	
3 19 20 54	+35·7	+134·8	14	1925 June 23	
3 23 53 50	+35·7	+134·8	4	1925 July 3	13
4 8 13 2	+30·0	+119·5	8	1921 Dec. 1	
4 9 9 45	− 8·4	+155·8	*60	1924 Sept. 6	
4 17 48 5	+46·0	+ 12·0	10	1922 Nov. 8	
4 22 16 54	+ 2·0	+126·0	*17		18
5 7 1 56	+13 0	− 43·0	*25		37
6 7 4 0	−18·5	−176·0	14	1923 June 18	
6 12 15 45	+38·0	+ 21·5	60	1918 July 11	
6 16 46 55	+35·7	+134·8	17	1925 July 3	21
7 8 4 5	−14·0	−174 0	6†	1925 May 3	
7 8 14 0	−34·0	+ 57·0	*37	1925 May 28	
7 14 12 12	+19·6	−106·5	*69	1919 Apr. 18	
7 15 5 8	+18·0	− 62·0	26		
7 17 43 30	+18·0	− 62·0	*52	1925 July 7	
7 18 28 50	+40·0	− 2·0	7		19
8 1 24 45	− 7·0	+150·0	*19	1923 June 5	
8 4 55 57	−13·5	+ 68·5	*18	1922 Feb. 14	
8 8 23 40	+ 3·0	+125·0	10	1924 Dec. 5	
8 11 27 30	+18·0	− 62·0	16	1925 July 7	
8 14 38 30	+18·0	− 62·0	16	1925 July 8	
8 18 38 15	+18·0	− 62·0	16	1925 July 8	
8 19 42 0	+37·4	+ 30·5	7	1922 June 3	12
9					19
10 15 58 10	−23·0	− 66·0	7	1924 Jan. 20	18
11 1 54 36	+18·0	− 62·0	12	1925 July 8	
11 21 52 22	+29·5	+ 59·5	5	1923 Sept. 14	7
12					13
13					9

19	16 38 20	+41·5	− 40·0	16	1923 July 21	38
20	13 4 4	+37·0	+ 72·0	*54†	1924 Oct. 13	7
21	3 0 30	+37·0	0·0	5†	1924 Mar. 4	
21	4 6 22	+24·0	+123·0	8	1925 June 14	
21	15 4 43	+35·7	+134·8	7	1925 June 14	
21	18 21 16	+35·7	+134·8	4	1925 June 21	12
22						19
23	3 58 0	+35·7	+134·8	15	1925 June 21	
23	4 43 50	+42·3	+140·0	*24	1920 Sept. 16	
23	16 46 48	0·0	− 75·0	*15†	1923 Sept. 9	
23	19 53 54	+54·0	+158·5	12		20
24	0 0 24	+41·0	+ 31·0	19		
24	1 37 15	+35·3	+ 3·5	6	1925 June 10	
24	16 11 24	+48·0	+105·0	6	1925 Feb. 7	26
25						26
26	17 27 12	+30·1	+131·6	5	1914 Nov. 28	7
27	8 22 5	+46·0	+ 17·5	8		5
28	1 20 59	+46·4	−111·2	*92†		
28	2 5 35	+46·4	−111·2	23	1925 June 28	
28	3 40 45	+46·4	−111·2	8	1925 June 28	
28	6 13 50	+29·0	+130·0	*55	1924 Oct. 18	
28	13 41 35	+10·2	+ 92·8	*33		
28	16 44 50	+43·4	+ 19·2	19	1923 Mar. 30	
28	22 31 50	+46·4	−111·2	12	1925 June 28	16
29	14 42 10	+34·0	−119·0	*75		
29	16 3 12	+34·0	−119·0	3	1925 June 29	
29	16 6 5	+34·0	−119·0	3	1925 June 29	
29	16 34 30	+34·0	−119·0	4	1925 June 29	
29	18 56 0	+34·0	−119·0	11	1925 June 29	14
30	3 44 12	−15·0	−172·0	21	1925 June 19	
30	6 6 15	+41·5	+ 40·5	8		
30	9 18 45	+34·0	−119·0	8	1925 June 29	20

1925 *July*.

1	1 18 10	+45·5	+ 15·0	11	1920 May 5	7
2	16 38 55	+36·5	+ 1·5	10	1922 Nov. 19	12
3	6 16 40	+42·4	+ 21·4	8	1922 Sept. 3	
14	20 18 12	−23·0	− 66·0	*5	1925 July 10	7
15						22
16	22 28 30	+45·0	+ 16·0	5	1924 Dec. 3	10
17	3 13 45	+12·0	+141·5	*42		
17	16 59 8	− 5·7	+103·8	*27		
17	21 7 40	− 2·0	+137·0	*47	1922 Apr. 5	
17	22 30 40	+12·0	+141·5	*31	1925 July 17	15
18						23
19	20 30 32	+23·6	+123·5	13	1915 Feb. 28	21
20	15 3 30	+42·5	+ 7·5	6	1924 May 20	15
21	13 40 6	+43·5	+ 85·5	11		16
22						14
23						6
24						25
25	13 5 48	+42·8	− 1·0	7	1924 Feb. 22	9
26	2 53 50	+40·5	+ 41·0	10		
26	12 46 0	+38·5	+139·0	7	1923 Aug. 24	9
27						14
28	4 37 55	0·0	+125·0	*13		15
29	4 54 18	−26·5	−179·0	25	1925 Mar. 8	
29	14 3 8	+58·0	+ 99·0	10		
29	19 8 54	+37·5	+ 27·5	10	1920 Nov. 27	9
30	12 16 50	+35·5	−101·5	13		
30	18 43 10	+30·0	+ 51·0	16		10
31	8 46 18	+ 5·5	− 77·5	*25	1924 June 22	10

1925 *August*.

1	2 25 40	−28·0	−163·5	14	1924 Aug. 6	25
2						19
3						20
4	0 22 6	+23·7	0·0	13		11
5	5 1 0	+37·4	+ 30·5	21	1925 July 8	
5	20 11 33	+40·0	+ 78·0	26		15
6	7 15 24	+36·7	+ 63·0	6		
6	10 37 4	+35·7	+134·8	3	1925 July 6	
6	14 20 48	− 0·5	+152·0	*19	1925 Mar. 18	14
7	2 52 45	+38·0	+137·5	5	1923 Dec. 4	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1925 *August*—contd.			
d. h. m. s.	°	°			
7 6 46 27	+37·4	+ 30·5	46	1925 Aug. 5	
7 7 47 40	+19·0	−100·0	*72	1924 Apr. 21	
7 16 12 56	+37·4	+ 30·5	5	1925 Aug. 7	
7 17 23 42	+52·0	− 36·0	15		28
8 3 4 12	+37·4	+ 30·5	9	1925 Aug. 7	30
9 17 16 40	+37·4	+ 30·5	8	1925 Aug. 8	24
10					13
11 17 12 18	+21·5	− 40·5	10†		
11 19 41 21	−35·5	− 72·0	*22		12
12 0 5 20	+37·4	+ 30·5	9	1925 Aug. 9	
12 6 58 33	+24·0	− 46·0	42†	1924 Oct. 14	13
13					21
14 4 8 30	−59·5	+151·5	*55		
14 6 19 10	− 7·0	+150·0	*17	1925 July 8	
14 9 17 6	+ 2·1	+127·8	9	1925 Apr. 20	23
15					8
16 2 25 12	+52 0	+148·0	*32		
16 20 58 54	+37·4	+ 30·5	34	1925 Aug. 12	17
17					14
18					19
19 4 6 30	+19·5	− 65·0	*11	1923 Mar. 15	
19 5 13 40	+37·4	+ 30·5	6	1925 Aug. 16	
19 5 24 50	+52·5	−170·0	*24		
19 12 7 22	+54·7	+167·0	*100		
19 12 51 22	+35·7	+134·8	6	1925 Aug. 6	25
20 23 1 0	+40·0	+ 2·0	11		
20 23 4 20	− 1·0	− 21·5	*28		11
21 11 14 20	+37·7	−118·5	7	1924 Feb. 21	
21 20 14 0	+14·5	+115·0	9		18
22					15
23					8

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1925 *September*—contd.			
d. h. m. s.	°	°			
16					15
17					14
18					6
19					13
20 7 10 30	− 1·5	+ 93·5	18	1923 Sept. 5	
20 18 6 52	+39·0	+ 31·0	9	1925 Sept. 14	9
21					17
22 6 8 36	+12·0	+127·0	6	1925 Sept. 15	6
23 20 12 15	+36·5	+ 70·5	6†	1925 May 14	6
24 4 38 36	+27·5	+ 55·0	38		
24 13 33 24	+40·0	+ 12·5	36†	1917 Dec. 28	31
25 2 32 24	+19·0	−100·0	7	1925 Aug. 7	
25 8 45 10	− 5·6	+102·0	*23†	1920 July 8	
25 19 37 18	+12·0	+127·0	7	1925 Sept. 22	19
26 5 4 42	+44·5	+ 4·0	12		
26 17 44 36	+12·0	+127·0	*12	1925 Sept. 25	31
27					10
28 21 42 25	+45·0	+ 77·0	17		6
29 17 33 40	+18·0	− 63·0	*46†		12
29 (17 33 40	+18·0	− 64·0	*45)		
30 13 25 25	+34·0	+ 4·0	*12	1924 July 19	21
		1925 *October*.			
1					15
2 4 35 45	+ 2·0	+126·0	4	1925 July 4	15
3					15
4 3 44 45	+10·0	−103·0	14	1919 July 25	
4 7 28 42	+41·0	+156·5	*12	1916 Feb. 6	17

24								24
25	5	10	48	+41·0	+ 16·0	14		
25	12	56	36	−13·0	− 10·0	*12	1917 Aug. 21	5
26	16	8	30	+31·0	+ 96·0	8†		9
27								8
28	8	57	30	+37·4	+ 30·5	6	1925 Aug. 19	16
29	22	36	25	+25·5	−110·5	*35		8
30	13	15	50	+38·0	+ 69·5	14		9
31	9	58	0	+35·0	+ 90·5	32	1920 May 2	
31	19	46	50	+37·5	+142·5	9	1923 Nov. 10	35

1925 *September.*

1	8	16	0	+39·0	+ 31·0	35	1924 Nov. 20	16
2								12
3								20
4	10	36	0	+16·0	− 90·0	11	1925 Feb. 10	8
5	7	43	24	+45·5	+ 15·0	28	1925 July 1	
5	16	30	10	+54·0	+170·0	*55		13
6	0	39	0	+45·5	+ 15·0	7	1925 Sept. 5	
6	1	4	40	−30·5	+ 53·0	*15		9
7								10
8								6
9								18
10	10	33	30	+45·5	+ 15·0	6	1925 Sept. 6	
10	12	56	48	− 7·0	+148·0	*19	1925 Mar. 21	16
11	3	33	5	−15·0	−172·0	10	1925 June 30	
11	4	41	0	+45·0	+ 14·8	33†		
11	5	9	0	+12·0	+127·0	*8		
11	6	58	56	+45·0	+ 14·8	26	1925 Sept. 11	
11	9	51	21	+45·0	+ 14·8	8	1925 Sept. 11	17
12	0	48	6	+43·0	+ 93·0	11	1924 July 12	
12	9	26	0	− 8·0	− 75·0	*16		
12	14	14	48	− 1·0	− 21·5	*17	1925 Aug. 20	13
13								12
14	9	6	45	+39·0	+ 31·0	6†	1925 Sept. 1	11
15	20	53	20	+12·0	+127·0	*5	1925 Sept. 11	15

5	4	9	2	+12·3	− 85·8	*74†		
5	4	10	55	+17·5	− 83·0	7	1925 June 14	
5	9	3	12	−29·0	− 73·0	6	1923 July 31	
5	11	9	25	+43·7	+141·2	7		11
6	4	11	0	+37·5	+ 23·0	21	1924 Feb. 16	
6	13	41	0	+75·0	+ 7·0	7		12
7								8
8								11
9								27
10								8
11								6
12	5	44	30	−34·0	+ 57·0	*62	1925 July 7	26
13	12	10	54	+38·0	+ 17·5	19		
13	17	40	28	+10·2	− 42·8	*102†		14
14	10	23	30	+35·3	+130·8	*15	1921 Nov. 16	
14	17	5	18	+27·0	+100·0	15		18
15	1	22	18	−15·0	−172·0	13	1925 Sept. 11	
15	12	36	12	+27·0	+100·0	*45	1925 Oct. 14	27
16								22
17								11
18	8	25	48	+ 4·8	+126·0	*38	1924 Sept. 11	5
19	10	43	36	+28·0	−112·5	5	1919 Sept. 30	
19	10	57	30	+42·5	− 85·5	22	1918 June 17	23
20	9	41	45	+27·3	+138·5	18†	1923 June 29	15
21	16	53	20	−39·0	180·0	23	1914 Oct. 28	15
22	17	1	36	− 4·0	+103·0	*68	1914 July 14	15
23	1	47	27	− 9·0	+115·0	*29		14
24								11
25	0	21	20	+ 5·0	+128·0	*23	1918 June 8	
25	4	30	0	−18·0	− 73·0	17†	1925 Mar. 16	14
26								17
27								19
28								12
29	19	31	40	+29·0	+104·0	7	1917 July 30	7
30	11	2	0	+ 5·0	+128·0	14†	1925 Oct. 25	
30	(11	2	22	+ 6·5	+126·0	9)	1922 June 27	
30	14	41	48	− 8·0	+160·0	*52	1920 Mar. 22	17
31	19	30	45	+12·0	+141·5	7	1925 July 17	13

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1925 *November.*

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1					29
2 18 44 10	+76·5	+ 15·0	10		22
3					26
4					15
5					14
6 13 57 40	−13·0	− 74·5	18		
6 15 13 35	+38·0	+137·5	12	1925 Aug. 7	
6 19 20 45	+26·5	+ 81·5	10		10
7					9
8					9
9 0 11 25	+37·5	+ 19·7	6	1925 May 20	42
10 13 50 27	− 1·0	+130·5	*108		25
11					11
12					6
13 12 14 40	+13·0	+124·7	*107†		
13 (17 shocks	+13·0	+124·7	17)	1925 Nov. 31	14
14 8 10 48	+13·0	+124·7	27†	1925 Nov. 13	
14 10 3 28	+13·0	+124·7	*38	1925 Nov. 14	
14 14 37 3	+13·0	+124·7	*33	1925 Nov. 14	
14 22 35 30	+39·0	− 27·5	24		
14 (17 shocks	+13·0	+124·7	17)	1925 Nov. 14	14
15 (7 shocks	+13·0	+124·7	7)	1925 Nov. 14	16
16 11 54 44	+19·8	−107·0	*94†		
16 (6 shocks	+13·0	+124·7	6)	1925 Nov. 15	20
17 0 17 45	−10·0	− 79·0	*47		
17 (6 shocks	+13·0	+124·7	6)	1925 Nov. 16	22
18 (3 shocks	+13·0	+124·7	3)	1925 Nov. 17	10
19 12 25 5	+26·5	+ 27·5	15		
19 14 6 42	0·0	+125·0	7	1925 July 28	
19 16 3 0	+31·0	−116·0	13	1923 Nov. 7	
19 19 10 35	−10·0	+176·0	11		8

1925 *December*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
14 7 0 0	−18·0	+173·5	16	1924 Sept. 7	6
15 7 44 30	+30·0	+ 85·0	12	1924 May 27	
15 10 31 24	−25·0	− 2·0	*11		5
16					9
17 5 41 45	−48·0	+170·0	8	1922 Feb. 15	8
18 2 28 42	+37·4	+ 30·5	10	1925 Aug. 28	
18 5 53 20	+30·0	+ 51·0	19	1925 July 30	
18 9 24 25	+41·5	+ 60·0	4		
18 10 47 15	−33·0	+152·0	2		
18 18 10 16	+36·8	+ 69·5	20†	1922 Dec. 6	
18 19 1 8	−23·0	− 66·0	4	1925 July 14	7
19 3 15 30	− 6·5	+153·5	*13	1921 May 12	
19 16 9 20	−32·5	−110·5	*59		23
20					9
21					14
22 5 5 25	+20·0	+101·5	*63		
22 5 18 42	+28·0	+130·0	7	1921 Nov. 29	
22 7 6 12	+35·7	+134·8	4	1925 Dec. 13	11
23 10 59 45	+56·0	−150·0	*9	1923 Sept. 23	
23 23 4 12	+20·0	+101·5	17	1925 Dec. 22	18
24					12
25					7
26 18 23 40	+ 9·8	+126·2	*34	1920 May 9	18
27 10 28 8	+ 2·0	+126·0	*37	1925 Oct. 2	
27 17 38 12	− 6·5	− 81·5	22		16
28 19 2 27	+10·0	+127·5	11	1923 Dec. 19	
28 21 56 10	+39·0	+155·0	*10	1925 Jan. 28	11
29 2 3 54	+45·3	+153·5	37	1922 Apr. 26	
29 16 4 6	− 1·0	+121·0	*35	1923 Dec. 5	14
30					15
31 8 46 48	−14·0	−174·0	*30	1925 July 7	12

20								12
21								9
22	0	5	45	+13·0	+124·7	6	1925 Nov. 14	13
23	14	38	22	+36·7	+163·0	6	1925 Aug. 6	10
24								16
25								15
26	15	49	56	+30·1	+131·6	11	1925 June 26	
26	17	0	0	+35·7	+134·8	9	1925 Aug. 19	16
27								21
28	5	43	6	+25·8	+128·0	19	1924 July 7	
28	8	14	40	+70·0	− 19·0	22		
28	12	33	25	+16·5	− 86·0	22		
28	16	13	20	−18·0	+167·0	*58	1922 Apr. 11	7
29								20
30	17	46	32	+29·5	+129·0	22		5

1925 *December.*

1								23
2								26
3	18	58	40	+44·5	+ 4·0	7	1925 Sept. 26	11
4								22
5								15
6	16	17	54	+37·7	−118·5	12†	1925 Aug. 21	
6	16	21	24	+30·0	− 97·0	6		16
7	8	34	24	+38·0	+ 76·5	38		10
8								21
9								33
10	4	59	40	+40·0	+ 60·0	10	1919 July 14	
10	14	14	42	+15·5	− 92·5	*92		
10	16	6	50	+15·5	− 92·5	8†	1925 Dec. 10	
10	20	34	20	+15·5	− 92·5	14	1925 Dec. 10	23
11	0	44	15	+48·0	−178·0	18	1913 June 22	
11	1	27	48	+15·5	− 92·5	*27	1925 Dec. 10	
11	7	19	40	+37·0	+138·5	4	1925 Feb. 14	18
12								14
13	15	31	36	+35·7	+134·8	4	1925 Nov. 26	17

1926 *January.*

1	18	4	6	+45·0	+ 14·8	52	1925 Sept. 11	
1	21	37	15	−22·5	− 70·5	*30†		33
2								18
3								16
4	4	1	36	+48·0	+170·0	10	1925 Dec. 17	18
5	7	27	40	−14·0	+166·5	*36	1923 May 11	
5	10	3	14	+11·0	+ 57·0	19		
5	23	37	30	+51·0	+ 6·0	11		11
6	23	45	20	+ 2·0	+126·0	*20	1925 Dec. 27	14
7	14	31	6	+34·0	− 39·8	*41		35
8	9	14	15	+42·8	+ 12·3	9	1918 May 13	
8	14	22	18	−23·0	− 66·0	3	1925 Dec. 18	19
9								16
10	9	2	40	+36·0	+142·0	8	1925 Sept. 14	9
11								12
12								30
13	1	46	44	+38·0	+ 29·5	42	1923 Sept. 11	
13	8	8	24	+38·0	+ 29·5	39	1926 Jan. 13	18
14	8	51	54	+36·5	+133·0	6	1925 May 27	14
15	14	52	45	+45·0	+143·0	13†	1924 Dec. 27	28
16								7
17								26
18	11	20	30	+43·0	+ 75·0	20		
18	16	55	45	+ 6·0	+125 0	*23	1925 May 14	
18	21	7	18	− 1·5	+ 88·5	*82		19
19								13
20								17
21	21	26	58	+33·5	+131·9	7	1922 Dec. 18	7
22								25
23	0	13	0	−34·0	+ 57·0	*11	1925 Oct. 12	
23	3	11	52	+13·7	+128·0	*14		8
24	1	25	22	−34·0	+ 57·0	*11	1926 Jan. 23	7
25	0	36	12	− 9·0	+159·5	*111		
25	14	39	36	+31·5	+130·0	5	1925 Mar. 16	20
26	7	4	24	−20·6	+168·8	*50	1924 Oct. 5	11
27								14

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1926 *January*—contd.			
28					19
29 3 27 48	−20·6	+168·8	19	1926 Jan. 26	
29 5 55 45	−20·6	+168·8	10	1926 Jan. 29	18
30 11 53 36	+33·5	+131·9	6	1926 Jan. 21	19
31 10 19 12	+42·3	+ 17·8	9	1923 Dec. 19	9
		1926 *February*.			
1 1 17 33	+10·6	− 65·6	*22†	1923 Aug. 8	6
2					14
3 11 52 6	−20·6	+168·8	*23	1926 Jan. 29	
3 19 30 16	+50·0	+171·0	4	1913 Apr. 29	
3 21 46 36	+34·6	+140·7	6	1924 May 11	10
4 6 44 10	+42·5	+139·2	*34		12
5					14
6 8 49 50	+45·1	+147·2	23	1919 July 16	15
7 2 43 54	+ 1·0	+147·0	*27	1922 Aug. 7	
7 (2 43 54	− 3·0	+151·5	*27†)		
7 4 37 0	−41·5	− 81·0	6		
7 7 49 22	−18·0	+173·5	*32	1925 Dec. 14	
7 22 41 58	+50·1	+178·7	20	1924 Sept. 14	10
8 15 17 40	+12·0	− 89·0	*108†		
8 19 48 32	+37·5	+ 19·7	7	1925 Nov. 9	25
9 0 24 24	−27·0	− 59·5	*53†		27
10 14 48 20	+13·0	− 85·4	24	1922 Aug. 18	23
11 5 5 48	+46·0	+149·0	7	1925 Feb. 20	16
12 7 40 12	−17·0	−177·5	18	1924 May 17	28
13 9 8 20	−23·5	+178·0	*54	1923 Apr. 13	12
14					20
15 2 59 42	+11·7	− 89·6	*94†		
15 14 36 48	+41·5	+ 20·0	12		

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1926 *March*—contd.			
16 17 37 25	−16·0	−171·0	*36†	1925 Apr. 5	23
17 4 36 40	+30·0	+129·0	30		
17 11 53 30	+13·0	− 83·0	*94	1919 Oct. 28	22
18 6 31 45	+35·0	+ 69·0	8	1925 Mar. 8	
18 14 6 0	+35·0	+ 29·5	*102†		
18 17 52 44	+35·5	+ 29·0	40	1925 Apr. 15	25
19 0 28 24	+35·5	+ 29·0	34	1926 Mar. 18	
19 3 41 33	+43·4	+ 17·8	5		
19 12 0 30	+22·5	+126·0	8	1926 Mar. 13	
19 19 3 24	− 3·5	+129·0	*34	1920 June 9	
19 20 32 33	+42·0	+139·5	10		17
20 7 17 50	− 7·0	+155·0	13	1918 July 21	28
21 12 5 48	−34·0	+ 57·0	*49	1926 Mar. 15	
21 14 19 6	−61·0	− 25·0	*78		
21 19 14 12	−61·0	− 25·0	6	1926 Mar. 21	
21 22 4 12	+35·5	+ 29·0	28	1926 Mar. 19	20
22 16 24 0	+35·0	+ 69·0	30	1926 Mar. 18	
22 18 29 0	− 7·0	+150·0	*60	1925 Aug. 14	12
23 1 58 35	+35·5	+ 29·0	26	1926 Mar. 21	32
24 5 41 6	+19·0	− 70·0	9	1924 Sept. 17	
24 7 4 30	+35·5	+ 29·0	37	1926 Mar. 23	
24 10 54 42	+14·0	− 89·0	12	1924 May 1	
24 11 7 8	+50·0	+ 97·0	27		
24 16 37 48	+43·4	+ 17·8	18	1926 Mar. 19	26
25 13 18 48	+43·5	+143·0	*25		
25 19 8 50	− 8·0	+135·0	*23†	1917 Jan. 11	
25 (19 8 50	−11·0	+134·0	*23)	1923 May 26	24
26					22
27 6 23 18	+ 0·3	− 80·4	9		
27 10 48 22	− 9·5	+157·0	*97	1924 July 8	9
28 17 49 50	+43·8	+ 11·2	13	1925 Mar. 15	20

15 23 11 40	+25·0	+123·0	16	1919 Sept. 29	8
16					14
17					9
18					21
19					7
20 11 37 15	+74·0	− 18·0	6		21
21					13
22					16
23					10
24					10
25					18
26 15 46 20	+37·5	+ 23·0	42	1925 Oct. 6	
26 16 8 10	+37·5	+ 23·0	42	1926 Feb. 26	
26 21 54 50	+54·0	+161·0	18	1923 Feb. 3	12
27					20
28 22 12 24	+39·0	− 7·5	13		9
		1926 *March.*			
1 20 1 42	+36·8	+ 30·0	57		13
2					6
3 13 16 42	−40·5	− 88·5	3		
3 18 6 27	+37·3	+ 85·3	7	1924 July 15	12
4 9 30 52	+ 6·5	+128·0	*65	1925 Mar. 14	10
5 23 58 50	−34·0	− 73·0	5	1922 Aug. 6	13
6 14 59 16	−30·2	+ 75·0	*8	1923 Mar. 26	
6 15 40 40	+ 6·5	+128·0	5	1926 Mar. 4	14
7(20 32 30	− 9·5	− 84·0	*21†)		
7 20 33 28	− 2·8	− 74·5	*21	1924 Mar. 10	20
8 20 21 32	+43·0	+148·5	*55		18
9					9
10 15 4 50	+66·5	−130·0	16		14
11 10 41 54	−10·0	− 74·0	*14		16
12					14
13 19 36 0	+22·5	+126·0	14		4
14 8 52 10	+38·0	+128·0	14	1922 July 14	9
15 1 30 30	−34·0	+ 57·0	*39	1926 Jan. 24	
15 7 59 36	+36·1	+137·3	5	1925 May 18	19
29 15 52 55	+20·0	+101·5	11	1925 Dec. 23	16
30					17
31 15 6 45	+35·5	+ 29·0	18	1926 Mar. 24	14
		1926 *April.*			
1 5 3 40	+35·5	+ 29·0	5	1926 Mar. 31	
1 16 3 46	+33·0	+137·5	*53†	1925 Apr. 19	10
2 11 56 0	+35·0	+ 44·0	12		15
3					12
4					16
5 23 29 6	+39·0	− 30·0	*49		3
6 19 32 20	+42·5	+144·0	*38	1916 Mar. 18	
6 23 45 50	+34·0	+131·0	15	1924 Aug. 28	
6 23 56 42	+34·0	+131·0	6	1926 Apr. 6	18
7 14 18 45	−24·0	−176·0	19		
7 22 59 10	+42·5	+144·0	8	1926 Apr. 6	10
8 10 20 30	− 5·5	+147·0	*36		20
9 10 4 35	+73·5	+127·0	39		34
10					13
11 6 26 12	+40·0	+ 71·0	15		11
12 8 32 18	−11·2	+161·2	*108		21
13 2 40 24	− 6·5	+107·5	5†	1924 June 22	21
14					14
15 9 27 2	−11·2	+161 2	*16	1926 Apr. 12	27
16 0 29 6	−11·2	+161·2	*22	1926 Apr. 15	10
17 3 7 0	−48·0	− 17·0	8	1921 Aug. 5	7
18 6 54 30	+35·5	+140·0	6	1922 Dec. 27	
18 18 18 35	+45·5	+ 19·0	11	1922 Nov. 24	12
19 7 49 48	+46·0	+ 38·5	9		
19 15 17 30	+31·0	−116·0	13	1925 Nov. 19	8
20					15
21					9
22 7 11 30	+35·5	+ 29·0	13	1926 Apr. 1	
22 23 47 52	+24·7	+145·3	*35		7
23 1 31 30	+27·5	+ 55·0	24	1925 Sept. 24	18
24 0 8 18	−30·2	−177·7	*20	1921 Apr. 22	
24 8 56 36	+82·0	+ 10·0	9	1924 Sept. 24	16

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1926 *April*—contd.			
25					12
26 5 18 0	+42·3	+ 17·8	15	1926 Jan. 31	7
27 21 20 36	− 3·5	+129·0	7	1926 Mar. 19	12
28 11 13 40	−21·5	− 72·0	*84	1920 Oct. 22	12
29					20
30					22
		1926 *May.*			
1					8
2 10 0 32	+39·5	+ 72·0	12	1923 Dec. 20	17
3					10
4					16
5 2 17 38	−32·9	− 68·3	4	1922 Dec. 19	
5 6 21 18	+ 3·0	− 91·0	*24		21
6					24
7 6 11 18	+31·5	+141·5	*63	1925 Mar. 16	
7 21 8 50	−38·0	− 73·5	13	1923 Nov. 6	20
8					10
9 9 47 30	−45·0	+ 34·0	*22	1924 Aug. 25	14
10 8 18 55	+27·0	+ 96·0	*26		18
11 11 20 15	+21·0	−106·5	35	1920 June 2	
11 12 1 10	− 5·0	+ 98·0	*22		15
12 3 45 30	−31·0	− 72·0	15	1923 Feb. 4	
12 14 53 30	+46·0	−130·0	24	1921 Feb. 21	20
13 13 44 20	−29·5	− 71·0	10	1923 Feb. 25	14
14					27
15					18
16 16 40 6	+40·0	+ 76·0	7	1924 May 11	9
17 17 18 0	− 9·0	+159·5	*28	1926 Jan. 25	
17 21 42 10	−14·5	− 14·0	*25		12

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1926 *June*—contd.			
10 19 16 0	+38·5	+ 22·5	34	1923 Aug. 28	10
11 9 46 0	+53·5	+158·5	5	1923 Dec. 7	25
12 23 29 45	+37·0	− 2·5	17		16
13 2 3 0	+20·0	+116·5	22		26
14 20 30 6	+43·5	+ 17·0	7	1924 May 30	
14 23 32 30	+40·0	+143·5	20		25
15 22 43 6	+48·5	+178·5	8	1917 Nov. 15	12
16 2 59 27	+46·5	+ 8·5	6		
16 3 12 0	+42·2	+ 20·7	21		17
17 18 13 30	+39·5	+ 91·5	9	1922 Oct. 16	20
18 10 43 20	+ 1·0	+118·0	*18	1924 Apr. 13	
18 18 29 35	+38·5	+ 22·5	10	1926 June 10	14
19 11 22 30	− 7·0	+145·0	*29†	1923 Aug. 10	33
20 6 54 18	−55·0	− 27·5	*68†	1921 Sept. 13	27
21 8 48 50	+32·5	+143·0	*30	1923 July 26	29
22 4 51 30	−12·0	−177·0	10	1924 Dec. 1	
22 23 19 50	+42·5	+ 75·5	7		21
23					10
24 21 16 24	− 7·6	+128·3	*29†	1922 Nov. 3	
24 (21 16 44	− 5·5	+130·0	*29†)	1924 Mar. 5	26
25 1 58 48	−16·2	+165·4	18	1924 Apr. 3	
25 3 36 42	−28·0	−115·0	11		
25 11 16 30	+37·0	− 4·5	5		
25 11 54 54	+37·0	− 4·5	3	1925 June 25	
25 15 14 42	+37·0	− 4·5	9	1925 June 25	
25 20 45 45	+22·0	+123·5	15	1923 Sept. 29	
25 23 19 0	+40·5	+ 41·0	11	1925 July 26	14
26 14 20 50	− 3·0	+117·0	5		
26 19 46 15	+36·0	+ 28·0	*114†	1922 Aug. 17	
26 21 19 24	+36·0	+ 28·0	6	1926 June 26	35
27 2 13 12	+36·0	+ 28·0	16	1926 June 26	

18	1	23	36	+39·5	+145·0	9	1923 Mar. 12	17
19	10	11	18	+44·5	+ 20·6	18		
19	21	13	44	+27·2	+ 59·5	14		10
20	7	2	10	+ 5·1	+124·8	*68†		
20	10	44	50	− 1·5	+ 88·5	5	1926 Jan. 18	39
21								19
22	7	38	48	+42·5	+139·2	11	1926 Feb. 4	
22	23	9	52	+34·0	+139·5	6	1924 June 3	22
23								27
24								14
25								14
26	9	40	36	+36·5	+ 70·5	6†	1925 Sept. 23	
26	17	53	30	+14·5	− 88·7	*20	1924 May 21	
26	18	43	56	−61·0	− 25·0	27	1926 Mar. 21	
26	19	44	58	+42·0	+142·0	*52	1924 July 5	22
27								27
28	22	31	24	+41·0	+ 54·0	8		14
29	22	37	25	+15·5	+ 92·5	20		26
30								29
31	13	35	38	−34·0	+ 57·0	*64	1926 Mar. 21	7

1926 *June*.

1	22	17	36	−10·0	+176·0	*17	1925 Nov. 19	26
2								10
3	4	46	44	−16·0	+168·0	*73	1924 Aug. 13	7
4	0	12	30	+47·0	+149·0	26		
4	6	50	45	+35·0	+ 90·5	43	1925 Aug. 31	
4	8	3	0	+35·0	+ 90·5	16	1926 June 4	
4	15	7	18	+43·0	+144·5	19		8
5	1	20	15	−17·0	− 78·5	*13		
5	9	9	34	+30·1	+131·6	*35†	1925 Nov. 26	
5	19	50	16	+43·0	−130·0	*59		18
6	6	49	0	+35·0	+ 90·5	11	1926 June 4	
6	18	20	0	+43·0	+144·5	*18	1926 June 4	20
7								16
8								20
9								38
27	18	1	54	−19·0	−177·0	*31	1922 Jan. 22	17
28	3	23	20	− 0·5	+100·5	*80		
28	6	15	36	− 0·5	+100·5	*67	1926 June 28	
28	11	58	0	− 0·5	+100·5	*10	1926 June 28	
28	21	14	36	+44·5	+ 11·0	19		
28	22	0	48	+48·0	+ 8·0	21	1924 Dec. 12	36
29	2	22	16	+27·0	+121·0	9	1918 June 7	
29	4	42	55	+39·0	+135·5	5	1924 July 3	
29	14	26	58	+27·3	+126·8	*103†		
29	18	55	40	+ 7·0	−107·0	*19†		
29	23	20	40	+33·0	−123·5	24		25
30	11	49	20	− 4·0	+103·0	*8	1925 Oct. 22	
30	22	50	30	+44·5	+ 11·0	14	1926 June 28	
30	22	51	48	+38·8	+ 70·0	30	1925 Jan. 2	53

1926 *July*.

1	1	18	0	+44·5	+ 11·0	9	1926 June 30	
1	2	59	0	+44·5	+ 11·0	10	1926 July 1	
1	14	8	45	− 3·0	+100·9	*89	1919 July 21	
1	19	33	50	− 3·0	+100·9	9	1926 July 1	
1	20	29	30	− 5·0	− 81·5	*43		28
2	5	25	30	+38·5	+ 22·5	16	1926 June 18	
2	6	2	0	−19·0	−177·0	17	1926 June 27	24
3	3	46	54	− 8·7	+111·0	*16		23
4								27
5	9	21	42	+37·5	+ 27·5	25	1925 July 29	18
6	7	39	8	+47·5	+ 15·8	18	1919 Sept. 5	
6	16	28	5	+38·5	+ 71·0	13	1923 Aug. 31	
6	21	20	30	+12·7	+ 94·5	12		22
7	2	38	57	− 8·7	+111·0	5	1926 July 3	
7	11	41	24	− 8·7	+111·0	17	1926 July 7	7
8	7	16	10	−34·0	+ 57·0	12	1926 May 31	
8	14	59	12	+39·7	+ 44·0	10		9
9	15	5	24	+38·5	− 30·5	23		13
10	1	17	0	− 3·5	+129·0	*31	1926 Apr. 27	
10	10	51	3	+ 1·0	+126·0	*84		
10	12	40	4	+ 1·0	+126·0	*15	1926 July 10	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1926 *July*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
10 23 1 32	+36·5	+139·5	24	1925 Jan. 9	19
11					32
12 14 32 8	+ 1·0	+126·0	8	1926 July 10	
12 16 51 30	+ 1·0	+126·0	13	1926 July 12	
12 22 12 30	+15·5	+ 92·5	14	1926 May 29	36
13 7 27 35	0·0	+125·0	10	1925 Nov. 19	
13 15 17 36	+38·5	− 30·5	17	1926 July 9	28
14 1 38 40	− 2·5	− 71·0	6	1921 Dec. 18	
14 6 40 14	+35·7	+134·8	5	1925 Dec. 22	
14 16 46 18	+ 0·5	+130·0	*21	1922 June 17	
14 16 58 54	+ 0·5	+130·0	*8	1926 July 14	
14 19 30 12	+37·2	+139·0	3	1922 May 28	
14 22 22 20	+66·0	−165·0	39		20
15 18 25 40	+35·0	+ 89·0	19		
15 21 47 10	+23·0	+121·7	*25	1921 July 18	8
16 2 4 30	− 5·5	+147·0	*53	1926 Apr. 8	19
17 19 14 12	+36·0	+ 84·5	17		25
18					48
19 4 51 54	+43·8	+ 11·2	5	1926 Mar. 28	
19 9 55 50	+35·7	+134·8	4	1926 July 14	17
20 13 59 26	+36·1	+137·3	5	1926 Mar. 15	11
21 2 23 0	+14·5	− 88·7	6	1926 May 26	16
22 22 54 10	−34·0	+ 57·0	*32	1926 July 8	22
23 4 32 42	+46·5	+ 13·0	8	1924 Dec. 12	
23 5 16 40	+ 6·5	+126·0	*29	1922 June 27	6
24					21
25 4 52 35	−51·5	+144·5	*24		
25 17 57 50	+36·0	−120·5	13		22
26 18 54 45	+36·0	+134·0	*41†	1922 Feb. 5	28
27 4 53 15	+52·0	− 36·0	15	1925 Aug. 7	
27 5 47 12	+ 6·5	+126·0	9	1926 July 23	

1926 *August*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
6 3 6 10	+25·0	+119·5	12	1926 Aug. 5	
6 3 55 10	+25·0	+119·5	6	1926 Aug. 6	
6 4 32 50	+25·0	+119·5	26	1926 Aug. 6	
6 5 23 48	+85·0	+ 85·0	44		
6 5 26 24	+25·0	+119·5	6	1926 Aug. 6	
6 6 0 40	+25·8	+128·0	*37	1925 Nov. 28	
6 7 1 48	+25·8	+128·0	30	1926 Aug. 6	
6 8 53 55	+25·0	+119·5	16	1926 Aug. 6	
6 9 48 20	+25·0	+119·5	8	1926 Aug. 6	
6 10 22 32	+25·0	+119·5	7	1926 Aug. 6	
6 11 0 36	+25·0	+119·5	11	1926 Aug. 6	
6 11 30 20	+25·0	+119·5	13	1926 Aug. 6	
6 12 5 40	+25·0	+119·5	6	1926 Aug. 6	
6 12 6 46	+25·0	+119·5	25	1926 Aug. 6	
6 13 17 48	+26·0	+ 96·0	9	1924 Aug. 1	
6 13 31 0	+25·0	+119·5	1	1926 Aug. 6	
6 13 48 24	+25·0	+119·5	10	1926 Aug. 6	
6 14 4 0	+25·0	+119·5	13	1926 Aug. 6	
6 14 30 0	+25·0	+119·5	4	1926 Aug. 6	
6 15 52 12	+24·0	+124·0	*48	1921 Dec. 1	
6 16 42 20	+30·1	+131·6	12†	1926 June 5	
6 19 51 0	+25·0	+119·5	7	1926 Aug. 6	
6 20 36 30	+35·0	+ 78·0	18	1914 Oct. 9	
6 20 44 20	+25·0	+119·5	2	1926 Aug. 6	
6 21 24 54	+25·0	+119·5	13	1926 Aug. 6	
6 22 7 3	+25·0	+119·5	3	1926 Aug. 6	
6 22 45 46	+35·0	+ 78·0	56	1926 Aug. 6	22
7 0 11 33	−42·5	+ 25·0	*18		
7 0 19 24	+25·0	+119·5	8	1926 Aug. 6	
7 1 13 24	+25·0	+119·5	6	1926 Aug. 7	
7 2 9 15	+25·8	+128·0	*36	1926 Aug. 6	

27	7	23	36	+30·5	+ 80·5	24		6
28	8	52	20	− 9·5	+157·0	*67	1926 Mar. 27	9
29								33
30	13	20	5	+49·2	− 1·7	32†		42
31	11	27	24	− 9·5	+157·0	19	1926 July 28	
31	18	9	40	+36·5	− 36·0	44		18

1926 *August.*

1								21
2	5	1	21	+13·5	+125·0	*85	1917 Feb. 25	
2	12	41	0	+13·5	+125·0	*36	1926 Aug. 2	31
3	3	16	12	−22·5	−173·5	31	1921 Jan. 9	
3	3	41	30	+22·0	+121·0	*72	1917 Jan. 6	
3	9	26	8	+35·5	+140·0	*33	1926 Apr. 18	
3	10	31	54	− 2·0	+127·3	*65		
3	19	41	12	+ 1·0	+ 97·5	*38		13
4								20
5	2	47	45	+25·0	+119·5	2†	1920 Dec. 6	
5	4	22	40	+25·0	+119·5	2	1926 Aug. 5	
5	4	55	55	+25·0	+119·5	1	1926 Aug. 5	
5	5	49	35	+25·0	+119·5	3	1926 Aug. 5	
5	6	7	36	+25·0	+119·5	5	1926 Aug. 5	
5	7	35	35	+25·0	+119·5	3	1926 Aug. 5	
5	8	53	5	+25·0	+119·5	5	1926 Aug. 5	
5	10	14	25	+25·0	+119·5	7	1926 Aug. 5	
5	10	27	0	+25·0	+119·5	2	1926 Aug. 5	
5	12	3	0	+25·0	+119·5	9	1926 Aug. 5	
5	12	46	36	+25·0	+119·5	6	1926 Aug. 5	
5	13	14	50	+25·0	+119·5	2	1926 Aug. 5	
5	14	53	20	+25·0	+119·5	3	1926 Aug. 5	
5	15	32	24	+25·0	+119·5	6	1926 Aug. 5	
5	16	41	10	+25·0	+119·5	13	1926 Aug. 5	
5	18	40	18	+25·0	+119·5	4	1926 Aug. 5	
5	20	40	0	+25·0	+119·5	6	1926 Aug. 5	
5	22	45	20	+25·0	+119·5	7	1926 Aug. 5	
5	23	31	50	+25·0	+119·5	13	1926 Aug. 5	
5	23	52	30	+25·0	+119·5	12	1926 Aug. 5	20

7	5	55	30	+25·0	+119·5	6	1926 Aug. 7	
7	6	14	36	+34·6	+140·7	*23	1926 Feb. 3	
7	9	8	0	+25·0	+119·5	12	1926 Aug. 7	
7	9	36	40	+25·8	+128·0	20	1926 Aug. 7	
7	11	3	40	+24·0	+124·0	12	1926 Aug. 6	
7	11	32	42	+25·0	+119·5	13	1926 Aug. 7	
7	12	34	20	+25·0	+119·5	11	1926 Aug. 7	
7	15	16	33	+24·0	+124·0	14	1926 Aug. 7	
7	17	5	36	+25·0	+119·5	14	1926 Aug. 7	
7	23	37	4	+25·0	+119·5	18	1926 Aug. 7	43
8	1	24	48	+25·0	+119·5	10	1926 Aug. 7	
8	4	11	0	+25·0	+119·5	5	1926 Aug. 8	
8	6	49	0	+25·0	+119·5	12	1926 Aug. 8	
8	8	20	42	+25·0	+119·5	6	1926 Aug. 8	
8	11	39	42	+25·0	+119·5	11	1926 Aug. 8	
8	14	57	24	+25·0	+119·5	7	1926 Aug. 8	
8	16	47	6	+25·0	+119·5	6	1926 Aug. 8	
8	20	41	9	+25·0	+119·5	8	1926 Aug. 8	25
9	1	0	36	−39·0	− 74·5	7	1920 Dec. 10	
9	3	39	22	+52·0	−176·0	*66†		
9	14	2	20	+24·0	+124·0	*50	1926 Aug. 7	
9	15	55	6	+25·0	+119·5	19	1926 Aug. 8	
9	16	50	12	+25·0	+119·5	14	1926 Aug. 9	
9	17	34	0	+25·0	+119·5	9	1926 Aug. 9	
9	21	40	12	−28·5	− 71·5	23	1924 Dec. 18	38
10	0	25	0	+24·0	+124·0	30	1926 Aug. 9	
10	13	41	28	+25·0	+119·5	21	1926 Aug. 9	
10	17	34	48	+25·0	+119·5	18	1926 Aug. 10	
10	21	16	20	−28·0	−163·5	*25	1925 Aug. 1	
10	23	51	40	+25·0	+119·5	5	1926 Aug. 10	16
11	5	47	30	+29·5	+101·0	24		
11	12	36	40	+25·0	+119·5	7	1926 Aug. 10	12
12	22	17	48	−22·5	− 66·0	*29		39
13								12
14	1	26	18	+25·0	+119·5	7	1926 Aug. 11	
14	8	36	10	−41·0	− 92·0	*15	1924 July 17	45
15	2	27	24	−58·5	+153·0	26	1923 Nov. 26	
15	3	58	22	+52·2	− 2·7	14†		

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1926 *August*—contd.			
d. h. m. s.	°	°			
15 6 31 36	+ 4·8	+126·0	*15	1925 Oct. 18	
15 9 53 45	+14·0	+109·0	20	1924 Dec. 26	
15 14 17 52	+36·0	− 5·0	4	1925 Jan. 2	17
16 2 35 24	− 5·5	+147·0	21	1926 July 16	
16 10 57 55	+36·0	− 5·0	3	1926 Aug. 15	28
17 1 42 45	+38·5	+ 15·0	46		5
18 15 54 40	+36·0	− 5·0	8	1926 Aug. 16	
18 17 4 52	+38·0	+ 20·5	47	1923 Apr. 3	
18 23 58 48	+24·5	+ 94·5	11		25
19 13 51 25	− 7·0	+145·0	*31	1926 June 19	14
20 3 9 6	+24·0	+124·0	15	1926 Aug. 10	
20 5 49 50	+25·0	+119·5	8	1926 Aug. 14	11
21					40
22					16
23 4 23 54	+40·0	+ 14·0	7	1920 July 11	20
24 6 41 50	+38·5	− 30·5	15	1926 July 13	25
25 5 44 32	−23·8	+172·5	*86	1920 June 12	
25 7 42 36	−23·8	+172·5	18	1926 Aug. 25	21
26 6 41 30	−21·5	+169·0	*32	1923 Feb. 1	
26 10 29 42	+39·0	+ 73·0	12	1925 Feb. 1	15
27					12
28					13
29 7 40 36	+46·0	+ 89·0	12	1923 Oct. 28	18
30 11 38 0	+37·5	+ 23·0	*88	1926 Feb. 26	11
31 10 40 0	+38·5	− 28·6	49		21
		1926 *September*.			
1 12 10 42	−59·5	+151·5	22	1925 Aug. 14	25
2 1 21 40	−34·0	+ 57·0	*92	1926 July 22	31
3 21 59 50	+41·5	+ 26·5	35		35

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1926 *September*—contd.			
d. h. m. s.	°	°			
19 20 8 20	−42·0	+130·0	5	1926 Sept. 19	
19 (20 22 0	+72·0	− 2·8	6)	1919 Sept. 12	
19 (20 22 10	+47·0	+ 10·0	6)	1924 Nov. 7	
19 (20 22 10	+59·0	+ 65·0	6)		23
20					6
21 5 34 6	−34·0	+ 57·0	*7	1926 Sept. 2	14
22 21 9 45	+49·0	−124·0	32	1926 Sept. 17	11
23 15 11 6	+45·0	− 29·0	29		
23 18 31 48	+ 2·8	+ 96·0	*25		26
24 21 4 20	+53·0	+135·5	5		32
25					17
26 1 0 21	+30·5	+138·5	8	1925 May 15	9
27 6 43 15	+43·0	+ 49·0	5		34
28 15 41 50	+48·0	+ 15·8	29		
28 15 55 2	− 9·0	+121·0	*23	1924 Apr. 4	
28 21 30 52	+46·5	+ 13·0	8	1926 July 23	17
29 3 52 20	+20·0	− 94·0	2	1922 Apr. 3	
29 3 58 55	+ 1·0	+143·5	*17	1923 Apr. 30	
29 5 16 30	+ 9·0	+155·0	11	1925 May 16	
29 5 43 30	+ 9·0	+155·0	12	1926 Sept. 29	
29 12 20 16	+ 3·0	+122·0	9†	1922 Aug. 30	15
30 4 16 30	+21·5	− 40·5	*22	1925 Aug. 11	
30 5 17 35	+ 3·0	+122·0	14†	1926 Sept. 29	25
		1926 *October*.			
1 9 7 45	+10·0	−103·0	27	1925 Oct. 4	
1 22 13 20	−10·5	+157·0	*32		28
2 19 3 5	+36·0	+142·0	9	1926 Jan. 10	12
3 8 26 24	+37·0	+143·0	*51	1918 May 31	
3 19 37 51	−50·5	+161·0	*117†		18

4	12	54	24	−22·0	+172·0	11	1925 Apr. 1	
4	15	36	58	+43·5	+143·0	*83	1926 Mar. 25	25
5								30
6	0	16	22	−35·0	− 75·0	*48	1924 Sept. 19	
6	0	49	42	−35·0	− 75·0	4	1926 Sept. 6	
6	0	58	40	−35·0	− 75·0	4	1926 Sept. 6	
6	1	51	40	−35·0	− 75·0	4	1926 Sept. 6	
6	8	7	15	−20·5	−178·5	23	1924 Jan. 16	
6	15	9	40	−14·0	+166·5	*33	1926 Jan. 5	14
7	12	22	58	− 5·5	+145·0	*91†		23
8	15	49	30	+23·0	+ 95·0	17	1924 Sept. 2	31
9	1	33	5	+28·0	+127·0	20	1924 May 23	
9	3	51	12	+45·6	+ 10·2	3	1918 July 19	
9	6	51	40	−35·0	− 75·0	5	1926 Sept. 6	
9	17	31	46	−42·0	+130·0	10†		
9	17	33	27	−42·0	+130·0	6	1926 Sept. 9	
9	17	38	10	−42·0	+130·0	4	1926 Sept. 9	
9	18	30	20	−58·5	+153·0	24	1926 Aug. 15	19
10	8	26	38	−44·0	− 80·5	13		
10	10	34	21	− 9·0	+111·0	*104†	1918 Sept. 4	
10	19	52	2	− 9·0	+111·0	5†	1926 Sept. 10	38
11	12	27	32	− 9·0	+111·0	*35†	1926 Sept. 10	
11	17	2	30	+20·8	+106·6	7		34
12	15	43	36	+22·0	+120·5	*72	1925 Apr. 16	40
13								28
14								18
15	11	29	35	− 3·0	+143·5	*26	1925 May 1	
15	11	55	0	− 3·0	+143·5	*37	1926 Sept. 15	20
16	17	59	12	−10·7	+159·7	*107†		28
17	1	45	50	−10·7	+159·7	*24†	1926 Sept. 16	
17	2	54	0	−10·7	+159·7	*23†	1926 Sept. 17	
17	5	41	50	−10·7	+159·7	*8†	1926 Sept. 17	
17	13	18	20	+41·7	+ 8·5	8	1924 Jan. 24	
17	23	14	36	+49·0	−124·0	34	1921 June 25	27
18								33
19	1	3	42	+35·5	+ 22·0	60		
19	14	37	48	+35·5	+ 22·0	15	1926 Sept. 19	
19	20	7	0	−42·0	+130·0	*22†	1926 Sept. 9	

4								16
5	15	15	45	−14·0	−174·0	17	1925 Dec. 31	21
6								5
7	0	48	54	−20·6	+168·8	16	1926 Feb. 3	12
8	19	59	3	+57·0	− 34·5	30†		11
9	19	16	0	+38·0	+ 42·0	3		
9	20	20	48	+38·0	+ 42·0	5	1926 Oct. 9	17
10								5
11	0	8	48	−21·5	−171·5	28	1924 Sept. 19	
11	6	38	40	+35·0	− 5·0	46	1923 May 17	
11	6	58	54	+35·0	− 5·0	3	1926 Oct. 11	
11	7	2	22	+35·0	− 5·0	3	1926 Oct. 11	
11	7	8	33	+35·0	− 5·0	1	1926 Oct. 11	
11	7	26	25	+ 8·0	+126·5	19	1924 Aug. 30	
11	7	41	45	+35·0	− 5·0	1	1926 Oct. 11	
11	18	36	45	−30·5	− 70·0	3	1923 Apr. 21	
11	21	50	12	+35·0	− 5·0	2	1926 Oct. 11	
11	22	44	8	+43·9	+ 9·5	11	1921 Dec. 13	12
12	1	55	0	− 1·0	+ 99·0	10	1913 Oct. 29	
12	11	57	5	+41·0	+ 21·5	25	1924 Apr. 25	
12	12	48	20	+43·0	+ 21·0	10	1922 June 9	
12	13	2	48	+43·0	+ 21·0	5	1926 Oct. 12	39
13	6	2	18	+51·0	−179·5	*97	1924 Aug. 21	
13	14	17	42	+51·0	−179·5	*89	1926 Oct. 13	
13	16	26	30	+27·0	+125·0	7	1925 June 4	
13	19	8	3	+51·2	−176·0	*112		26
14	2	11	6	+51·2	−176·0	25	1926 Oct. 13	25
15	6	47	45	+35·0	− 5·0	16	1926 Oct. 11	
15	7	53	24	+35·0	− 5·0	5	1926 Oct. 15	
15	14	0	30	+51·2	−176·0	10	1926 Oct. 14	28
16								22
17								27
18								34
19	0	29	56	+42·0	+139·5	*16	1926 Mar. 19	
19	4	34	30	+35·5	− 2·5	10	1922 Aug. 2	
19	6	28	0	−48·5	+162·5	9	1918 Sept. 16	
19	14	4	58	+34·5	+135·0	5		
19	20	48	30	+11·0	− 83·0	*39		16

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1926 *October*—contd.					
d. h. m. s.	°	°			
20 1 41 20	+35·2	+136·3	6		16
21 9 29 50	+45·0	+ 14·8	18	1926 Jan. 1	26
22 12 35 8	+36·5	−122·0	*56†		
22 13 35 22	+36·5	−122·0	*53	1926 Oct. 22	
22 14 41 50	+36·5	−122·0	4	1926 Oct. 22	
22 16 3 50	+36·5	−122·0	5	1926 Oct. 22	
22 16 44 5	+40·5	+ 45·0	23	1923 May 12	
22 17 20 52	− 2·4	+ 98·8	5		
22 18 39 0	− 2·4	+ 98·8	10	1926 Oct. 22	
22 19 59 20	+40·5	+ 45·0	50	1926 Oct. 12	
22 23 53 54	+42·0	+ 22·5	18	1925 Jan. 15	16
23 1 58 40	+40·0	+ 20·0	48	1924 Nov. 13	
23 10 31 24	+41·0	+ 44·0	8	1925 May 13	
23 14 30 18	+25·0	+ 93·0	15	1924 Jan. 30	
23 21 27 32	−30·2	+ 75·0	3	1926 Mar. 6	34
24 22 51 45	+36·5	−122·0	7	1926 Oct. 22	16
25 14 2 0	+41·5	+ 40·5	7	1925 June 30	
25 15 38 40	−34·0	− 73·0	12	1926 Mar. 5	36
26 1 59 0	− 2·7	+138·8	*18		
26 3 44 35	− 2·7	+138·8	*113	1926 Oct. 26	
26 6 11 25	− 2·7	+138·8	*37	1926 Oct. 26	
26 8 35 3	− 2·7	+138·8	*37	1926 Oct. 26	
26 14 15 45	− 2·7	+138·8	*51	1926 Oct. 26	
26 23 43 20	− 2·7	+138·8	*28	1926 Oct. 26	33
27 4 58 35	− 2·7	+138·8	*39	1926 Oct. 26	
27 9 21 40	− 2·7	+138·8	*15	1926 Oct. 27	
27 11 50 12	−58·5	+145·5	9	1925 Apr. 26	
27 14 14 0	−23·0	− 66·0	5	1926 Jan. 8	
27 19 57 16	− 2·7	+138·8	*12	1926 Oct. 27	38
28 1 0 35	− 2·7	+138·8	*27	1926 Oct. 27	
28 12 58 30	−28·0	− 69·0	3		20

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
1926 *November*—contd.					
d. h. m. s.	°	°			
13 3 41 8	+50·5	−177·5	*31		
13 8 47 0	+35·5	− 2·5	3	1926 Nov. 6	
13 13 40 15	−31·0	− 72·0	3	1926 May 12	20
14					14
15 4 21 6	+64·2	−147·0	12		12
16					5
17 21 21 36	+35·5	− 2·5	10	1926 Nov. 13	20
18 16 31 18	+29·7	+147·0	8		19
19 0 40 0	− 6·0	+113·0	5	1922 May 10	18
20					15
21 11 14 45	+23·0	+ 97·0	15		23
22 19 8 12	+30·5	+102·0	6		12
23 0 20 10	+46·0	+154·0	*21	1926 Nov. 9	
23 11 5 5	+35·2	+136·3	4	1926 Oct. 20	
23 20 37 8	+25·0	+108·5	6		28
24 17 40 54	+29·7	+147·0	5	1926 Nov. 18	15
25					20
26 0 19 28	+43·5	+ 79·0	9		13
27 5 19 18	+12·0	+126·0	*49	1925 May 7	
27 9 25 42	+36·5	+133·0	5	1926 Jan. 14	
27 14 40 0	+15·0	−117·0	9		27
28					15
29					21
30 10 56 6	+47·0	+ 9·0	5		15
1926 *December*.					
1 1 8 27	+49·0	+174·0	11	1924 Sept. 17	
1 3 55 41	+31·5	+130·0	7	1926 Jan. 25	
1 4 57 42	+35·0	+132·5	14		
1 20 35 41	+36·5	− 3·5	3		

29	0	2	32	− 2·7	+138·8	*10	1926 Oct. 28	
29	0	8	40	+16·3	+120·6	31		25
30	1	37	58	+11·5	+ 43·5	17		
30	10	11	21	+16·3	+120·6	*46	1926 Oct. 29	
30	13	46	24	+ 9·5	+123·0	*30†	1925 May 5	
30	19	41	42	+48·0	−127·5	*54	1921 May 28	38
31	11	43	15	+11·5	+ 43·5	7	1926 Oct. 30	
31	17	12	38	+11·5	+ 43·5	7	1926 Oct. 31	22
				1926 *November.*				
1	1	39	15	+48·0	−127·5	*73	1926 Oct. 30	
1	15	5	18	+52·5	−162·0	*10		
1	23	29	30	+23·7	+127·0	18		10
2	1	51	30	+15·5	+122·0	10		
2	16	3	55	− 4·5	+131·0	*21	1919 Nov. 18	
2	19	46	0	+46·0	+154·0	*38	1922 May 4	
2	21	9	26	+46·0	+154·0	*49	1926 Nov. 2	
2	22	58	54	+46·0	+154·0	*12	1926 Nov. 2	9
3	17	59	42	+36·0	− 5·0	4	1926 Aug. 18	
3	18	34	30	−14·0	−174·0	*25	1926 Oct. 5	30
4								13
5	7	55	33	+12·3	− 85·8	*106†	1925 Oct. 5	
5	11	17	36	+36·0	− 5·0	3	1926 Nov. 3	
5	19	5	15	+37·5	+142·5	5	1925 Aug. 31	21
6	9	19	55	− 8·0	+157·0	*31†		
6	9	53	22	− 8·0	+157·0	18†	1926 Nov. 6	
6	21	0	30	+35·5	− 2·5	8	1926 Oct. 19	
6	21	8	36	− 4·5	+131·0	*6	1926 Nov. 2	29
7	16	1	35	− 3·0	+143·5	*19	1926 Sept. 15	
7	22	7	30	+ 8·0	−103·0	9		12
8								17
9	3	57	0	− 6·0	+ 99·0	10	1917 Apr. 16	
9	10	54	42	+46·0	+154·0	5	1926 Nov. 2	11
10	8	56	54	+34·0	+136·0	8		12
11	3	1	15	+36·0	+143·8	33		24
12	17	53	12	+56·8	− 33·6	11	1924 Dec. 12	
12	18	21	5	+56·8	− 33·6	16	1926 Nov. 12	9
1	21	4	12	+36·5	− 3·5	3	1926 Dec. 1	17
2	8	13	34	−34·0	+ 57·0	*33	1926 Sept. 21	
2	16	41	47	+ 3·0	+ 65·0	8		
2	17	28	54	+22·0	+121·0	7	1926 Aug. 3	
2	23	12	40	+57·3	−165·0	10	1920 Apr. 18	22
3	5	19	20	−34·0	− 73·0	9	1926 Oct. 25	
3	6	50	15	+47·2	+ 6·0	3	1925 Jan. 8	
3	22	42	45	−18·0	+167·0	*19	1925 Nov. 28	
3	23	1	54	+47·2	+ 6·0	4	1926 Dec. 3	
3	23	39	20	−51·5	+144·5	6	1926 July 25	18
4	11	14	23	+29·6	+ 87·8	5	1923 Apr. 24	19
5	5	52	24	+30·2	+140·3	8		
5	19	40	36	+27·0	+100·0	12	1925 Oct. 15	
5	19	44	8	+27·0	+100·0	12	1926 Dec. 5	
5	21	12	16	+37·0	+138·5	7	1925 Dec. 11	15
6								17
7	2	8	50	−34·0	+ 57·0	4	1926 Dec. 2	
7	19	40	20	−47·0	− 78·0	3	1921 July 7	24
8								22
9	0	40	38	+33·0	−121·5	3	1922 Mar. 10	
9	3	22	24	+24·7	+145·3	5	1925 Apr. 22	
9	12	6	42	+46·5	− 28·3	6†	1924 Dec. 7	
9	22	38	48	−29·5	− 71·0	3	1926 May 13	25
10	8	38	45	+41·0	−127·0	*36†	1925 Feb. 1	18
11								14
12	22	1	12	+35·5	+141·0	7	1925 Mar. 31	13
13								8
14	17	10	22	−14·0	+119·5	*25		10
15	13	58	52	+46·7	+ 7·2	15		
15	23	20	42	− 7·0	+121·5	*11		16
16	0	24	8	−10·5	−174·5	*30†		
16	3	41	0	−14·0	−174·0	13	1926 Nov. 3	
16	17	53	50	+39·0	+ 31·0	49	1925 Sept. 20	29
17	6	17	33	+41·0	+ 19·5	6	1923 Sept. 27	
17	6	20	45	+41·0	+ 19·5	24	1926 Dec. 17	
17	6	31	5	+41·0	+ 19·5	54	1926 Dec. 17	
17	11	39	55	+41·0	+ 19·5	59	1926 Dec. 17	30
18	9	38	45	+22·0	+151·0	6	1918 Nov. 30	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

To (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1926 *December*—contd.			
d. h. m. s.	°	°			
18 14 44 54	+42·3	− 10·5	8†		34
19 9 17 45	+52·0	− 32·0	25		
19 11 1 30	+37·7	+ 73·6	6	1923 Nov. 28	20
20 10 31 6	+39·0	+ 31·0	15†	1926 Dec. 16	17
21 20 3 12	+ 6·5	+127·0	13	1924 Apr. 26	19
22 4 22 2	+41·0	−127·0	11	1926 Dec. 10	19
23					32
24 6 26 36	+42·0	+ 44·0	9		
24 7 1 0	−19·0	+ 65·0	*18		21
25 5 13 12	+75·5	+ 5·0	10		
25 6 43 18	− 5·5	+145·0	*48	1926 Sept. 7	
25 15 43 45	+ 1·0	+116·0	*21†		
25 16 14 40	+41·0	+ 19·5	11	1926 Dec. 17	12
26 22 2 52	+41·0	+ 19·5	8	1926 Dec. 25	20
27 8 42 43	−58·0	−108·5	17		
27 9 20 15	−58·0	−108·5	22	1926 Dec. 27	25
28 4 51 20	−12·5	− 58·5	4		24
29 12 50 0	−34·0	+ 57·0	*23	1926 Dec. 7	
29 21 25 30	+38·5	+ 34·5	7		26
30					18
31 16 53 45	+25·0	+ 77·5	8		15
		1927 *January*.			
1 8 16 35	+29·0	−115·0	26		
1 9 13 20	+29·0	−115·0	25	1927 Jan. 1	
1 12 58 20	+29·0	−115·0	7	1927 Jan. 1	
1 18 51 20	+ 8·5	+126·0	9		39
2 0 17 24	+ 8·5	+126·0	9	1927 Jan. 1	
2 14 44 39	+51·2	−176·0	*17	1926 Oct. 15	17
3 12 31 5	+42·3	+ 17·8	9	1926 Apr. 26	

To (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1927 *January*—contd.			
d. h. m. s.	°	°			
27 8 13 30	− 6·0	+ 60·0	7		20
28					21
29 18 37 27	−44·0	+ 37·5	*13		18
30 8 54 0	+31·2	+ 70·3	23	1923 Oct. 15	13
31 0 23 15	+54·0	+161·0	19	1926 Feb. 26	
31 3 43 36	+35·0	+137·2	3		
31 6 2 12	+38·0	+ 17·5	24	1925 Oct. 13	25
		1927 *February*.			
1 17 56 34	− 7·0	+155·0	*81†	1926 Mar. 20	35
2					34
3 3 53 5	+32·7	+120·7	*76		
3 4 52 5	+32·7	+120·7	53	1927 Feb. 3	12
4 2 49 17	−18·5	+168·5	*68	1927 Jan. 26	15
5 0 0 36	+36·0	+ 84·5	5	1926 July 17	
5 7 36 18	+13·7	+128·0	18	1926 Jan. 23	26
6					31
7 6 4 36	+39·0	+ 31·0	19	1926 Dec. 20	23
8					24
9					29
10					33
11 10 21 12	+56·0	+115·0	7	1917 Apr. 29	63
12 7 7 54	+16·0	− 96·0	10	1919 Jan. 17	25
13 3 33 20	+25·5	+ 93·5	21		18
14 3 43 15	+42·3	+ 17·8	64	1927 Jan. 15	
14 4 49 50	+36·5	+ 23·0	11		52
15					28
16 1 35 12	+46·0	+154·0	*116	1926 Nov. 23	
16 2 56 20	+46·0	+154·0	*39	1927 Feb. 16	
16 8 36 35	+46·0	+154·0	*39	1927 Feb. 16	

4								40
5	7	43	0	−17·0	− 63·0	3		
5	13	24	0	−18·5	+168·5	*5	1925 Mar. 22	
5	16	24	12	+17·0	+118·0	8		35
6								29
7	10	43	0	+80·5	+113·0	16		
7	18	40	17	+43·1	+ 0·3	3		
7	18	58	0	−20·5	− 36·5	4		
7	22	10	10	+40·0	+138·0	10	1922 Apr. 27	34
8	7	16	53	+46·7	+ 7·2	4	1926 Dec. 15	19
9								18
10								19
11	19	45	40	−15·0	− 78·3	*11†		9
12	0	5	22	+17·0	+122·0	20†	1923 Aug. 24	
12	(0	5	22	+15·0	+119·7	20)		
12	21	34	30	−20·0	+176·5	25†	1923 Jan. 22	14
13								9
14	8	35	18	+37·5	+140·0	5	1924 Sept. 24	23
15	14	31	16	+36·2	+134·5	14†		
15	15	53	54	+42·3	+ 17·8	13	1927 Jan. 3	
15	20	47	35	+42·3	+ 17·8	20	1927 Jan. 15	26
16								16
17	21	58	4	+38·5	+143·0	*64		8
18	22	26	9	+47·0	+ 13·2	6		18
19	1	16	40	+16·0	−103·0	23	1923 Nov. 9	43
20	8	46	45	+39·0	+ 73·0	17	1926 Aug. 26	
20	10	56	18	−21·0	− 67·0	*40†	1922 Mar. 28	23
21	8	53	6	−32·0	−179·0	14†	1923 Oct. 1	28
22								5
23	3	23	33	+43·5	+ 17·0	7	1926 June 14	17
24	1	5	33	−18·5	+168·5	*111	1927 Jan. 5	
24	5	18	24	+58·5	+ 6·0	45		
24	6	42	10	−18·5	+168·5	*38	1927 Jan. 24	37
25	7	52	35	−18·5	+168·5	*20	1927 Jan. 24	
25	23	10	35	−18·5	+168·5	*44	1927 Jan. 25	13
26	11	6	45	−18·5	+168·5	6	1927 Jan. 25	
26	15	36	30	−18·5	+168·5	*31	1927 Jan. 26	10
							1924 Oct. 20	
16	11	52	25	+46·0	+154·0	*52	1927 Feb. 16	
16	13	26	42	+38·5	+ 22·5	7	1926 July 2	
16	13	57	48	+46·0	+154·0	*31	1927 Feb. 16	16
17	13	49	10	+46·0	+154·0	7	1927 Feb. 16	
17	16	17	48	+38·5	+ 22·5	8	1927 Feb. 16	
17	23	17	40	+49·2	− 1·7	9	1926 July 30	20
18	12	11	40	+32·7	+131·9	8	1921 Apr. 18	
18	22	56	12	+ 6·5	+128·0	*39	1926 Mar. 6	10
19	3	55	0	+50·5	+159·0	24	1921 Mar. 24	
19	23	35	28	+37·0	+ 28·7	20	1921 May 22	18
20	2	0	30	+24·0	+121·0	13	1924 July 22	
20	6	47	42	+46·3	+ 16·8	7		14
21	12	24	57	0·0	+122·4	*46	1923 Apr. 24	25
22	19	54	6	+26·0	+143·0	33	1919 June 7	19
23	2	43	24	0·0	+145·0	*13	1919 Oct. 8	14
24	4	13	52	+14·5	− 91·0	24	1920 Dec. 11	18
25	8	6	36	+41·0	+ 44·0	8	1926 Oct. 23	
25	11	25	12	−28·0	−163·5	8	1926 Aug. 10	
25	15	41	20	−38·0	+178·0	*36		41
26	2	4	40	−20·0	+176·5	*34	1927 Jan. 12	
26	13	24	24	+30·1	+131·6	*15	1926 Aug. 6	
26	23	54	24	+13·5	+ 50·0	6	1923 Dec. 10	22
27	3	20	0	+48·0	+105·0	6	1925 June 24	
27	3	53	45	+26·3	+121·5	11	1924 July 14	
27	3	57	50	+40·0	−129·5	8		25
28	3	32	32	+46·7	+ 7·2	4	1927 Jan. 8	
28	14	7	45	−29·0	− 71·0	*75	1923 Mar. 9	21
					1927 *March.*			
1	3	7	0	+19·0	− 68·0	9	1920 Feb. 12	17
2								5
3	1	4	57	− 6·3	+122·5	*100†		
3	16	50	4	+45·3	+153·5	*56	1925 Dec. 29	11
4								23
5	4	12	30	+20·5	− 68·0	12		35
6	1	33	30	+26·0	− 45·5	*28		20

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1927 *March*—contd.			
d. h. m. s.	°	°			
7 9 27 36	+35·7	+134·8	*127†	1926 July 19	
7 (164 shocks	+35·7	+134·8	378)	1927 Mar. 7	24
8 (115 shocks	+35·7	+134·8	162)	1927 Mar. 7	23
9 16 13 15	+ 9·5	− 84·0	*40	1924 Nov. 1	
9 (60 shocks	+35·7	+134·8	93)	1927 Mar. 8	13
10 22 35 55	+35·7	+134·8	13	1927 Mar. 9	
10 (41 shocks	+35·7	+134·8	54)	1927 Mar. 9	35
11 (17 shocks	+35·7	+134·8	38)	1927 Mar. 10	29
12 1 13 36	−50·5	+161·0	5	1926 Oct. 3	
12 12 7 45	+16·0	+148·0	11	1918 Dec. 3	
12 18 44 22	−42·0	−104·0	38		
12 20 35 36	+42·3	+ 2·5	24		
12 (32 shocks	+35·7	+134·8	37)	1927 Mar. 11	9
13 5 32 16	− 6·5	− 81·5	*33	1925 Dec. 27	
13 (25 shocks	+35·7	+134·8	34)	1927 Mar. 12	20
14 0 0 20	+37·0	− 4·5	4	1926 June 25	
14 4 11 48	−13·5	+ 68·5	8	1925 July 8	
14 7 42 55	−25·0	− 71·0	6	1925 May 15	
14 15 20 40	− 7·0	+121·5	4	1926 Dec. 15	
14 17 37 32	+26·0	+102·5	38		
14 (12 shocks	+35·7	+134·8	20)	1927 Mar. 13	14
15 7 57 25	+24·0	+123·0	9	1925 June 21	
15 8 21 4	+24·0	+123·0	8	1927 Mar. 15	
15 10 38 54	+ 7·5	− 79·0	9	1925 Mar. 29	
15 16 2 58	+24·0	+123·0	4	1927 Mar. 15	
15 16 56 27	+26·0	+ 96·0	*35	1926 Aug. 6	
15 17 26 46	+24·0	+123·0	1	1927 Mar. 15	
15 21 48 25	+37·5	+ 99·0	58		
15 (13 shocks	+35·7	+134·8	14)	1927 Mar. 14	21
16 6 52 30	+40·0	+144·5	*33	1920 Sept. 20	
16 15 16 0	+41·0	+ 38·0	4		

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1927 *March*—contd.			
d. h. m. s.	°	°			
29 23 16 15	+35·0	+ 26·0	7	1927 Mar. 29	
29 (3 shocks	+35·7	+134·8	3)	1927 Mar. 28	27
30 7 17 18	−20·0	− 1·0	8		
30 7 55 36	+62·0	−150·0	10		
30 8 15 27	−23·2	− 62·2	4		
30 14 10 10	−36·0	−113·0	18		
30 (4 shocks	+35·7	+134·8	11)	1927 Mar. 29	17
31 21 8 35	+35·7	+134·8	42	1927 Mar. 10	
31 (31 shocks	+35·7	+134·8	32)	1927 Mar. 31	23
		1927 *April.*			
1 19 6 6	−21·5	−176·0	*83†		
1 (17 shocks	+35·7	+134·8	32)	1927 Mar. 31	13
2 (7 shocks	+35·7	+134·8	7)	1927 Apr. 1	27
3 13 47 8	+30·6	+141·8	16†	1925 May 22	
3 (5 shocks	+35·7	+134·8	8)	1927 Apr. 2	11
4 4 58 35	+40·0	+141·5	20	1925 Apr. 20	
4 (4 shocks	+35·7	+134·8	4)	1927 Apr. 3	13
5 5 18 0	+ 3·0	+125·0	7	1925 July 8	
5 14 24 47	+46·3	+ 16·8	7	1927 Feb. 20	
5 (7 shocks	+35·7	+134·8	7)	1927 Apr. 4	10
6 18 54 5	− 9·0	− 66·0	21†	1922 Sept. 4	
6 19 4 25	− 9·0	− 66·0	3†	1927 Apr. 6	
6 19 15 15	− 9·0	− 66·0	2†	1927 Apr. 6	
6 20 14 35	− 9·0	− 66·0	11†	1927 Apr. 6	
6 (7 shocks	+35·7	+134·8	9)	1927 Apr. 5	21
7 0 8 25	−17·0	− 60·0	6	1915 June 6	
7 17 48 56	+ 6·5	+126·0	*13	1926 July 27	
7 21 16 50	+ 6·5	+126·0	8	1927 Apr. 7	
7 (9 shocks	+35·7	+134·8	9)	1927 Apr. 6	22

17 ([illegible] shocks	+35·7	+134·8	23)	1927 Mar. 15	16
17 (12 shocks	+35·7	+134·8	12)	1927 Mar. 16	22
18 21 27 0	+ 6·0	+125·0	10	1926 Jan. 18	
18 (10 shocks	+35·7	+134·8	19)	1927 Mar. 17	16
19 10 40 36	−27·8	− 70·2	4	1924 Jan. 29	
19 19 51 30	+42·0	+142·0	8	1926 May. 26	
19 20 30 30	+ 2·8	+ 96·0	10	1926 Sept. 23	
19 (7 shocks	+35·7	+134·8	9)	1927 Mar. 18	15
20 16 13 0	+48·0	−178·0	*27	1925 Dec. 11	
20 21 13 37	+ 2·5	+126·7	*16	1925 May 13	
20 (15 shocks	+35·7	+134·8	23)	1927 Mar. 19	23
21 8 46 12	+48·0	−178·0	15	1927 Mar. 20	
21 9 58 27	+48·0	−178·0	*24	1927 Mar. 21	
21 15 5 24	−34·0	+ 57·0	*77	1926 Dec. 29	
21 (5 shocks	+35·7	+134·8	5)	1927 Mar. 20	34
22 0 59 0	+48·0	−178·0	*34	1927 Mar. 21	
22 7 31 36	−22·0	+114·7	31	1919 Nov. 21	
22 22 53 0	+56·0	− 34·5	8		
22 (5 shocks	+35·7	+134·8	9)	1927 Mar. 21	20
23 7 37 25	−12·0	−177·0	11	1926 June 22	
23 9 13 30	−63·0	180·0	25		
23 (7 shocks	+35·7	+134·8	11)	1927 Mar. 22	24
24 7 42 34	+40·0	+ 78·0	10	1925 Aug. 5	
24 14 46 35	+35·0	+ 26·0	45		
24 (4 shocks	+35·7	+134·8	8)	1927 Mar. 23	28
25 3 46 28	+56·0	− 34·5	34	1927 Mar. 22	
25 12 54 50	+54·5	−156·5	*41	1923 May 4	
25 20 47 54	+75·0	− 85·0	10		
25 (8 shocks	+35·7	+134·8	11)	1927 Mar. 24	25
26 2 26 40	−25·0	−167·0	9		
26 18 32 40	+85·0	+ 85·0	6	1926 Aug. 6	
26 (2 shocks	+35·7	+134·8	2)	1927 Mar. 25	20
27 (2 shocks	+35·7	+134·8	2)	1927 Mar. 26	28
28 7 56 4	+46·0	−130·0	12	1926 May 12	
28 (3 shocks	+35·7	+134·8	5)	1927 Mar. 27	18
29 18 5 24	+40·0	+ 78·0	7	1927 Mar. 24	
29 22 34 6	+35·0	+ 26·0	17	1927 Mar. 24	
29 23 8 40	+35·0	+ 26·0	16	1927 Mar. 29	
8 (10 shocks	+35·7	+134·8	22)	1927 Apr. 7	15
9 8 56 50	+ 6·5	+126·0	12	1927 Apr. 7	
9 16 51 30	−21·0	− 67·0	*17†	1927 Jan. 20	
9 19 5 8	+17·0	− 97·0	10	1920 Mar. 9	
9 (8 shocks	+35·7	+134·8	8)	1927 Apr. 8	23
10 (12 shocks	+35·7	+134·8	17)	1927 Apr. 9	9
11 22 3 40	−34·0	+ 57·0	*15	1927 Mar. 21	
11 (8 shocks	+35·7	+134·8	8)	1927 Apr. 10	12
12 23 13 18	−18·5	+168·5	*24	1927 Feb. 4	
12 (8 shocks	+35·7	+134·8	12)	1927 Apr. 11	11
13 13 44 10	+15·8	+119·4	*68†		
13 14 34 32	+15·8	+119·4	*16†	1927 Apr. 13	
13 (7 shocks	+35·7	+134·8	7)	1927 Apr. 12	21
14 6 23 28	−32·5	− 69·5	*116†		
14 (8 shocks	+35·7	+134·8	12)	1927 Apr. 13	14
15 (3 shocks	+35·7	+134·8	3)	1927 Apr. 14	26
16 8 14 51	+51·0	−179·5	*81	1926 Oct. 13	
16 9 11 10	−34·0	+ 57·0	*32	1927 Apr. 11	
16 13 3 35	+ 6·5	+126·0	7	1927 Apr. 9	
16 (7 shocks	+35·7	+134·8	11)	1927 Apr. 15	15
17 9 5 42	− 6·5	+126·0	*13†	1925 Jan. 18	
17 (6 shocks	+35·7	+134·8	7)	1927 Apr. 16	12
18 15 1 45	+38·5	+ 71·0	19	1926 July 6	
18 (4 shocks	+35·7	+134·8	5)	1927 Apr. 17	28
19 8 33 42	− 7·7	+106·5	4		
19 9 28 58	− 7·7	+106·5	2	1927 Apr. 19	
19 15 51 52	− 7·7	+106·5	1	1927 Apr. 19	
19 17 30 0	+15·8	+119·4	*85†	1927 Apr. 13	
19 (1 shock	+35·7	+134·8	4)	1927 Apr. 18	12
20 3 10 30	−31·0	− 65·5	4		
20 7 56 50	+34·5	+135·0	5	1926 Oct. 19	
20 14 15 30	− 4·0	+ 68·0	11	1922 Sept. 8	
20 (2 shocks	+35·7	+134·8	2)	1927 Apr. 19	16
21 3 15 36	+31·0	+140·0	13	1923 Sept. 17	
21 (3 shocks	+35·7	+134·8	3)	1927 Apr. 20	20
22 10 54 50	+43·0	+142·5	9	1921 June 22	
22 (5 shocks	+35·7	+134·8	6)	1927 Apr. 21	24
23 13 20 30	+19·0	+120·5	14	1924 Dec. 24	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1927 *April*—contd.			
d. h. m. s.	°	°			
23 (4 shocks	+35·7	+134·8	4)	1927 Apr. 22	21
24 1 13 8	+37·5	+140·0	8	1927 Jan. 14	
24 11 20 20	+36·5	+ 70·5	12†	1926 May 26	
24 (3 shocks	+35·7	+134·8	3)	1927 Apr. 23	19
25 (6 shocks	+35·7	+134·8	9)	1927 Apr. 24	23
26 7 55 24	+39·5	+ 72·0	5	1926 May 2	
26 (10 shocks	+35·7	+134·8	10)	1927 Apr. 26	23
27 2 50 12	−19·0	+179·0	*37	1924 May 25	
27 13 57 0	+16·0	− 96·0	14	1927 Feb. 12	
27 19 16 14	+30·6	+141·8	*61	1927 Apr. 3	
27 21 53 0	+16·0	− 96·0	13	1927 Apr. 27	
27 (2 shocks	+35·7	+134·8	6)	1927 Apr. 26	10
28 0 49 42	+38·0	+ 69·5	5	1925 Aug. 30	
28 2 4 42	+15·5	+ 92·5	11	1926 July 12	
28 2 59 10	− 5·2	+103·3	6†		
28 10 24 36	+26·3	+121·5	14	1927 Feb. 27	
28 (2 shocks	+35·7	+134·8	2)	1927 Apr. 27	19
29 11 19 40	+70·0	− 19·0	23	1925 Nov. 28	
·29 (7 shocks	+35·7	+134·8	8)	1927 Apr. 28	13
30 13 56 30	+39·5	+ 79·0	53		
30 (10 shocks	+35·7	+134·8	10)	1929 Apr. 29	20
		1927 *May*.			
1 (3 shocks	+35·7	+134·8	3)	1927 Apr. 30	41
2 6 20 24	+32·5	+ 31·0	8		
2 11 23 30	+16·0	− 96·0	5	1927 Apr. 27	
2 11 47 37	−32·5	− 69·5	2†	1927 Apr. 14	
2 12 34 10	− 5·7	+151·8	*25	1923 Nov. 4	
2 22 4 55	+39·0	+ 81·5	22		
2 (2 shocks	+35·7	+134·8	2)	1927 May 1	21

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1927 *May*—contd.			
d. h. m. s.	°	°			
17 17 40 6	+46·3	+ 16·8	6	1927 Apr. 5	
17 21 44 12	+44·0	+131·0	36†	1920 May 6	
17 (3 shocks	+35·7	+134·8	3)	1927 May 16	38
18 1 42 30	+39·0	− 7·5	24	1926 Feb. 28	
18 9 24 57	+30·6	+141·8	15	1927 May 16	
18 22 52 12	+31·0	+132·0	25	1914 Jan. 12	
18 (1 shock	+35·7	+134·8	1)	1927 May 17	35
19 5 25 50	+ 3·0	− 85·0	*36	1923 Sept. 28	
19 19 18 3	+35·5	+140·0	12	1926 Aug. 3	
19 (3 shocks	+35·7	+134·8	3)	1927 May 18	8
20 10 51 0	+24·5	+ 94·5	15	1926 Aug. 18	
20 13 59 6	+37·5	+ 27·5	9	1926 July 5	
20 22 9 9	+30·6	+141·8	17	1927 May 18	
20 (5 shocks	+35·7	+134·8	5)	1927 May 19	18
21 8 4 45	+30·5	+ 69·0	16	1914 Nov. 4	
21 16 53 30	−22·5	−173·5	*38	1926 Aug. 3	
21 (2 shocks	+35·7	+134·8	2)	1927 May 20	21
22 1 45 10	−21·0	− 67·0	*24†	1927 Apr. 9	
22 11 56 40	+14·0	+126·0	*32	1917 May 12	
22 21 43 0	+36·8	+102·8	21†		
22 22 32 32	+36·8	+102·8	*131†	1927 May 22	
22 (6 shocks	+35·7	+134·8	6)	1927 May 21	21
23 2 45 40	+36·8	+102·8	38†	1927 May 22	
23 6 38 6	+50·0	+ 91·8	17	1922 Aug. 25	
23 10 11 42	+37·5	+100·5	7		
23 10 56 30	+37·5	+100·5	5	1927 May 23	
23 13 51 6	+37·5	+100·5	40	1927 May 23	
23 (13 51 6	+36·8	+102·8	25†)	1927 May 23	
23 16 18 40	+39·5	+140·5	10	1927 May 14	
23 16 25 30	+37·5	+100·5	4	1927 May 23	
23 22 0 54	−49·0	+ 97·0	*27		

3 13 40 40	− 7·0	+150·0	*35	1926 Mar. 22	
3 (4 shocks	+35·7	+134·8	6)	1927 May 2	8
4 (5 shocks	+35·7	+134·8	5)	1927 May 3	20
5 (1 shock	+35·7	+134·8	1)	1927 May 4	11
6 (6 shocks	+35·7	+134·8	11)	1927 May 5	8
7 21 56 52	+49·0	−124·0	19	1926 Sept. 22	
7 (4 shocks	+35·7	+134·8	4)	1927 May 6	18
8 7 57 3	+35·7	+132·5	9		
8 (8 shocks	+35·7	+134·8	10)	1927 May 7	25
9 10 31 40	+28·5	+ 56·0	66		
9 20 5 40	+15·5	− 92·5	*57	1925 Dec. 11	
9 (8 shocks	+35·7	+134·8	10)	1927 May 8	21
10 6 3 46	− 1·0	+ 99·0	*25	1926 Oct. 12	
10 7 26 38	− 1·0	+ 99·0	14	1927 May 10	
10 18 52 3	+42·3	+ 17·8	14	1927 Feb. 14	
10 19 59 22	+52·0	+ 89·0	21		
10 20 47 20	−34·0	+ 57·0	*7	1927 Apr. 16	
10 (2 shocks	+35·7	+134·8	2)	1927 May 9	28
11 1 18 40	− 2·0	+146·5	*28		
11 (5 shocks	+35·7	+134·8	5)	1927 May 10	26
12 4 6 45	− 1·0	+127·0	*10	1923 Apr. 27	
12 (1 shock	+35·7	+134·8	1)	1927 May 11	13
13 0 23 40	+45·0	− 29·0	24	1926 Sept. 23	
13 15 13 0	+14·5	+120·5	*38		
13 23 9 8	− 1·3	+143·4	*60	1918 Nov. 14	
13 (2 shocks	+35·7	+134·8	6)	1927 May 12	26
14 2 24 55	+37·0	− 2·5	3	1926 June 12	
14 6 36 30	+39·5	+140·5	10	1923 Oct. 9	
14 20 29 15	+42·0	+ 46·0	14	1920 Feb. 20	
14 (6 shocks	+35·7	+134·8	7)	1927 May 13	15
15 2 47 5	+44·0	+ 21·0	62		
15 3 11 55	+44·0	+ 21·0	35	1927 May 15	
15 (1 shock	+35·7	+134·8	1)	1927 May 14	12
16 12 1 2	+30·6	+141·8	*56	1927 Apr. 27	
16 23 57 30	+39·5	+ 72·0	5	1927 Apr. 26	
16 (3 shocks	+35·7	+134·8	3)	1927 May 15	23
17 0 22 18	+54·0	+161·0	6	1927 Jan. 31	
17 6 11 40	+ 8·0	+ 94·0	*21		

23 23 44 54	+37·5	+100·5	36†	1927 May 23	
23 (2 shocks	+35·7	+134·8	2)	1927 May 22	56
24 9 3 30	+37·5	+100·5	2	1927 May 23	
24 9 15 20	+37·5	+100·5	6	1927 May 24	
24 11 52 24	+74·0	−173·0	5†		
24 12 8 0	+74·0	−173·0	13	1927 May 24	
24 16 1 24	+37·5	+100·5	19	1927 May 24	
24 (3 shocks	+35·7	+134·8	3)	1927 May 23	62
25 2 50 30	+41·0	+ 16·0	39	1925 Aug. 25	
25 3 23 20	+41·0	+ 16·0	3	1927 May 25	
25 5 9 0	+41·0	+ 16·0	3	1927 May 25	
25 6 18 7	+41·0	+ 16·0	3	1927 May 25	
25 6 21 10	+41·0	+ 16·0	3	1927 May 25	
25 6 54 50	+41·0	+ 16·0	3	1927 May 25	
25 10 12 25	+41·0	+ 16·0	5	1927 May 25	
25 10 13 35	+41·0	+ 16·0	3	1927 May 25	
25 13 34 55	+41·0	+ 16·0	4	1927 May 25	
25 18 17 30	+41·0	+ 16·0	3	1927 May 25	
25 23 5 35	+41·0	+ 16·0	3	1927 May 25	
25 (5 shocks	+35·7	+134·8	5)	1927 May 24	30
26 2 20 7	+41·0	+ 16·0	3	1927 May 25	
26 2 41 57	+41·0	+ 16·0	8	1927 May 26	
26 5 23 40	+41·0	+ 16·0	3	1927 May 26	
26 12 3 50	+41·0	+ 16·0	3	1927 May 26	
26 13 57 0	+41·0	+ 16·0	1	1927 May 26	
26 17 26 0	+41·0	+ 16·0	3	1927 May 26	
26 (1 shock	+35·7	+134·8	1)	1927 May 25	32
27 2 54 40	+40·0	+110·0	21	1918 Apr. 10	
27 (3 shocks	+35·7	+134·8	3)	1927 May 26	50
28 17 37 40	+37·35	−121·8	3†		
28 (3 shocks	+35·7	+134·8	6)	1927 May 27	43
29 10 28 34	+41·2	+ 75·2	11		
29 (4 shocks	+35·7	+134·8	4)	1927 May 28	17
30 (3 shocks	+35·7	+134·8	3)	1927 May 29	24
31 7 40 0	+38·5	+139·0	7	1925 July 26	
31 13 0 54	+13·0	− 97·0	11		
31 22 58 15	+45·0	+ 22·0	20	1924 Aug. 12	
31 (2 shocks	+35·7	+134·8	2)	1927 May 30	17

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1927 *June.*

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1 7 27 12	+22·0	+125·5	9	1922 Aug. 20	
1 17 0 25	+45·5	+ 94·0	16	1920 Sept. 20	
1 19 9 36	−45·0	180·0	14†		
1 (1 shock	+35·7	+134·8	1)	1927 May 31	40
2 16 37 24	+24·0	+ 82·3	49		27
3 1 53 40	−34·0	+ 57·0	*4	1927 May 10	
3 7 12 6	− 6·7	+131·2	*114†		25
4					21
5 8 24 48	+36·5	+ 31·0	*53		
5 17 29 36	−28·0	− 69·0	4†	1926 Oct. 28	
5 (1 shock	+35·7	+134·8	1)	1927 June 1	39
6 3 23 12	+24·0	+124·0	13	1926 Aug. 20	
6 5 35 28	+ 8·0	+128·0	*16	1922 June 2	
6 12 29 8	− 8·0	+135·0	*15	1926 Mar. 25	
6 18 24 6	−30·2	−179·0	*60	1924 Aug. 10	
6 (3 shocks	+35·7	+134·8	3)	1927 June 5	18
7 2 58 24	+14·5	+145·5	*8	1921 Dec. 16	
7 9 36 25	+ 9·8	+126·2	*13	1925 Dec. 26	
7 15 14 15	+50·0	−170·0	*9	1924 July 8	
7 23 4 20	+32·7	+120·7	9	1927 Feb. 3	15
8 (3 shocks	+35·7	+134·8	3)	1927 June 6	19
9 3 23 42	+39·3	+142·4	15		
9 11 36 30	+22·0	+120·5	12	1926 Sept. 12	
9 (2 shocks	+35·7	+134·8	2)	1927 June 8	12
10 17 8 12	− 1·0	− 79·0	*29	1924 July 22	
10 18 13 24	+47·5	+137·0	8		
10 (2 shocks	+35·7	+134·8	2)	1927 June 9	10
11 2 32 6	− 1·0	+130·5	*41	1925 Nov. 10	
11 2 49 25	− 1·0	+130·5	9	1927 June 11	
11 (1 shock	+35·7	+134·8	1)	1927 June 10	15
12 8 20 0	+37·5	+134·5	5	1921 Oct. 10	

1927 *July.*

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1 8 18 54	+37·5	+ 23·0	*82	1926 Aug. 30	
1 15 27 44	+35·7	+134·8	5	1927 Mar. 31	26
2 20 38 36	+29·5	+101·0	23	1926 Aug. 11	29
3 8 16 22	+13·0	+124·7	*35	1925 Nov. 22	
3 10 37 39	−14·0	−174·0	*50	1926 Dec. 16	32
4 13 6 0	+36·0	+134·0	4†	1926 July 26	
4 14 27 27	+72·0	− 2·8	18	1926 Sept. 19	
4 15 0 54	+54·0	+161·0	11	1927 May 17	
4 17 10 56	+34·5	+135·0	6	1927 Apr. 20	
4 17 20 42	+34·5	+135·0	2	1927 July 4	
4 17 41 30	+34·5	+135·0	2	1927 July 4	26
5 7 22 51	−19·5	−174·2	13	1923 Nov. 4	16
6 0 3 36	+53·7	− 34·2	19		
6 20 34 38	+35·7	+134·8	3	1927 July 1	15
7 7 39 12	+31·0	+ 96·0	16	1925 Aug. 26	
7 20 6 21	+28·0	+ 62·0	56		10
8 0 27 50	+21·1	+121·7	12	1920 Aug. 5	
8 21 11 25	+38·5	+139·0	5	1927 May 31	23
9					22
10 4 0 0	−16·2	+165·4	20	1926 June 25	25
11 8 8 24	+43·5	+143·0	*35	1926 Sept. 4	
11 13 3 55	+32·0	+ 35·5	79		
11 16 12 10	+36·7	+ 63·0	4	1925 Nov. 23	10
12 21 7 55	+44·0	+146·2	*76†		26
13					19
14 12 59 38	+44·0	−127·0	22	1924 Feb. 24	
14 23 16 56	− 5·5	+130·0	*32	1926 June 24	
14 23 27 30	− 8·8	− 82·3	*30		33
15 3 46 30	+35·0	+ 69·0	29†	1926 Mar. 22	
15 21 10 30	+27·0	+ 96·0	13	1926 May 10	39
16 1 26 46	+71·7	− 17·0	27	1924 Oct. 10	

12 (1 shock	+35·7	+134·8	1)	1927 June 11	17
13 (1 shock	+35·7	+134·8	1)	1927 June 12	11
14 0 35 15	+26·3	+121·5	15	1927 Apr. 28	
14 4 2 12	+43·2	+147·2	*25	1925 Feb. 3	
14 4 44 36	+43·2	+147·2	8	1927 June 14	
14 9 23 52	+ 6·5	+127·0	*16	1926 Dec. 21	
14 17 16 45	−51·0	+140·0	*59		
14 (3 shocks	+35·7	+134·8	3)	1927 June 13	12
15 6 46 10	+35·5	+ 48·0	5	1924 Nov. 12	9
16 2 40 12	+ 6·0	+ 99·5	*9		14
17 6 4 0	− 3·0	−101·0	21		
17 (4 shocks	+35·7	+134·8	4)	1927 June 14	26
18 0 56 0	+18·0	+119·5	25	1915 Nov. 18	
18 2 26 15	+32·0	+139·0	14†	1924 Apr. 3	
18 (2 shocks	+35·7	+134·8	2)	1927 June 17	32
19 0 27 42	+55·0	+ 35·0	29	1924 Apr. 29	
19 (4 shocks	+35·7	+134·8	4)	1927 June 18	17
20 14 15 20	+43·2	+147·2	*43†	1927 June 14	
20 (2 shocks	+35·7	+134·8	2)	1927 June 19	25
21 15 13 30	+44·6	+ 7·7	5		
21 23 46 20	−14·0	+ 59·0	20		
21 (1 shock	+35·7	+134·8	1)	1927 June 20	17
22 (1 shock	+35·7	+134·8	1)	1927 June 21	8
23 23 42 15	+37·5	+100·5	32	1927 May 24	16
24 (2 shocks	+35·7	+134·8	2)	1927 June 22	16
25 8 20 27	−29·0	− 73·0	11	1925 Oct. 5	
25 (3 shocks	+35·7	+134·8	3)	1927 June 24	40
26 11 20 42	+44·5	+ 34·0	71		18
27 8 12 15	+34·0	+ 73·0	7		
27 12 24 0	−23·5	+178·0	22	1926 Feb. 13	11
28 1 41 39	+11·0	+122·0	*15	1924 June 9	
28 17 19 25	+40·0	+168·0	*13		
28 (1 shock	+35·7	+134·8	1)	1927 June 25	34
29 21 21 20	−32·0	−179·0	14	1927 Jan. 21	
29 22 0 50	+34·0	+ 73·0	6	1927 June 27	
29 (2 shocks	+35·7	+134·8	2)	1927 June 28	31
30 22 59 36	+39·0	+ 22·0	56	1925 June 6	16

16 1 34 50	+71·7	− 17·0	24	1927 July 16	
16 2 15 50	+71·7	− 17·0	22	1927 July 16	21
17 8 48 30	+13·5	+139·0	*24		28
18 11 19 40	−32·0	−179·0	*63	1927 June 29	25
19					30
20 3 48 0	+34·0	+136·0	5	1926 Nov. 10	
20 19 6 0	+22·7	+ 99·0	12	1923 June 22	17
21					17
22 3 54 54	+34·7	+ 54·0	*94		
22 4 42 0	+35·7	+134·8	5	1927 July 6	
22 8 37 30	+34·7	+ 54·0	30	1927 July 22	
22 20 33 30	+34·7	+ 54·0	12†	1927 July 22	
22 (20 33 8	+33·5	+ 54·0	12)		33
23 17 20 48	+36·0	+142·0	24	1926 Oct. 2	
23 19 13 40	+43·0	+ 28·0	10	1917 Apr. 4	
23 20 17 46	+34·7	+ 54·0	67	1927 July 22	
23 21 16 33	−30·2	− 71·0	5		
23 22 40 18	+34·7	+ 54·0	62	1927 July 23	32
24 13 23 12	+28·5	+ 56·0	10	1927 May 9	
24 14 0 24	+35·5	+ 77·0	13	1923 Sept. 30	
24 20 17 5	+45·0	+ 28·0	14		
24 21 20 45	+45·0	+ 4·8	10	1918 Aug. 11	44
25 3 15 30	−54·7	− 30·0	*17		
25 20 35 30	+47·5	+ 15·5	51		19
26 12 11 27	+47·5	+ 15·5	26	1927 July 25	17
27 14 51 36	+34·0	+141·5	*24		
27 20 41 42	+34·7	+ 54·0	7	1927 July 23	12
28 6 49 30	+39·3	+ 21·0	30	1923 Oct. 9	
28 16 17 40	+54·7	−157·8	*69		15
29 0 3 5	+15·0	+ 88·5	*48		
29 11 33 12	+35·5	+ 55·0	8	1924 July 3	18
30 4 0 40	+28·7	+ 51·9	4		
30 14 18 15	+36·0	+142·0	*36	1927 July 23	24
31 17 27 42	+54·0	+161·0	14	1927 July 4	
31 20 58 52	+65·5	− 19·5	19	1922 Nov. 13	23
1927 *August.*					
1 11 28 36	−23·3	− 68·5	*40†		

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1927 *August*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1 17 5 55	+51·0	−179·5	*41	1927 Apr. 16	
1 18 46 18	+51·0	−179·5	*48	1927 Aug. 1	19
2 0 51 36	+18·5	− 65·5	*37		15
3 6 3 40	0·0	+122·4	*17	1927 Feb. 21	
3 7 12 5	+26·0	+143·0	6	1927 Feb. 22	
3 11 44 10	+42·0	+146·0	11	1922 June 5	34
4 15 47 40	− 1·7	+122·7	*35		45
5 3 43 3	0·0	− 85·0	*19		
5 12 40 44	+35·7	+134·8	7	1927 July 22	
5 21 12 50	+38·5	+142·5	*107	1922 Feb. 10	27
6 0 13 52	+54·5	−156·5	*64	1927 Mar. 25	
6 14 32 0	+10·0	+127·5	*6	1925 Dec. 28	30
7 1 40 6	+35·5	+140·0	4	1927 May 19	
7 6 33 50	+41·5	+ 20·0	41	1926 Feb. 15	
7 21 39 50	+ 5·0	− 20·0	*16		
7 23 56 45	+75·0	+ 7·0	24	1925 Oct. 6	39
8 0 25 8	+75·0	+ 7·0	26	1927 Aug. 7	
8 0 57 45	+49·0	+156·0	*49†	1920 Sept. 23	
8 3 44 8	+75·0	+ 7·0	23	1927 Aug. 8	
8 18 43 48	+ 1·0	+118·0	*31†	1926 June 18	19
9 1 19 0	+12·5	−109·7	25		14
10 1 35 22	+ 8·0	− 81·5	*88	1913 Oct. 23	
10 11 36 10	+ 0·5	+130·0	*105	1926 July 14	34
11					41
12 0 33 42	+27·5	+142·0	*36†	1924 Apr. 25	
12 1 24 54	+34·7	+134·5	5		
12 10 22 33	+41·0	+ 72·5	52		
12 16 16 34	+41·0	+ 72·5	26	1927 Aug. 12	
12 17 31 35	+37·5	+134·5	4	1927 June 12	
12 17 45 54	+41·0	+ 72·5	7	1927 Aug. 12	62
13 0 58 0	+47·0	+ 10·0	24	1926 Sept. 19	

1927 *September*.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
1 22 18 27	−34·0	+ 57·0	8	1927 June 3	18
2 2 14 9	+25·0	+123·0	16	1926 Feb. 15	14
3 19 47 37	+10·5	− 44·2	*86†	1918 Dec. 2	22
4 16 9 21	+34·0	+134·8	5		
4 19 47 40	− 7·0	+124·0	*10	1924 Sept. 10	25
5 0 33 0	+38·5	+139·0	8	1927 July 8	
5 0 46 24	−41·5	+ 80·0	*21	1924 Dec. 11	
5 20 10 30	+34·2	+ 72·0	11		
5 22 39 36	+37·0	+137·0	6		25
6 7 16 0	+77·0	+ 10·0	26		21
7 10 33 28	+36·5	+139·5	6	1926 July 10	
7 19 57 12	−53·8	+148·0	*41	1924 Mar. 25	33
8 8 52 50	+35·3	− 3·7	41		
8 17 10 56	− 7·0	+145·0	*31	1926 Aug. 19	
8 21 45 20	− 7·7	+106·5	6	1927 Apr. 19	
8 23 22 40	− 7·7	+106·5	*29	1927 Sept. 8	21
9					22
10 3 37 18	− 3·0	−101·0	15	1927 June 17	
10 16 28 6	−34·0	+ 57·0	*31	1927 Sept. 1	16
11 6 54 8	+30·5	+131·0	6		
11 22 15 40	+44·5	+ 34·5	*105		
11 23 44 30	+44·5	+ 34·5	40	1927 Sept. 11	26
12 3 20 0	+44·5	+ 34·5	57	1927 Sept. 11	
12 6 33 24	+44·5	+ 34·5	42	1927 Sept. 12	
12 7 42 25	+44·5	+ 34·5	22	1927 Sept. 12	
12 13 1 15	+44·5	+ 34·5	32	1927 Sept. 12	
12 14 23 50	+44·5	+ 34·5	57	1927 Sept. 12	
12 15 29 20	+33·7	+139·0	7		
12 16 48 27	+34·5	− 4·0	8		
12 19 30 40	+35·0	+ 26·0	19	1927 Mar. 29	59
13 2 8 36	+44·5	+ 34·5	6	1927 Sept. 12	

13 11 46 10	+12·0	+127·0	*13	1925 Sept. 26	55
14					16
15					23
16 11 22 54	+34·0	+136·0	5	1927 July 20	
16 14 14 51	+34·0	+136·0	3	1927 Aug. 16	
16 21 15 45	−55·0	− 27·5	20	1926 June 20	23
17 3 44 51	+36·7	− 2·0	4		36
18 1 50 45	+ 4·5	+ 61·5	10		
18 19 27 44	+35·0	+142·0	*106	1925 Feb. 6	13
19 12 43 15	+36·5	+141·5	8		
19 23 16 48	+35·0	+142·0	26	1927 Aug. 18	22
20 20 6 12	+40·5	−122·0	14	1924 Sept. 9	
20 21 37 18	+35·0	+142·0	*54	1927 Aug. 19	
20 22 12 56	+33·6	+138·4	6		
20 23 54 22	+ 5·0	− 81·0	*92†		11
21 10 19 0	+ 5·0	− 81·0	29	1927 Aug. 20	
21 17 27 30	+42·5	+ 36·5	12		
21 22 39 42	−24·0	−176·0	20	1926 Apr. 7	37
22 2 51 33	+ 9·5	− 84·0	13	1927 Mar. 9	
22 18 14 20	−53·5	+150·0	16		
22 23 18 40	− 5·0	+105·0	7		15
23 6 29 0	+35·0	+142·0	*62	1927 Aug. 20	18
24 5 29 48	+32·0	+139·0	5	1927 June 18	
24 8 55 54	+36·2	+143·0	*57†		
24 15 18 42	+35·0	+142·0	27	1927 Aug. 23	
24 18 9 0	+23·2	+120·6	*70†	1923 May 4	
24 23 55 12	+33·5	+143·0	17		19
25 14 5 24	+46·4	+ 10·0	5	1919 Sept. 16	
25 16 52 38	+ 3·0	+125·0	*27	1927 Apr. 5	
25 22 56 38	+22·0	+ 90·0	16		39
26 0 37 40	+38·5	+143·0	15	1927 Jan. 17	
26 16 22 15	+ 4·5	+ 17·0	12		27
27 12 13 15	+40·5	+160·5	16		22
28					20
29 5 34 22	+38·5	+143·0	27	1927 Aug. 26	
29 7 41 36	+42·0	+142·0	*34	1927 Mar. 19	
29 17 43 50	+36·2	+143·0	12	1927 Aug. 24	15
30					19
31					25

13 10 15 50	−18·0	+167·0	*44	1926 Dec. 3	38
14 2 32 50	+44·5	+ 34·5	35	1927 Sept. 13	
14 2 45 33	+44·5	+ 34·5	13	1927 Sept. 14	26
15 8 30 50	+41·0	+ 77·5	4	1923 Aug. 10	14
16 8 21 50	+44·5	+ 34·5	30	1927 Sept. 14	
16 15 46 22	+46·0	+154·0	*34	1927 Feb. 17	13
17 0 45 15	0·0	+135·0	*32	1925 Jan. 15	
17 12 20 8	+30·5	+131·0	5	1927 Sept. 11	
17 13 45 28	+44·0	+ 21·0	3	1927 May 15	
17 15 9 56	+30·5	+131·0	19	1927 Sept. 17	31
18 2 7 8	+37·7	−118·5	*21	1925 Dec. 6	45
19 8 30 8	− 5·7	+151·8	*21	1927 May 2	16
20					14
21					27
22					17
23 13 54 10	+43·0	+ 85·5	*83†		25
24 6 13 51	+44·5	+ 34·5	55	1927 Sept. 16	
24 17 41 0	+47·5	−169·0	*25		35
25					42
26					13
27					10
28					21
29 6 14 55	+29·6	+ 87·8	5	1926 Dec. 4	9
30 6 42 0	+35·5	− 2·5	4	1926 Nov. 17	
30 7 38 0	+40·7	+145·8	*43	1924 Jan. 10	
30 10 24 50	−32·5	− 69·5	4†	1927 May 2	
30 18 40 6	+34·2	+ 72·0	11	1927 Sept. 5	17
		1927 *October.*			
1					29
2 3 7 26	+35·0	+ 69·0	8†	1927 July 15	
2 4 47 45	+14·0	− 88·0	*48		
2 9 29 15	+14·0	− 88·0	19	1927 Oct. 2	29
3 23 55 42	−19·5	− 66·0	*27	1924 Mar. 6	49
4 2 14 24	+25·0	+123·0	17	1927 Sept. 2	
4 17 32 31	+25·0	+123·0	14	1927 Oct. 4	
4 21 5 40	−55·0	− 27·5	13	1927 Aug. 16	14
5 7 51 30	−54·0	+ 8·0	23		

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1927 *October*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
5 16 36 48	+25·0	+123·0	16	1927 Oct. 4	28
6 13 21 37	+25·0	+123·0	12	1927 Oct. 5	25
7 14 19 30	+38·0	+ 21·5	26	1925 July 6	
7 15 28 14	+38·0	+ 21·5	15	1927 Oct. 7	
7 19 3 29	+25·0	+123·0	16	1927 Oct. 6	
7 21 34 25	+36·8	+ 69·5	21	1925 Dec. 18	52
8 10 34 28	+30·5	+ 80·5	29	1926 July 27	
8 12 26 5	+34·0	+144·5	26		
8 19 49 0	+48·1	+ 16·6	46		47
9 3 37 25	−34·0	+ 57·0	*7	1927 Sept. 10	
9 4 47 3	+25·0	+123·0	18	1927 Oct. 7	44
10 17 49 29	+25·0	+123·0	20	1927 Oct. 9	
10 23 17 55	−29·2	−177·0	21	1925 Feb. 13	20
11 1 12 54	+38·3	+141·0	*20	1923 Jan. 27	
11 3 5 45	+25·0	+123·0	17	1927 Oct. 10	
11 4 23 58	+25·0	+123·0	22	1927 Oct. 11	
11 14 45 3	+42·0	+ 13·5	33	1922 Dec. 29	
11 15 29 8	+44·5	+ 20·6	9	1926 May 19	
11 17 30 23	+44·0	+141·5	*34	1924 May 22	28
12 6 28 2	+25·0	+123·0	*31	1927 Oct. 11	
12 6 29 25	+44·5	+ 34·5	5	1927 Sept. 24	
12 7 20 15	+44·0	+ 21·0	9	1927 Sept. 17	
12 7 55 47	+25·0	+123·0	24†	1927 Oct. 12	30
13 4 28 15	+47·5	+ 15·8	9	1926 July 6	
13 5 46 0	−34·0	+ 57·0	*5	1927 Oct. 9	39
14					16
15 6 25 27	+24·0	+124·0	20	1927 June 6	
15 10 59 0	−40·7	+ 46·8	*25		
15 12 43 56	−40·7	+ 46·8	*8	1927 Oct. 15	20
16 6 7 10	+36·5	+133·0	6	1926 Nov. 27	
16 7 0 48	+46·0	+89·0	9	1926 Aug. 29	

1927 *November*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
2 21 6 12	− 5·9	+102·9	*33		
2 22 56 25	+28·0	+127·0	20	1926 Sept. 9	22
3					26
4 13 50 51	+34·9	−121·0	*117		
4 18 47 25	+34·9	−121·0	3	1927 Nov. 4	
4 20 0 42	+34·9	−121·0	4	1927 Nov. 4	
4 20 44 6	+34·9	−121·0	3	1927 Nov. 4	18
5 5 14 38	+37·0	− 4·5	3	1927 Oct. 21	
5 6 38 0	+27·0	+122·5	*31		
5 21 56 41	+11·0	+ 57·0	7	1926 Jan. 5	29
6 2 39 54	+34·9	−121·0	24	1927 Nov. 4	
6 15 34 27	− 6·7	+131·2	*32†	1927 June 3	28
7 0 3 30	−32·0	−179·0	*29	1927 July 18	15
8 3 10 18	−34·0	+ 57·0	*77	1927 Oct. 19	
8 4 1 54	+37·5	− 9·0	5	1924 Mar. 2	24
9 1 5 36	− 5·5	+147·0	*30†	1926 Aug. 16	12
10 3 2 12	− 2·7	+138·8	*22	1926 Oct. 29	
10 19 48 24	+36·2	+137·8	10		26
11 2 47 44	+35·7	+134·8	5	1927 Oct. 25	25
12 14 45 40	+33·5	+ 46·5	47	1920 May 25	
12 21 56 12	+56·4	−136·0	*20	1927 Oct. 25	44
13					52
14 0 12 0	+70·0	+128·0	94		
14 4 56 24	+70·0	+128·0	105	1927 Nov. 14	
14 7 19 20	−30·2	− 71·0	*88	1927 July 23	
14 15 4 30	−54·0	+ 8·0	*53	1927 Oct. 5	
14 19 44 10	+25·0	+141·5	14	1921 July 4	12
15 8 29 16	+51·0	+179·0	*64†		
15 14 39 12	+33·5	+ 48·0	9		
15 21 48 36	+70·0	+128·0	51	1927 Nov. 14	19
16 1 27 0	+27·5	+ 53·8	6	1924 June 30	

16 12 21 0	−41·5	+ 80·0	*31	1927 Sept. 5	
16 14 12 0	−43·7	+ 41·0	*31		45
17					24
18 12 44 42	+32·2	+129·5	11		30
19 13 48 38	−34·0	+ 57·0	*29	1927 Oct. 13	
19 14 41 45	− 1·5	− 76·0	8	1924 Jan. 26	
19 21 58 36	−49·5	+124·0	20		20
20					21
21 0 57 50	− 8·2	− 79·3	10	1919 May 23	
21 23 7 40	+37·0	− 4·5	4	1927 Mar. 14	13
22					14
23 4 2 12	+15·5	+ 56·5	5	1925 Feb. 1	18
24 13 36 36	+36·5	− 1·0	5		
24 15 59 44	+56·4	−136·0	*123		
24 19 5 32	+33·5	+143·0	*34	1927 Aug. 24	26
25 8 35 25	−30·0	− 70·0	7	1923 June 1	
25 14 28 32	+35·7	+134·8	5	1927 Aug. 5	
25 15 41 18	−22·0	+133·5	5		
25 17 59 14	+56·4	−136·0	9	1927 Oct. 24	
25 21 37 30	+36·0	+138·0	15	1925 Jan. 25	24
26					16
27 1 53 50	+37·4	+138·8	11†		
27 7 31 6	−14·5	+128·0	*23		
27 19 41 6	+ 9·8	+126·2	*19	1927 June 7	17
28 15 22 50	+33·5	+143·0	*34	1927 Oct. 24	
28 21 49 40	+44·6	+ 9·5	23		49
29 1 24 44	+39·0	+ 75·0	13		29
30 3 8 52	+72·5	− 12·0	*35		
30 23 47 10	+44·6	+ 9·5	9	1927 Oct. 28	32
31 6 23 0	+36·5	+ 49·0	7		
31 13 25 0	+30·6	+144·0	9	1924 June 22	
31 17 41 15	− 7·0	+147·0	*17		
31 23 29 45	+39·0	+ 78·0	13		11

1927 *November*.

1					14
2 6 9 38	−20·7	− 69·0	4		
16 21 10 9	+ 7·0	+126·0	*100†	1925 Apr. 23	27
17 13 45 25	− 2·7	+138·8	*21	1927 Nov. 10	
17 14 33 25	−11·0	+167·0	*19	1925 Jan. 14	
17 20 54 42	−23·8	− 67·5	12†		
17 22 35 22	+ 7·0	+126·0	14†	1927 Nov. 16	19
18 3 24 36	+ 9·8	+126·2	*62	1927 Oct. 27	
18 11 1 36	+21·5	+ 68·0	12		
18 12 36 30	+34·5	+ 25·0	12	1925 Jan. 19	31
19 3 32 36	+37·7	−118·5	6	1927 Sept. 18	
19 6 50 40	+ 8·0	−103·0	20	1926 Nov. 7	
19 7 29 36	−19·0	−173·0	26†	1924 Nov. 5	
19 18 5 45	+72·5	− 12·0	5	1927 Oct. 30	
19 23 3 36	+48·8	− 0·5	15†		15
20 10 24 0	+43·9	+ 9·5	8	1926 Oct. 11	
20 17 14 36	+ 1·5	+121·0	*14		17
21 15 13 50	+56·4	−136·0	15	1927 Nov. 12	
21 18 50 40	− 9·2	− 80·0	*26		
21 23 12 14	−44·7	− 73·0	*95		17
22 12 52 52	+44·0	+150·5	*23		26
23 0 12 55	+29·5	+129·0	16	1925 Nov. 30	12
24					29
25 19 52 30	+ 1·0	−129·0	15	1924 June 17	20
26 12 53 52	−25·0	− 67·0	*79†		17
27					21
28 10 12 8	− 3·0	+177·5	21	1921 Feb. 10	
28 14 28 42	−47·0	− 78·0	6	1926 Dec. 7	26
29 11 34 26	+30·0	+ 83·0	7	1913 Mar. 6	15
30 2 58 8	+43·5	+ 11·8	8	1918 Jan. 14	24

1927 *December*.

1 4 37 21	− 0·7	+119·7	*53	1917 Nov. 14	
1 9 55 36	+43·5	+ 11·8	11	1927 Nov. 30	
1 22 47 18	+39·0	+ 81·5	13	1927 May 2	11
2 6 55 10	+34·0	+136·0	11	1927 Aug. 16	18
3 10 9 10	+35·7	− 2·3	4		
3 10 13 30	+35·7	− 2·3	4	1927 Dec. 3	14
4 3 53 4	+32·2	+129·5	18	1927 Oct. 18	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1927 *December*—contd.			
d. h. m. s.	°	°			
4 12 18 20	+32 2	+129 5	10	1927 Dec. 4	
4 (41 shocks	+32·2	+129 5	42)	1927 Dec. 4	26
5 17 49 30	−68 0	− 90 0	25		12
6					2
7 9 33 30	+37 0	+141·0	8	1924 Jan. 15	15
8					21
9					10
10 2 44 27	+38·0	+138·9	4		
10 18 28 58	+44·6	+ 9·5	4	1927 Oct. 30	
10 19 48 24	+42·0	+139·5	6	1926 Oct. 19	22
11 15 33 12	−27·0	−172·0	*29	1918 Jan. 13	
11 15 49 12	+45·0	+ 7·2	18		
11 17 25 30	− 1·0	+124·0	*37	1924 Mar. 7	24
12 13 21 15	−27·0	−172·0	10	1927 Dec. 11	
12 18 23 42	+44·6	+ 7·7	3	1927 June 21	
12 18 53 15	−27·0	−172·0	23	1927 Dec. 12	20
13					33
14 7 50 18	+24·7	+ 63·0	5		14
15 16 11 50	− 3·0	+138·0	*23	1923 Sept. 16	16
16 10 44 40	+48·3	+ 9·0	10		
16 22 21 36	− 1·0	+124·0	*6	1927 Dec. 11	13
17 7 26 15	−34·0	+ 57·0	*7	1927 Nov. 8	19
18 19 49 15	+41·5	+132·0	9†		30
19					19
20					17
21					14
22 13 50 48	−11·0	+115·0	*13		9
23					16
24 4 28 52	+15·6	− 97·8	11	1920 Apr. 6	8
25					11
26 15 6 14	+41·8	+ 12·7	6		15

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *January*—contd.			
d. h. m. s.	°	°			
12 13 6 39	−29·5	− 71·0	56	1926 Dec. 9	14
13					13
14 0 17 6	+51·0	+ 6·0	10	1926 Jan. 5	
14 12 58 16	−29·0	− 71·0	4	1927 Feb. 28	10
15 2 55 18	+ 4·8	+ 96·8	*10	1925 Mar. 19	12
16 4 8 12	+36·5	+140·5	8	1928 Jan. 1	20
17 0 47 45	− 1·5	+ 93·5	6	1925 Sept. 20	19
18 12 22 12	−14·0	− 77·0	28	1922 Apr. 6	25
19 22 45 54	−22·5	−173·5	22	1927 May 21	11
20 4 10 36	+29·0	−115·0	13	1927 Jan. 1	37
21 1 28 42	+43·9	+ 9·5	6	1927 Nov. 20	
21 15 4 50	+36·5	+ 70·5	9	1927 Apr. 24	15
22 0 18 15	+38·5	+ 22·5	25	1927 Feb. 17	10
23					23
24 7 36 0	+41·0	+ 31·0	34	1925 June 24	
24 21 35 45	+35·0	+142·0	7	1927 Aug. 24	13
25 21 6 40	+16·0	− 96·0	17	1927 May 2	20
26 18 50 35	+28·5	+141·5	*24	1923 June 29	
26 21 51 30	− 4·0	+ 97·0	*45		12
27 22 22 28	+22·0	+122·0	*19		26
28 22 20 16	+35·2	+136·3	4	1926 Nov. 23	
28 23 59 0	+47·4	+176·7	*17		10
29					12
30 3 15 12	−34·0	+ 57·0	*66	1927 Dec. 17	15
31					13
		1928 *February*.			
1					26
2					22
3 13 47 28	+70·0	+128·0	77	1927 Nov. 15	

27 20 31 45	+16·5	− 89·5	6	1925 May 26	
27 23 31 15	+15·6	− 97·8	14	1927 Dec. 24	15
28 8 54 45	+54·0	+161·0	*41	1927 July 31	
28 14 33 24	+36·2	+143·0	8	1927 Aug. 29	
28 18 20 18	+54·0	+161·0	*112	1927 Dec. 28	22
29					31
30 6 0 42	− 4·0	+129·0	*7		
30 12 31 12	+19·0	− 57·0	25†		
30 23 24 54	+44·0	+146·2	*17	1927 July 12	14
31 4 59 28	+46·5	+ 13·0	11	1926 Sept. 28	
31 5 50 45	+36·0	+139·0	8†	1921 Dec. 8	
31 19 6 45	+56·4	−136·0	*32	1927 Nov. 21	
31 21 10 54	+45·0	+ 11·0	8	1924 Dec. 22	
31 23 13 18	−51·0	+140·0	28	1927 June 14	22

1928 *January.*

1 3 12 36	+45·0	+ 11·0	6	1927 Dec. 31	
1 7 16 55	+36·5	+140·5	15	1925 Jan. 24	
1 9 25 36	+16·5	−100·2	*49		
1 13 14 24	+45·0	+ 11·0	3	1928 Jan. 1	
1 18 43 22	+53·0	+135·5	45	1926 Sept. 24	23
2					12
3 6 21 54	+39·0	+ 67·0	10		29
4 21 25 20	− 3·5	+146·5	*62	1925 Feb. 25	27
5 13 57 18	+ 9·8	+126·2	7	1927 Nov. 18	
5 14 9 12	+43·5	+ 79·0	14	1926 Nov. 26	
5 21 46 0	−19·5	− 62·7	*28†		8
6 4 7 38	+ 7·0	+126·0	10	1927 Nov. 17	
6 19 31 33	+ 0·2	+ 36·2	*95†		14
7 (15 shocks	+ 0·2	+ 36·2	15)	1928 Jan. 6	17
8 (6 shocks	+ 0·2	+ 36·2	6)	1928 Jan. 7	29
9 5 51 38	+34·0	+134·8	5	1927 Sept. 4	
9 (3 shocks	+ 0·2	+ 36·2	3)	1928 Jan. 8	19
10 2 25 18	+ 0·2	+ 36·2	50†	1928 Jan. 6	
10 3 32 22	+35·7	+134·8	6	1927 Nov. 11	
10 5 9 30	−22·0	+179·0	14	1924 May 4	20
11 (2 shocks	+ 0·2	+ 36·2	2)	1928 Jan. 9	15
11 3 18 49 4	+37·5	+142·5	13	1926 Nov. 5	23
4 6 7 54	− 0·5	+152·0	*46	1925 Aug. 6	18
5 22 45 20	−10·0	+176·0	27	1926 June 1	27
6 0 23 12	+28·0	+ 91·0	6		
6 3 52 6	+ 7·0	+126·0	*53	1928 Jan. 6	
6 17 10 18	+39·5	+ 15·0	5	1913 June 28	24
7 0 1 35	− 1·5	+ 88·5	*90	1926 May 20	
7 8 33 21	+ 7·0	+126·0	6	1928 Feb. 6	
7 13 23 33	+37·0	+137·0	5	1927 Sept. 5	
7 23 28 20	+41·5	+ 9·0	10	1922 Oct. 11	31
8					20
9					16
10 4 38 20	+18·2	− 97·5	*61	1923 Feb. 8	10
11 1 29 8	+43·8	+ 15·7	16	1925 May 30	
11 11 7 24	− 3·5	+102·5	5	1919 Oct. 9	
11 18 26 20	+32·0	− 1·5	5		
11 21 10 12	+36·5	+139·5	15	1927 Sept. 7	12
12					18
13 5 33 27	+12·0	+141·5	*39	1925 Oct. 31	
13 16 34 50	− 8·5	+124·5	*21	1919 Mar. 13	14
14					15
15 13 59 55	+34·0	+136·0	4	1927 Dec. 2	10
16					21
17 12 39 15	−10·5	+157·0	24	1926 Oct. 1	
17 23 13 0	0·0	− 28·2	14	1923 Aug. 8	10
18 14 33 30	−32·5	− 69·5	4†	1927 Sept. 30	15
19 20 42 10	+37·2	− 3·6	3	1925 Feb. 7	
19 21 9 22	+60·0	−150·0	17		32
20 3 2 33	+35·5	+133·5	8		4
21 19 48 58	+67·0	−172·0	*95		29
22 12 57 20	−23·0	−163·0	13		
22 17 50 48	+32·0	+ 35·5	3	1927 July 11	
22 21 18 0	+35·7	+134·8	3	1928 Jan. 10	18
23 9 20 50	+22·0	+120·5	15	1927 June 9	
23 19 3 40	+ 1·5	+121·0	8	1927 Nov. 20	6
24 11 26 12	+38·0	+ 33·5	14	1924 Dec. 13	
24 14 10 18	+67·0	−172·0	54	1928 Feb. 21	18
25 10 52 54	− 3·0	+138·0	*28	1927 Dec. 15	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *February*—contd.			
d. h. m. s.	°	°			
25 17 23 42	+36·5	+ 65·5	19		17
26 0 59 36	+45·0	− 29·0	7	1927 May 13	
26 1 19 8	+67·0	−172·0	*80	1928 Feb. 24	10
27					7
28 2 12 16	+50·1	+178·7	*25	1926 Feb. 7	
28 8 37 18	−59·0	+147·5	21		13
29 21 56 45	−59·0	+147·5	*53	1928 Feb. 28	20
		1928 *March.*			
1					21
2 18 44 35	+39·0	+ 75·0	5	1927 Oct. 29	14
3 17 15 10	+ 9·0	+155·0	*13	1926 Sept. 29	
3 18 49 15	−30·0	+173·0	15		33
4 20 58 12	+41·5	+153·0	*17		7
5					11
6					11
7 9 45 55	+39·0	+ 75·0	12	1928 Mar. 2	
7 10 55 2	+38·6	+ 15·8	69		
7 22 43 14	+36·0	+102·0	70		11
8 18 13 54	+32·0	+ 59·0	26		24
9 0 28 34	+36·2	+143·0	23	1927 Dec. 28	
9 10 53 18	+ 4·0	+128·0	*34	1925 May 4	
9 18 5 20	− 2·3	+ 88·5	*121		14
10 3 17 50	− 2·3	+ 88·5	23	1928 Mar. 9	
10 5 53 20	− 2·3	+ 88·5	13	1928 Mar. 10	
10 10 19 21	− 2·3	+ 88·5	3	1928 Mar. 10	
10 15 49 45	− 2·3	+ 88·5	5	1928 Mar. 10	25
11					11
12 16 55 45	+10·7	+124·7	16		
12 20 2 9	+10·7	+124·7	7	1928 Mar. 12	14

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *March*—contd.			
d. h. m. s.	°	°			
28 11 57 42	+40·0	+ 47·0	9	1919 Jan. 8	
28 12 23 56	+28·0	+130·0	15	1925 Dec. 22	
28 14 20 33	+46·5	+ 13·0	7	1928 Mar. 27	12
29 5 5 58	+31·5	+137·8	*89†		
29 14 52 33	+46·5	+ 13·0	9	1928 Mar. 28	
29 15 25 18	+46·5	+ 13·0	3	1928 Mar. 29	
29 19 19 6	−20·6	+168·8	7	1926 Oct. 7	11
30 1 1 18	+42·0	+ 72·5	9		
30 9 38 57	+44·5	+ 26·5	10		10
31 0 29 42	+38·5	+ 28·0	*89		
31 5 12 24	+38·5	+ 28·0	26	1928 Mar. 31	17
		1928 *April.*			
1 17 51 58	+10·0	+140·0	16		9
2 4 37 42	−25·0	− 68·5	4		29
3 16 42 40	−11·5	− 14·7	*53		18
4					15
5 16 48 58	+35·7	+134·8	3	1928 Feb. 22	9
6 10 38 12	−29·0	− 71·0	8	1928 Jan. 14	23
7 7 33 33	+22·0	+120·5	12	1928 Feb. 23	
7 20 10 36	−55·0	− 24·0	32	1925 Mar. 14	10
8					11
9 17 34 8	−13·0	− 69·5	*94		
9 (12 shocks	−13·0	− 69·5	31)	1928 Apr. 9	22
10 1 3 18	+37·4	+ 26·1	16		
10 (50 shocks	−13·0	− 69·5	48)	1928 Apr. 9	71
11 16 24 0	+34·0	+135·5	5		
11 21 44 54	+ 2·5	+126·7	8	1927 Mar. 20	
11 (21 shocks	−13·0	− 69·5	21)	1928 Apr. 10	24
12 15 25 48	+36·5	+ 75·0	9		

13 1 37 28	− 2·3	+ 88·5	18	1928 Mar. 10	
13 18 31 44	− 5·5	+153·5	*86†		
13 22 40 4	− 3·0	+128·0	*9	1922 Sept. 2	10
14					21
15					6
16 5 0 57	−22·8	+170·5	*120		29
17 2 59 6	−22·8	+170·5	13	1928 Mar. 16	
17 14 21 54	−43·7	+ 41·0	*28	1927 Oct. 16	
17 19 40 54	+41·5	+ 20·0	24	1927 Aug. 7	29
18 1 33 40	+39·5	+ 79·0	9	1927 Apr. 30	
18 3 2 15	−22·8	+170·5	44	1928 Mar. 17	
18 11 59 18	−22·8	+170·5	36	1928 Mar. 18	
18 20 54 12	−17·5	+168·8	10	1923 Dec. 2	
18 23 49 36	+45·4	+ 17·2	27		7
19 10 1 54	+14·5	+ 53·0	26		17
20 2 23 28	+36·8	+102·8	7†	1927 May 23	
20 20 47 0	+40·0	+137·0	7		
20 21 1 35	−34·0	+ 57·0	*15	1928 Jan. 30	11
21 3 53 24	+36·8	+102·8	5†	1927 May 23	
21 (3 53 18	+36·0	+103·0	5)		20
22 4 16 50	+16·0	− 96·0	*128	1928 Jan. 25	34
23 1 21 30	+38·5	+137·0	6		
23 11 6 20	−18·0	− 73·0	6	1925 Oct. 25	
23 18 34 15	+34·0	+134·8	5	1928 Jan. 9	
23 20 2 9	−33·5	+179·5	*33		34
24 10 53 16	+37·8	+ 47·3	17		
24 21 35 10	−45·0	+170·0	4		20
25 18 29 28	−38·0	−176·0	9		2
26 5 26 15	− 0·3	+123·8	*58		
26 6 43 6	− 0·3	+123·8	*33	1928 Mar. 26	
26 8 6 0	− 0·3	+123·8	*32	1928 Mar. 26	
26 9 47 40	− 0·3	+123·8	*23	1928 Mar. 26	
26 14 40 35	+46·5	+ 13·0	51	1927 Dec. 31	16
27 5 9 28	−16·5	− 89·5	29	1927 Dec. 27	
27 8 32 28	+46·5	+ 13·0	73†	1928 Mar. 26	
27 14 37 20	− 9·0	+115·0	*23	1925 Oct. 23	
27 17 46 20	+84·0	+100·0	7	1923 Nov. 11	
27 19 6 42	−34·0	+ 57·0	*56	1928 Mar. 20	16

12 16 36 36	+37·4	+138·8	5	1927 Oct. 27	
12 18 8 30	−28·5	− 73·0	35		
12 (11 shocks	−13·0	− 69·5	11)	1928 Apr. 11	37
13 23 15 57	+15·5	− 96·4	*61†		
13 (7 shocks	−13·0	− 69·5	7)	1928 Apr. 12	20
14 8 59 43	+41·7	+ 26·3	*112		
14 9 23 33	+41·7	+ 26·3	7	1928 Apr. 14	
14 10 23 33	+41·7	+ 26·3	36	1928 Apr. 14	
14 13 16 33	+35·5	+ 55·0	16	1927 July 29	
14 (9 shocks	−13·0	− 69·5	11)	1928 Apr. 13	42
15 10 9 28	+28·7	+ 51·9	9	1927 July 30	
15 21 57 15	+40·5	−122·0	13	1927 Aug. 20	
15 (10 shocks	−13·0	− 69·5	10)	1928 Apr. 14	12
16 8 41 0	+44·0	+152·0	*28	1922 May 5	
16 19 56 36	+43·0	+ 85·5	8†	1927 Sept. 23	
16 (3 shocks	−13·0	− 69·5	3)	1928 Apr. 15	39
17 3 25 12	+17·5	− 94·4	*86		
17 5 47 22	+41·7	+ 26·3	23	1928 Apr. 14	
17 (10 shocks	−13·0	− 69·5	12)	1928 Apr. 16	33
18 3 47 15	+26·7	−112·0	26		
18 11 25 10	+44·5	+ 11·5	7	1925 June 16	
18 19 22 37	+41·7	+ 26·3	*116†	1928 Apr. 17	
18 (19 22 40	+41·8	+ 25·0	*116)		
18 19 40 56	+41·7	+ 26·3	7	1928 Apr. 18	
18 19 51 4	+41·7	+ 26·3	3	1928 Apr. 18	
18 19 57 52	+41·7	+ 26·3	2	1928 Apr. 18	
18 20 5 45	+41·7	+ 26·3	6	1928 Apr. 18	
18 20 49 51	+41·7	+ 26·3	7	1928 Apr. 18	
18 21 58 12	+41·7	+ 26·3	5	1928 Apr. 18	
18 22 48 52	+41·7	+ 26·3	3	1928 Apr. 18	
18 23 14 36	+41·7	+ 26·3	45	1928 Apr. 18	
18 (4 shocks	−13·0	− 69·5	4)	1928 Apr. 17	42
19 1 1 10	+41·7	+ 26·3	6	1928 Apr. 18	
19 1 10 0	+41·7	+ 26·3	25	1928 Apr. 19	
19 4 59 15	+41·7	+ 26·3	19	1928 Apr. 19	
19 5 12 45	+41·7	+ 26·3	2	1928 Apr. 19	
19 5 23 57	+41 7	+ 26·3	10	1928 Apr. 19	
19 5 55 12	+41·7	+ 26·3	2	1928 Apr. 19	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

1928 *April*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
19 6 32 8	+41·7	+ 26·3	3	1928 Apr. 19	
19 6 46 18	+41·7	+ 26·3	6	1928 Apr. 19	
19 7 45 56	+41·7	+ 26·3	7	1928 Apr. 19	
19 8 7 24	+41·7	+ 26·3	1	1928 Apr. 19	
19 9 57 6	+41·7	+ 26·3	9	1928 Apr. 19	
19 10 9 6	+41·7	+ 26·3	2	1928 Apr. 19	
19 22 21 3	+41·7	+ 26·3	1	1928 Apr. 19	
19 22 40 18	+41·7	+ 26·3	26	1928 Apr. 19	
19 (4 shocks	−13·0	− 69·5	4)	1928 Apr. 18	17
20 6 15 10	+41·7	+ 26·3	26	1928 Apr. 19	
20 8 15 40	+42·0	+ 46·0	8	1927 May 14	
20 (3 shocks	−13·0	− 69·5	3)	1928 Apr. 19	22
21 (4 shocks	−13·0	− 69·5	4)	1928 Apr. 20	37
22 4 54 58	+47·0	+135·0	40		
22 19 59 18	+38·0	+ 23·5	43	1922 June 4	
22 20 13 46	+38·0	+ 23·5	*76	1928 Apr. 22	
22 (2 shocks	−13·0	− 69·5	2)	1928 Apr. 21	39
23 (1 shock	−13 0	− 69 5	1)	1928 Apr. 22	8
24 1 14 48	+38·0	+ 23·5	9	1928 Apr. 22	
24 15 44 28	+51·2	−176 0	*20	1927 Jan. 2	
24 19 44 58	+24·0	+121·0	*30	1927 Feb. 20	
24 20 21 48	+51·2	−176·0	9	1928 Apr. 24	
24 21 32 30	+51·2	−176·0	17	1928 Apr. 24	
24 (2 shocks	−13·0	− 69·5	2)	1928 Apr. 23	28
25 0 31 18	+38·0	+ 23·2	37		
25 1 16 40	+39·0	+ 75·0	20	1928 Mar. 7	
25 9 25 40	+41·7	+ 26·3	56	1928 Apr. 20	
25 (4 shocks	−13·0	− 69·5	4)	1928 Apr. 24	26
26 15 39 50	+37·5	+ 55·0	8		
26 19 37 22	+18·5	−104·5	13	1921 May 1	
26 23 59 40	+41·7	+ 26·3	10	1928 Apr. 25	

1928 *May*—contd.

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
16 5 13 6	+49·3	−179·3	*19		
16 7 56 42	− 5·0	− 78·0	*23†	1928 May 15	
16 (7 56 42	− 4·0	− 77·5	*13)		
16 (16 shocks	− 5·0	− 78·0	16)	1928 May 15	17
17 10 53 30	−11·4	− 74·5	18		
17 10 55 20	+ 3·0	+126·0	*22	1925 June 3	
17 16 55 54	+34·8	+140·2	6		
17 22 39 10	− 8·2	+152·5	*14		
17 (5 shocks	− 5·0	− 78·0	7)	1928 May 16	13
18 2 14 8	+52·0	−178·0	15	1924 Aug. 13	
18 (5 shocks	− 5·0	− 78·0	5)	1925 May 17	58
19 3 28 36	+13·0	+ 93·0	*42		
19 6 32 30	+45·5	+ 13·0	8		
19 9 32 0	+36·2	+142·2	*51	1923 May 7	
19 (3 shocks	− 5·0	− 78·0	3)	1925 May 18	51
20 16 29 6	+37·5	+140·0	*46	1927 Apr. 24	
20 17 31 54	+37·5	+140·0	6	1928 May 20	
20 17 58 28	+37·5	+140·0	5	1928 May 20	
20 19 23 32	+37·5	+140·0	6	1928 May 20	
20 (2 shocks	− 5·0	− 78·0	2)	1928 May 19	23
21 2 16 8	+13·5	− 92·5	10		
21 17 2 25	− 5·0	− 78·0	*14	1928 May 16	18
22 13 22 33	−12·0	+125·0	15		
22 (1 shock	− 5·0	− 78·0	1)	1928 May 21	18
23 20 24 44	−30·0	− 77·0	3	1925 June 6	
23 20 54 40	− 2·0	+131·0	*22		16
24 5 37 30	+ 3·0	− 91·0	*24	1926 May 5	
24 19 52 0	+82·0	− 8·0	9		
24 (1 shock	− 5·0	− 78·0	1)	1928 May 22	7
25 10 35 20	+41·1	+ 20·8	4		9
26 5 54 27	+40·0	+ 20·0	41	1926 Oct. 23	

26	(6 shocks			−13·0	− 69·5	6)	1928 Apr. 25	11
27	0	7	0	+18·5	−104·5	11	1928 Apr. 26	
27	13	18	0	+34·5	+ 27·5	14	1923 Mar. 10	
27	13	48	50	+21·0	+120·0	14	1918 Sept. 18	
27	20	34	50	−13·0	− 69·5	*71	1928 Apr. 9	
27	(16 shocks			−13·0	− 69·5	22)	1928 Apr. 26	25
28	17	58	50	+41·7	+ 26·3	42	1928 Apr. 26	
28	(17 shocks			−13·0	− 69·5	18)	1928 Apr. 27	12
29	9	49	12	+38·0	+ 23·2	41	1928 Apr. 25	
29	(10 shocks			−13·0	− 69·5	11)	1928 Apr. 28	15
30	11	19	48	+27·6	+ 57·8	6		14

1928 *May.*

1	0	11	12	−35·5	− 73·3	*40		
1	11	38	6	+22·3	+143·2	7	1922 July 11	
1	15	58	18	+38·5	+ 60·0	7		
1	18	54	36	+67·0	−170·0	53		23
2	14	3	13	+34·2	+ 72·0	5	1927 Sept. 30	
2	21	54	21	+39·7	+ 29·3	*74		43
3	1	25	13	+39·7	+ 29·3	12	1928 May 2	12
4								18
5	13	40	50	+36·0	+102·0	14	1928 Mar. 7	15
6								22
7								24
8	4	45	54	+50·0	+149·0	*76†	1924 Oct. 23	22
9	20	1	30	+40·0	+ 42·0	8	1925 Mar. 12	19
10								21
11								14
12	20	27	52	0·0	− 18·0	*49		18
13	20	6	10	+42·0	+ 46·0	7	1928 Apr. 20	13
14	2	46	55	−15·0	+144·0	16		
14	6	55	15	+27·5	+142·0	8	1927 Aug. 12	
14	22	14	36	− 5·0	− 78·0	*122		18
15	2	36	4	− 5·0	− 78·0	*64	1928 May 14	
15	5	43	30	−54·0	− 22·5	*37	1923 June 2	
15	14	3	22	+46·5	+ 13·0	15	1928 Mar. 29	
15	(40 shocks			− 5·0	− 78·0	43)	1928 May 15	35
26	8	28	54	−23·3	− 68·5	*31†	1927 Aug. 1	
26	14	3	15	− 5·0	− 78·0	*30	1928 May 21	21
27	5	40	24	+40·0	+142·5	17		
27	9	50	18	+40·0	+142·5	*119	1928 May 27	49
28	6	41	6	−16·5	180·0	*50	1924 Mar. 26	
28	15	35	36	+40·0	+142·5	*68	1928 May 27	
28	15	52	20	+40·0	+142·5	5	1928 May 28	
28	19	29	40	+40·0	+142·5	13	1928 May 28	58
29	12	25	12	− 8·5	+ 67·0	10	1924 Nov. 3	27
30	20	1	50	+43·6	+ 13·5	36	1917 Nov. 13	49
31	7	25	54	+40·0	+142·5	*44	1928 May 28	
31	8	35	50	+40·0	+142·5	14	1928 May 31	
31	12	33	24	+35·5	+140·0	10	1927 Aug. 7	
31	13	48	48	+25·8	+128·0	*44	1926 Aug. 7	
31	20	53	33	+ 3·2	+127·5	*35		
31	23	23	54	−41·5	+ 80·0	*53	1927 Oct. 16	49

1928 *June.*

1	4	56	32	+40·0	+143·5	10	1926 June 14	
1	8	0	0	+ 3·2	+127·5	*20	1928 May 31	
1	12	23	20	+40·0	+143·5	*41	1928 June 1	
1	13	12	13	+40·0	+143·5	*98	1928 June 1	
1	15	5	8	+40·0	+143·5	16	1928 June 1	
1	18	21	40	+40·0	+143·5	28	1928 June 1	
1	22	6	12	+40·0	+143·5	*31	1928 June 1	51
2	0	2	4	+40·0	+143·5	9	1928 June 1	
2	9	8	3	+40·0	+143·5	7	1928 June 2	
2	17	30	15	+40·0	+143·5	5	1928 June 2	
2	20	12	54	+83·0	+ 70·0	9		19
3	6	38	12	− 5·0	−108·0	13		
3	8	30	48	+30·5	+129·0	*77		
3	9	18	35	+30·5	+129·0	20	1928 June 3	64
4	7	52	45	+30·5	+129·0	3	1928 June 3	32
5	5	55	18	+30·5	+129·0	*34	1928 June 4	9
6	19	10	15	−19·5	−174·2	25	1927 July 5	28
7	6	24	32	+44·0	+131·0	21†	1927 May 17	
7	12	53	36	+35·0	+ 20·0	20		27

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *June*—contd.			
d. h. m. s.	°	°			
8 9 33 6	+31·7	+131·0	9	1913 Jan. 5	
8 14 39 10	−12·0	−177·0	*50	1927 Mar. 23	23
9 2 40 50	+33·6	−111·4	11	1924 June 18	
9 8 44 40	+44·5	+ 11·5	5	1928 Apr. 18	
9 14 52 3	+35·7	+134·8	5	1928 Apr. 5	23
10					17
11 4 16 0	+34·0	+136·0	5	1928 Feb. 15	
11 6 11 0	+15·5	+ 56·5	10	1927 Oct. 23	28
12					12
13 7 54 48	+45·0	+ 11·0	22	1928 Jan. 1	
13 8 6 28	+34·0	+134·8	5	1928 Mar. 23	17
14 0 27 36	+31·5	+130·0	6	1926 Dec. 1	
14 16 41 15	+35·0	+ 26·0	17	1927 Sept. 12	32
15 6 12 30	+12·3	+121·0	*108		
15 17 16 10	+12·3	+121·0	*91	1928 June 15	
15 (30 shocks	+12·3	+121·0	30)	1928 June 15	29
16 18 26 36	− 7·0	+145·0	*31	1927 Sept. 8	
16 (6 shocks	+12·3	+121·0	6)	1928 June 15	16
17 3 19 19	+16·2	− 97·2	*135		
17 6 40 54	−23·5	+178·0	*47	1927 June 27	
17 22 20 57	+16·2	− 97·2	*44	1928 June 17	
17 23 24 40	+16·2	− 97·2	*51	1928 June 17	
17 (4 shocks	+12·3	+121·0	4)	1928 June 16	74
18 12 59 28	− 7·0	+124·0	11	1927 Sept. 4	
18 15 40 15	+16·2	− 97·2	*24	1928 June 17	
18 21 56 40	+ 2·1	+127·8	*22	1925 Aug. 14	
18 (5 shocks	+12·3	+121·0	5)	1928 June 17	35
19 (2 shocks	+12·3	+121·0	2)	1928 June 18	38
20 (3 shocks	+12·3	+121·0	3)	1928 June 19	28
21 3 45 54	−17·5	+168·8	*33	1928 Mar. 18	
21 10 40 8	−18·0	−179·5	*91		

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *July*—contd.			
d. h. m. s.	°	°			
10 21 33 42	+37·7	+ 64·5	4		31
11 2 50 27	−32·0	−179·0	*48	1927 Nov. 7	8
12 15 17 5	+40·0	+143·5	18	1928 June 2	4
13 9 27 28	−55·0	− 24·0	42	1928 Apr. 7	
13 19 49 8	+ 5·0	+141·0	14		16
14					14
15 9 33 24	+38·0	+ 27·3	59		
15 23 15 50	+ 7·0	+125·0	*10	1913 Mar. 14	30
16					33
17					19
18 9 22 12	+44·6	+ 9·5	9	1927 Dec. 10	
18 11 26 46	+44·6	+ 9·5	7	1928 July 18	
18 19 4 52	− 5·0	− 79·5	*117		
18 (5 shocks	− 5·0	− 79·5	6)	1928 July 18	13
19 20 13 40	+31·5	+102·0	*26		
19 23 38 38	−55·0	+ 10·5	*51		
19 (21 shocks	− 5·0	− 79·5	23)	1928 July 18	31
20 18 29 45	+38·0	+ 23·2	12	1928 Apr. 29	
20 19 53 20	+44·6	+ 9·5	12	1928 July 18	
20 (1 shock	− 5·0	− 79·5	1)	1928 July 19	28
21 2 40 0	− 3·5	+119·5	*26		
21 (3 shocks	− 5·0	− 79·5	3)	1928 July 20	47
22 7 28 8	+16·2	− 97·2	*34	1928 July 6	16
23 7 40 42	−51·0	+164·0	30		33
24 (1 shock	− 5·0	− 79·5	1)	1928 July 21	20
25 (1 shock	− 5·0	− 79·5	2)	1928 July 24	38
26 12 15 10	− 9·5	+119·0	*29		24
27 15 22 54	+ 7·0	+ 94·0	*25	1924 Jan. 24	
27 (1 shock	− 5·0	− 79·5	2)	1928 July 25	15
28 19 49 45	−31·9	− 75·0	*28		27
29 18 15 54	+41·7	+ 26·3	21	1928 Apr. 28	5

21	16	27	7	+59·4	−146·0	*117		
21	(1 shock			+12·3	+121·0	1)	1928 June 20	42
22	(6 shocks			+12·3	+121·0	6)	1928 June 21	32
23	(2 shocks			+12·3	+121·0	2)	1928 June 22	31
24	4	34	22	+35·0	+ 69·0	56	1927 Oct. 2	21
25	7	20	42	−20·5	− 72·0	25		25
26	23	26	3	+47·2	+ 13·7	7	1923 Nov. 28	
26	(1 shock			+12·3	+121·0	1)	1928 June 23	14
27	0	51	5	+16·2	− 97·2	10	1928 June 18	
27	1	31	30	+20·0	+121·0	14	1924 Jan. 27	
27	(1 shock			+12·3	+121·0	1)	1928 June 26	19
28	1	27	3	− 8·5	+ 67·0	9	1928 May 29	9
29	19	39	45	+ 4·8	+126·0	*21	1926 Aug. 15	
29	22	49	38	−15·5	+171·0	*104		24
30	9	33	0	−31·0	− 65·5	7	1927 Apr. 20	
30	22	21	45	+25·0	+150·0	*13		25
					1928 *July.*			
1	9	22	48	+15·5	−101·2	26	1922 Sept. 29	27
2								44
3	0	24	18	+42·0	+141·0	14	1924 Jan. 22	
3	7	46	50	− 1·5	− 76·0	4	1927 Oct. 19	32
4	17	53	28	+10·0	+ 56·5	22		
4	21	38	33	+24·1	+126·7	23		12
5	3	31	12	+39·2	+ 34·8	14		
5	3	39	35	+36·5	+ 1·5	4	1925 July 2	
5	23	12	6	+43·5	+ 17·0	14	1927 Jan. 23	22
6	0	48	0	+ 4·5	+ 61·5	12	1927 Aug. 18	
6	0	54	42	+16·2	− 97·2	*23	1928 June 27	39
7	3	33	42	+17·5	−102·0	*38		
7	8	39	35	+34·0	+134·8	8	1928 June 13	
7	18	0	22	+43·0	+144·5	*40	1926 June 6	23
8	11	55	54	+15·5	− 96·4	*31†	1928 Apr. 13	19
9	15	47	40	+27·0	+ 96·0	13	1927 July 15	
9	21	23	22	− 9·5	+160·8	*94		22
10	2	2	24	+15·6	− 97·8	*49	1927 Dec. 27	
10	10	22	40	+15·6	− 97·8	7	1928 July 10	

30	2	41	10	+ 9·0	−115·5	*34		26
31	0	48	30	− 1·5	+ 88·5	16	1928 Feb. 7	
31	19	28	24	+40·0	+143·5	21	1928 July 12	30
					1928 *August.*			
1	2	53	44	+43·5	+143·0	10	1927 July 11	
1	16	53	0	+62·7	− 22·0	6		
1	19	3	22	+62·7	− 22·0	5	1928 Aug. 1	
1	19	46	18	+62·7	− 22·0	17	1928 Aug. 1	
1	20	28	7	+62·7	− 22·0	14	1928 Aug. 1	
1	20	35	3	+62·7	− 22·0	1	1928 Aug. 1	
1	20	45	49	+62·7	− 22·0	11	1928 Aug. 1	
1	21	0	29	+62·7	− 22·0	1	1928 Aug. 1	
1	21	34	59	+62·7	− 22·0	1	1928 Aug. 1	
1	21	51	4	+62·7	− 22·0	1	1928 Aug. 1	32
2	1	31	14	+36·5	+ 65·5	6	1928 Feb. 25	
2	8	42	15	+46·5	+ 13·0	9	1928 May 15	53
3	7	2	54	− 2·0	− 14·0	14	1921 Dec. 18	
3	11	44	39	− 2·0	− 14·0	*56	1928 Aug. 3	
3	23	10	24	+44·0	+ 10·0	8		36
4	4	20	25	+44·6	+ 9·5	23	1928 July 20	
4	18	26	6	+16·2	− 97·2	*124	1928 July 22	32
5	14	41	51	+16·0	+119·0	*49	1924 May 6	45
6								26
7								27
8	2	15	3	−34·0	+ 57·0	*27	1928 Mar. 27	17
9								21
10	15	33	37	+36·5	+ 70·5	55†	1928 Jan. 21	19
11								11
12	8	8	45	+ 2·1	+127·8	*68†	1928 June 18	40
13								34
14	0	9	9	+27·6	+ 57·8	7	1928 Apr. 30	
14	8	26	12	+36·5	+139·5	4	1928 Feb. 11	6
15	0	48	10	−26·3	− 70·0	3		
15	12	5	36	+35·0	+ 26·0	18	1928 June 14	
15	15	38	36	+32·5	− 42·0	29	1922 July 28	
15	17	15	40	−28·0	− 62·0	*55†		22

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *August*—contd.			
d. h. m. s.	°	°			
16 3 49 6	+28·5	+140·5	7†		
16 7 36 12	+70·0	+128·0	27	1928 Feb. 3	
16 16 44 18	+40·0	+143·5	9	1928 July 31	16
17					20
18					42
19 2 50 0	+46·5	− 28·3	20	1926 Dec. 9	
19 3 54 36	+30·0	+ 64·0	15	1914 Feb. 6	19
20 1 56 3	+39·5	+157·0	*25		
20 17 47 48	+16·2	− 97·2	18	1928 Aug. 4	11
21 19 1 52	+35·5	+ 59·0	25		
21 23 40 22	+43·1	+ 0·3	7	1927 Jan. 7	9
22 0 4 32	+46·5	+ 6·5	6		
22 1 30 33	+33·8	+129·5	12		
22 6 16 15	−35·5	− 99·5	12		45
23 1 17 44	+50·0	+146·0	31†		
23 3 53 25	+42·0	+ 74·0	48		
23 6 15 48	+36·5	+ 36·0	29		19
24 9 44 0	+34·3	+ 1·3	53		
24 14 21 18	+40·8	+ 34·2	15		
24 15 12 40	+40·8	+ 34·2	5	1928 Aug. 24	
24 21 43 30	−16·0	+168·0	*88†	1926 June 3	
24 23 18 10	−13·0	+136·0	29	1918 Dec. 28	44
25 0 18 5	+40·8	+ 35·8	5	1918 Aug. 9	
25 1 48 12	+49·0	+144·0	22	1924 Apr. 11	
25 7 3 5	+34·7	+134·5	4	1927 Aug. 12	
25 21 9 10	+45·9	+ 15·6	41		42
26 4 1 55	−19·0	−173·0	*25	1927 Nov. 19	
26 18 11 20	+36·2	+142·2	17	1928 May 19	
26 22 11 0	+24·0	+121·0	13	1928 Apr. 24	
26 23 16 21	+28·7	+ 51·9	6	1928 Apr. 15	68
27 3 37 54	+28·7	+ 51·9	8	1928 Aug. 26	

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *September*—contd.			
d. h. m. s.	°	°			
17					8
18 8 7 50	+32·5	+ 53·0	5		
18 17 19 15	− 0·4	− 20·0	76	1921 Apr. 27	
18 19 52 27	+13·5	+ 52·0	77		17
19 2 45 51	+32·0	−117·0	8		
19 8 15 30	+27·5	+142·0	*39	1928 May 14	11
20 14 59 0	+25·2	+ 56·8	4	1924 Dec. 11	7
21 2 5 30	−17·5	− 62·0	6		
21 13 27 0	−15·5	− 70·0	*33†		23
22 5 56 10	−14·0	−174·0	24	1927 July 3	
22 7 31 22	−13·0	+165·5	*104		
22 10 5 55	+42·8	+ 12·3	5	1926 Jan. 8	
22 21 54 42	−14·0	−174·0	*13	1928 Sept. 22	22
23 6 54 48	+40·0	+147·0	7		
23 13 40 33	+15·4	− 94·5	*24		24
24 9 12 25	0·0	+125·0	*24	1926 July 13	25
25 4 58 27	+33·5	+131·9	*25	1926 Jan. 30	
25 8 2 30	+45·3	+153·5	*50	1927 Mar. 3	
25 19 1 0	+34·5	+ 25·0	18	1927 Nov. 18	11
26					13
27 0 44 0	+11·8	− 60·5	*64	1922 May 11	4
28					13
29 21 18 10	+36·5	+ 141·5	6	1927 Aug. 19	17
30					16
		1928 *October*.			
1 12 49 15	+42·0	+142·0	15	1927 Aug. 29	15
2					47
3 0 56 50	+39·7	+ 34·0	35		14
4 11 13 54	+39·7	+ 34·0	33	1928 Oct. 3	

27	4	19	57	+28·7	+ 51·9	9	1928 Aug. 27	
27	17	58	48	+33·0	+139·0	7	1920 Apr. 15	17
28	1	39	30	+40·0	+ 14·0	22	1926 Aug. 23	
28	8	23	40	− 7·0	+147·0	*22	1927 Oct. 31	8
29	17	16	3	+23·0	+121·7	*20	1927 Jan. 3	72
30	6	30	58	+23·0	+121·7	*28	1928 Aug. 29	
30	10	54	15	+23·0	+121·7	13	1928 Aug. 30	
30	12	12	20	+27·0	+ 96·0	17	1928 July 9	
30	20	10	52	+48·4	+ 8·9	7†		
30	21	58	51	+12·0	− 95·5	*18	1918 Nov. 16	33
31	0	45	36	+23·0	+121·7	9	1928 Aug. 30	
31	5	14	24	+ 8·0	− 37·5	20	1922 Nov. 20	25
					1928 *September.*			
1	6	8	52	+30·0	+ 71·0	*88	1919 June 15	
1	23	53	42	+15·2	− 95·7	*45		29
2	16	56	51	−13·8	−171·8	19†	1917 Aug. 6	27
3	1	5	52	− 8·0	+105·0	*7	1923 May 15	
3	4	1	54	+34·5	−122·5	5		
3	5	40	51	−55·0	− 24·0	*18	1928 July 13	25
4								10
5	2	23	48	+22·3	+143·2	12	1928 May 1	29
6	6	28	30	+40·0	+143·5	*32	1928 Aug. 16	44
7	2	49	20	− 5·5	+145·0	42†	1926 Dec. 25	17
8								15
9								23
10	17	28	51	+32·5	+ 64·0	8		25
11	0	37	0	− 5·7	+151·8	*46	1927 Sept. 19	
11	12	36	12	+43·0	−130·0	*79	1926 June 5	33
12	1	19	0	−31·0	+179·0	*62	1918 Nov. 28	9
13	3	26	12	+ 3·2	+127·5	*79	1928 June 1	
13	19	3	20	+35·0	+ 20·0	13	1928 June 7	18
14	8	1	52	+22·3	− 46·4	*24		
14	21	10	58	+12·3	+121·0	5	1928 June 15	
14	21	14	18	+12·3	+121·0	6	1928 Sept. 14	25
15	9	32	24	− 5·0	− 80·0	*8	1923 Sept. 9	13
16	2	58	6	+39·3	+ 18·0	18	1915 Aug. 11	16

4	18	22	45	+ 6·5	+ 37·0	*69		12
5	6	58	24	+35·7	+140·4	5		43
6								25
7								21
8								26
9	3	1	0	+16·2	− 97·2	*136	1928 Aug. 20	
9	14	36	50	−16·0	+163·5	*17		17
10	20	36	30	+13·0	+144·5	*26		23
11	23	32	28	+26·8	+172·0	*19		
11	23	44	16	+26·8	+172·0	*14	1928 Oct. 11	8
12	7	26	9	+23·0	+ 95·0	14	1926 Sept. 8	
12	7	29	30	+45·3	+153·5	*51	1928 Sept. 25	
12	12	23	5	+35·7	+132·5	6	1927 May 8	32
13	13	8	33	+16·2	− 97·2	23	1928 Oct. 9	
13	15	16	56	+ 2·5	+126·7	*44	1928 Apr. 11	30
14								14
15	8	30	45	− 3·0	+151·5	*45	1926 Feb. 7	
15	14	19	32	+28·5	+ 66·3	*106		17
16								19
17	6	15	22	−28·7	+179·0	*32		
17	15	19	25	−53·0	− 56·0	*55		
17	17	38	21	+41·0	+ 16·0	9	1927 May 26	18
18								30
19	5	41	30	−35·5	− 73·3	13	1928 May 1	
19	5	49	0	−15·3	− 73·0	4	1922 Oct. 11	
19	10	18	50	−28·0	−177·5	*68		41
20	12	46	44	+30·5	+129·0	*49	1928 June 5	19
21	13	11	55	+28·5	+ 66·3	8	1928 Oct. 15	
21	15	17	6	− 7·0	+178·0	10		
21	16	16	45	− 5·0	+135·0	*26†	1923 Feb. 19	22
22								34
23	17	52	6	+51·0	+157·3	*68		22
24	7	2	0	+44·5	+ 34·5	4	1927 Oct. 12	23
25	12	32	48	+12·3	− 85·8	*87†	1926 Nov. 5	
25	12	36	9	−13·5	+ 68·5	*26	1927 Mar. 14	16
26	4	29	36	+43·5	+ 17·0	27	1928 July 5	16
27								12
28								21

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *October*—contd.			
d. h. m. s.	°	°			
29					7
30 4 23 5	+16·2	− 97·2	*36	1928 Oct. 13	24
31 20 4 18	+43·2	+147·2	*29	1927 June 20	4
		1928 *November*.			
1 4 12 39	+27·0	−107·5	*77		
1 16 8 18	+ 5·5	− 71·5	29	1923 Dec. 22	
1 16 28 30	+30·2	+140·3	4	1926 Dec. 5	33
2					15
3 4 2 51	+36·0	− 84·0	5		
3 9 5 51	+21·1	+121·7	14	1927 July 8	15
4					13
5 4 41 2	+33·2	+131·0	7		24
6 4 4 48	−20·6	+168·8	*100	1928 Mar. 29	
6 13 42 25	+39·7	+ 53·3	12		10
7 15 26 40	+54·5	−156·5	23	1927 Aug. 6	
7 18 36 45	+52·5	+ 95·0	6		14
8					3
9 11 2 36	− 5·5	+153·5	*18	1928 Mar. 13	22
10 12 27 30	−20·6	+168·8	*40	1928 Nov. 6	32
11 22 40 46	−34·0	+ 57·0	*59	1928 Aug. 8	20
12					12
13					32
14 4 32 54	+35·0	+ 71·5	38		25
15 2 32 18	+ 2·4	+133·0	*17		
15 7 37 9	+ 2·4	+133·0	*15	1928 Nov. 15	
15 13 17 35	+51·2	−176·0	*19	1928 Apr. 24	
15 15 34 56	+25·5	+ 93·5	7	1927 Feb. 13	8
16 3 17 15	+46·5	+ 13·0	15	1928 Aug. 2	
16 11 1 48	+26·0	+143·0	14	1927 Aug. 3	46
17					20

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1928 *December*—contd.			
d. h. m. s.	°	°			
6					13
7 9 13 48	− 4·5	+134·0	*87		
7 17 7 20	+44·5	+ 34·5	4	1928 Oct. 24	20
8 13 23 38	−35·0	− 72·5	5	1928 Dec. 3	
8 17 17 57	−35·0	− 72·5	5	1928 Dec. 8	
8 23 57 36	−10·5	+157·0	*45	1928 Feb. 17	32
9 3 51 0	−40·0	+174·0	5		
9 5 5 18	−10·5	+157·0	*49	1928 Dec. 8	
9 18 10 25	−10·5	+157·0	*42	1928 Dec. 9	50
10 4 33 33	+ 3·0	+ 97·8	*38		
10 7 2 53	+37·4	+ 26·1	44	1928 Apr. 10	
10 15 38 48	+ 8·5	− 40·0	*16		14
11 18 54 3	−36·0	− 71·5	11		14
12 1 25 30	+30·5	+ 69·0	13	1927 May 21	
12 20 19 40	−27·5	−176·8	*93		17
13 3 5 16	+44·8	+ 81·7	17		
13 19 36 14	+51·0	+ 6·5	10†		
13 20 6 6	+35·5	+141·0	12	1926 Dec. 12	16
14 0 28 20	+30·5	+ 69·0	35	1928 Dec. 12	
14 1 58 24	+ 2·8	+ 96·0	20†	1927 Mar. 19	50
15 18 1 54	−31·2	− 69·6	9	1923 Apr. 24	61
16 18 43 6	−35·0	− 75·0	15	1926 Sept. 9	18
17					34
18 3 39 27	+43·5	+ 90·5	7		
18 9 16 24	+52·0	+103·0	10	1924 Nov. 9	19
19 4 42 27	+31·5	+143·5	11		
19 11 37 0	+ 7·0	+125·0	*121	1928 July 15	
19 15 15 50	+21·4	+143·5	15†		15
20 6 34 42	−35·5	− 72·0	13	1925 Aug. 11	24
21 1 40 36	+35·0	+142·0	9	1928 Jan. 24	
21 23 17 35	+33·2	+131·0	6	1928 Nov. 5	39

18	18	42	18	+17·0	− 97·0	18	1927 Apr. 9	20
19	15	27	52	−20·6	+168·8	17	1928 Nov. 10	15
20	20	35	5	−22·5	− 70·5	*107	1926 Jan. 1	35
21	16	59	50	+15·5	+122·0	20	1926 Nov. 2	12
22	8	30	56	−56·0	− 3·0	*76		21
23	4	23	30	+47·5	+ 29·7	8		
23	17	48	32	+35·7	+132·5	8	1928 Oct. 12	14
24								21
25								16
26								17
27	9	18	38	+60·3	−144·0	21		15
28	1	23	0	+16·2	− 97·2	*31	1928 Oct. 30	
28	7	36	50	+25·5	− 56·0	24		
28	9	3	10	+19·0	+120·5	7	1927 Apr. 23	
28	10	43	0	− 8·0	+122·0	*99		
28	14	16	15	+41·3	+ 2·5	6		15
29	12	23	45	−22·5	− 70·5	*26	1928 Nov. 20	
29	15	42	20	−29·0	−174·0	33		
29	17	59	48	−29·0	−174·0	*67†	1928 Nov. 29	
29	23	9	8	−29·0	−174·0	*34	1928 Nov. 29	27
30								18
				1928 *December.*				
1	4	6	8	−34·0	− 73·0	*130	1926 Dec. 3	
1	9	19	30	−34·0	− 73·0	23	1928 Dec. 1	
1	18	32	25	−34·0	− 73·0	*31	1928 Dec. 1	44
2	4	20	16	−35·0	− 72·5	*108		
2	5	41	15	−35·0	− 72·5	8	1928 Dec. 2	
2	23	15	52	−35·0	− 72·5	9	1928 Dec. 2	
2	23	41	40	+42·8	+ 77·2	5		60
3	1	44	33	−35·0	− 72·5	6	1928 Dec. 2	
3	5	29	0	+34·5	+ 7·0	30		
3	11	31	26	−35·0	− 72·5	5	1928 Dec. 3	
3	12	26	10	+ 4·2	− 85·0	24		39
4								22
5	2	42	20	+36·5	− 3·5	6	1926 Dec. 1	
5	11	4	12	+ 3·0	− 95·0	11		15
22								44
23								8
24								14
25	6	7	0	−54·7	− 30·0	7	1927 July 25	
25	12	3	44	+37·3	− 4·0	4		12
26	21	32	38	+ 6·0	− 99·0	*30		14
27	4	45	56	−61·3	− 50·0	27		28
28	14	19	27	+ 7·2	+123·0	*99		
28	18	44	21	+ 7·2	+123·0	8	1928 Dec. 28	28
29								31
30	7	32	52	+47·7	+ 8·8	5		
30	17	34	35	+46·5	+ 6·5	7	1928 Aug. 22	49
31	7	33	36	+26·5	+ 99·0	13		13
				1929 *January.*				
1	13	38	5	+ 9·5	+ 60·0	19	1925 Feb. 2	
1	16	40	6	+32·9	+130·8	18		25
2	2	26	56	+23·2	+120·6	16	1927 Aug. 24	
2	6	3	0	+41·5	+142·7	5		23
3								7
4	2	9	25	+33·8	+132·5	5		
4	20	58	24	+34·5	− 1·5	13	1922 May 9	11
5								35
6	0	1	45	+62·7	− 22·0	26	1928 Aug. 1	20
7	14	45	48	− 0·7	+119·7	8	1927 Dec. 1	26
8	7	23	20	−34·0	+ 57·0	*48	1928 Nov. 11	
8	18	7	12	+36·5	+141·5	5	1928 Sept. 29	28
9								15
10	22	52	0	+42·2	+143·0	8		18
11	1	52	0	+35·5	− 0·5	15		
11	8	25	14	−36·0	− 71·5	5	1928 Dec. 11	
11	13	37	20	− 5·0	+155·0	*16	1920 Apr. 6	20
12								13
13	0	3	3	+49·7	+154·8	*138†		
13	18	44	39	+40·8	+110·3	40		24
14	9	45	21	+31·7	+ 77·0	14		
14	17	29	40	+17·0	+120·6	12		75

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *January*—contd.			
d. h. m. s.	°	°			
15					17
16 8 6 0	+17·0	+120·6	*86	1929 Jan. 14	
16 14 3 28	+17·0	+120·6	12	1929 Jan. 16	34
17 0 6 40	+39·3	+ 18·0	40	1928 Sept. 16	
17 11 45 34	+10·6	− 65·6	*93	1926 Feb. 1	
17 22 28 40	+12·2	+142·0	*40		24
18 21 27 30	0·0	− 18·0	*32	1928 May 12	28
19 0 42 6	+ 5·4	+125·2	8	1925 Mar. 26	
19 3 17 39	+ 9·5	− 82·0	*35		
19 11 19 33	+25·5	+ 98·0	12		23
20 14 54 14	+ 2·3	+127·2	*47		17
21 2 22 28	+33·5	+133·2	4	1923 Apr. 2	
21 4 55 25	−51·0	+137·0	47		
21 10 30 45	+62·6	−147·6	*68		
21 15 48 5	+30·5	+ 54·5	12		12
22 10 6 50	+42·8	+ 12·3	12	1928 Sept. 22	
22 14 43 0	+11·5	+ 43·5	45	1926 Oct. 31	25
23 11 14 12	+34·8	+ 24·9	51		34
24 20 36 28	+12·8	− 91·0	*109†		
24 23 29 0	+12·8	− 91·0	13	1929 Jan. 24	19
25 1 28 12	+12·8	− 91·0	27	1929 Jan. 24	41
26 2 30 40	+12·8	− 91·0	19	1929 Jan. 25	
26 23 33 52	+47·0	+ 9·0	6	1926 Nov. 30	37
27 16 6 57	+ 6·0	− 36·5	*52		9
28 21 56 42	+12·8	− 91·0	25	1929 Jan. 26	26
29					13
30 16 53 56	+ 2·3	+127·2	*38	1929 Jan. 20	16
31 18 5 17	+12·8	− 91·0	41	1929 Jan. 28	29
		1929 *February*.			
1 17 14 12	+36·5	+ 70·5	*108†	1928 Aug. 10	20

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *February*—contd.			
d. h. m. s.	°	°			
26 9 0 41	+53·7	−163·0	*95†		14
27 9 34 41	+33·1	+141·2	7		
27 17 20 57	+47·4	+ 9·5	8		39
28 0 12 54	0·0	+122·4	22	1927 Aug. 3	
28 1 43 50	+46·5	+ 6·5	6	1928 Dec. 30	28
		1929 *March*.			
1 7 31 0	+50·2	−130·7	*61		
1 8 52 36	+50·2	−130·7	19	1929 Mar. 1	
1 10 32 15	+46·5	+ 6·5	17	1929 Feb. 28	
1 15 39 40	+13·9	− 91·2	22	1929 Feb. 13	
1 20 57 0	+13·9	− 91·2	10	1929 Mar. 1	41
2					43
3 3 10 50	+36·5	+ 70·5	25†	1929 Feb. 1	
3 16 51 50	+55·7	− 35·5	36		65
4					27
5 16 4 36	+53·5	+158·5	21	1926 June 11	21
6 16 59 23	+38·7	+ 70·5	4		23
7 1 34 34	+49·5	−170·0	*139†		
7 5 45 6	+49·5	−170·0	*14†	1929 Mar. 7	
7 11 6 28	− 6·0	+102·5	*17		21
8 10 54 5	− 6·0	+102·5	12	1929 Mar. 7	31
9 2 11 44	+25·0	+143·0	*81		
9 10 50 33	−42·5	+172·0	*99		28
10 14 34 40	+18·5	+145·0	*64†		
10 22 46 58	+52·6	−168·7	*35		33
11 13 21 30	+43·1	+143·4	4		
11 13 25 32	+10·5	− 75·5	23		23
12					38
13 11 1 12	+37·6	+ 72·6	31		26

2	0	0	14	− 1·5	− 21·8	*106		
2	14	41	58	− 5·5	+130·0	*11	1927 July 14	10
3	2	44	18	+29·0	+130·0	*41	1925 June 28	
3	7	4	55	+29·0	+130·0	18	1929 Feb. 3	
3	18	0	40	+12·8	− 91·0	24	1929 Jan. 31	25
4	10	19	34	+14·0	− 88·0	24	1927 Oct. 2	26
5	1	57	13	+31·5	+ 47·5	8		44
6	6	49	7	+49·7	+149·3	*62		42
7								27
8	2	4	36	+12·3	− 93·8	31		
8	7	41	0	+25·0	+119·5	11	1926 Aug. 20	32
9	1	55	40	+23·5	+102·5	12		
9	12	27	50	+32·9	+130·8	13	1929 Jan. 1	47
10	3	37	4	+12·3	− 93·8	23	1929 Feb. 8	
10	15	39	4	+13·9	− 91·2	*80		
10	17	20	10	+43·6	+ 43·6	27		82
11								28
12								29
13	22	13	20	+13·9	− 91·2	33	1929 Feb. 10	24
14	14	39	21	+30·5	+126·5	35		12
15	5	40	49	+ 9·8	+126·2	*42	1928 Jan. 5	
15	8	4	24	+12·8	− 91·0	*56	1929 Feb. 3	28
16	9	13	45	+41·5	+153·0	10	1928 Mar. 4	
16	19	23	16	−55·0	−121·5	43		13
17	20	44	12	− 8·5	+ 67·0	11	1928 June 28	23
18	18	59	27	+42·1	− 2·1	35		40
19								74
20	13	27	9	+35·7	+134·8	5	1928 June 9	
20	21	3	15	−19·0	−177·0	*50	1926 July 2	26
21								26
22	4	0	16	+37·5	+141·3	8		
22	19	38	36	+42·0	+ 46·0	7	1928 May 13	
22	20	41	39	+10·6	− 42·5	*114		37
23	11	10	18	−31·0	− 71·0	5		30
24	3	36	33	+44·5	+ 34·5	4	1928 Dec. 7	
24	15	55	12	+44·5	+ 34·5	4	1929 Feb. 24	25
25								28
26	3	29	45	−20·6	+168·8	*26	1928 Nov. 19	

14	14	14	45	+39·5	+147·5	20		
14	18	37	10	+28·0	+139·5	19		30
15	1	56	58	+39·7	+143·7	*28		
15	8	25	33	+12·2	+142·0	9	1929 Jan. 17	
15	10	13	48	+32·7	+131·9	8	1927 Feb. 18	
15	17	57	18	+32·0	− 46·0	*25		49
16	3	22	3	+14·2	+ 53·8	6		
16	6	0	0	−18·0	+164·0	*19		
16	12	30	40	+14·2	+ 53·8	9	1929 Mar. 16	25
17	12	14	10	+49·0	+144·0	10†	1928 Aug. 25	
17	21	18	33	+43·8	+ 34·4	4		31
18	1	42	56	− 2·7	+138·8	*29	1927 Nov. 17	
18	11	30	38	+38·9	+141·5	5		
18	23	20	52	+38·5	+144·5	*54	1922 July 5	39
19	20	53	42	+14·5	− 91·0	*72	1927 Feb. 24	53
20	21	10	32	+19·5	+120·0	*34	1923 July 8	46
21	2	36	56	+14·5	− 91·0	*88	1929 Mar. 19	30
22	3	3	54	+25·0	+102·0	37		36
23	10	5	9	+44·5	+ 34·5	4	1929 Feb. 24	
23	10	34	30	+44·5	+ 34·5	4	1929 Mar. 23	
23	19	59	36	− 0·8	+130·1	52		48
24	5	32	36	−22·0	+174·0	21	1921 Jan. 3	
24	12	11	9	+32·0	+ 35·5	4	1928 Feb. 22	
24	16	17	36	+39·5	+ 42·5	9		28
25	3	46	54	+29·5	+ 95·0	21		
25	14	54	24	+ 5·5	+ 93·0	12		18
26	5	25	8	+74·2	+ 4·0	13		
26	8	25	12	+ 1·0	+ 97·5	12	1926 Aug. 3	
26	14	0	10	+28·0	+ 62·0	16	1927 July 7	
26	23	36	36	+38·5	+144·5	15	1929 Mar. 18	30
27	2	11	55	+39·1	+ 71·6	4		
27	2	36	8	+39·1	+ 71·6	4	1929 Mar. 27	
27	3	37	18	+39·1	+ 71·6	7	1929 Mar. 27	
27	5	2	40	+39·0	+143·5	12	1923 Feb. 5	
27	5	11	2	+39·0	+143·5	3	1929 Mar. 27	
27	7	41	36	+36·8	+ 26·5	30		
27	9	23	29	+39·0	+143·5	14	1929 Mar. 27	
27	16	32	28	+34·6	+140·7	11	1926 Aug. 7	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *March*—contd.			
d. h. m. s.	°	°			
27 21 6 10	+35·0	+ 20·0	23	1928 Sept. 13	
27 21 40 10	+37·4	+138·8	6	1928 Apr. 12	52
28 3 9 45	+13·0	− 97·0	29	1927 May 31	
28 11 3 12	+35·5	− 5·5	7	1923 July 9	
28 20 17 42	−55·0	− 27·5	*51	1927 Oct. 4	
28 20 48 10	+34·0	+ 4·0	7	1925 Sept. 30	13
29					14
30 16 15 54	+12·3	− 93 8	14	1929 Feb. 10	22
31 3 9 48	− 0 6	− 16 8	*24		
31 5 24 36	− 3 0	+143 5	*38	1926 Nov. 7	
31 20 17 18	+38·5	+144·5	*62	1929 Mar. 26	29
		1929 *April.*			
1					17
2 3 26 20	+37·2	+101·4	19	1925 Apr. 20	42
3					18
4					13
5 8 26 46	+20·0	+121·0	16	1928 June 27	
5 23 38 15	+41·5	+ 31·5	31		25
6 20 34 6	+36·0	+136·5	4		41
7 19 31 45	+12·0	− 95·5	*54	1928 Aug. 30	17
8 1 12 14	+41·2	+ 32·3	15		
8 10 16 48	+ 7·8	+124·6	*72†		28
9 3 52 39	−34·0	+ 57·0	*51	1929 Jan. 8	37
10 5 43 12	+43·8	+ 11·2	50	1926 July 19	
10 6 4 24	+28·5	+140·5	13	1928 Aug. 16	
10 6 48 28	+43·8	+ 11·2	14	1929 Apr. 10	
10 16 32 30	+43·8	+ 11·2	18	1929 Apr. 10	
10 20 46 22	+43·8	+ 11·2	8	1929 Apr. 10	
10 23 53 0	+25·0	+ 77·5	12	1926 Dec. 31	61

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *April*—contd.			
d. h. m. s.	°	°			
25 22 42 38	+44·2	+ 34·4	4		
25 22 43 59	+44·2	+ 34·4	4	1929 Apr. 25	31
26 18 5 5	− 4·7	+107·5	6		22
27 11 41 6	+12·3	− 93·8	*31	1929 Mar. 30	
27 21 2 48	− 3·5	+146·5	*44	1928 Jan. 4	
27 22 18 3	+41·0	+ 31·0	18	1928 Jan. 24	13
28 4 58 32	+14·5	+ 54·0	15		
28 8 35 45	+43·8	+ 11·2	9	1929 Apr. 24	
28 14 33 3	− 4·5	+134·0	8	1928 Dec. 7	
28 19 39 54	+43·8	+ 11·2	28	1929 Apr. 28	33
29 18 35 59	+43·8	+ 11·2	52	1929 Apr. 28	20
30 18 48 36	+12·7	+ 94·5	29	1926 July 6	46
		1929 *May.*			
1 7 38 36	+13·0	+144·0	*42		
1 15 37 22	+38·0	+ 56·8	*125		
1 19 36 33	+33·5	+ 27·0	11	1925 Jan. 27	
1 21 12 20	+43·8	+ 11·2	28	1929 Apr. 29	
1 22 3 32	− 5·0	− 78·5	19		
1 22 42 45	+38·0	+ 56·8	11	1929 May 1	51
2 14 25 51	+44·6	+149·5	*60		39
3 8 8 27	−34·0	+ 57·0	*18	1929 Apr. 9	
3 16 19 56	+38·4	+ 57·7	33		44
4 6 31 12	+38·4	+ 57·7	21	1929 May 3	40
5 16 56 40	−13·0	+ 66·0	23		45
6 5 8 36	− 5·2	+132·7	*61		23
7 8 44 37	+ 3·2	+127·5	12	1928 Sept. 13	
7 16 14 4	−40·0	+174·0	5	1928 Dec. 9	
7 16 35 8	− 3·2	+135·6	*89		
7 21 17 48	+37·3	+141·7	14		26

11 0 30 8	+43·8	+ 11·2	30	1929 Apr. 10	
11 1 40 0	+43·8	+ 11·2	31	1929 Apr. 11	37
12 0 32 12	+43·8	+ 11·2	24	1929 Apr. 11	
12 5 20 55	+43·8	+ 11·2	25	1929 Apr. 12	
12 8 10 20	+44·5	+ 34·5	4	1929 Mar. 23	
12 23 31 10	+44·5	+ 34·5	4	1929 Apr. 12	
12 23 42 32	+44·5	+ 34·5	4	1929 Apr. 12	42
13 6 43 45	−57·0	− 20·0	*38		
13 21 5 55	−55·0	− 24·0	37	1928 Sept. 3	
13 21 24 26	+43·8	+ 11·2	19	1929 Apr. 12	58
14 19 25 41	−21·5	+169·0	18	1926 Aug. 26	22
15 16 14 27	− 7·0	+162·0	11		
15 19 15 57	+43·8	+ 11·2	11	1929 Apr. 13	25
16 0 52 54	+36·5	+141·5	*40	1929 Jan. 8	
16 14 2 51	−31·0	− 71·0	25	1929 Feb. 23	27
17 3 14 42	+35·0	+ 27·5	27		
17 6 19 50	−34·5	− 71·5	6		
17 11 48 27	+37·8	+ 25·0	17		
17 18 34 12	+36·5	+140·5	31†	1928 Jan. 16	8
18 3 38 38	+ 5·1	+124·8	9	1926 May 20	8
19 4 15 22	+43·8	+ 11·2	45	1929 Apr. 15	
19 12 16 21	+44·5	+ 34·5	4	1929 Apr. 12	36
20 1 9 46	+43·8	+ 11·2	61	1929 Apr. 19	
20 5 49 16	+43·8	+ 11·2	14	1929 Apr. 20	
20 (13 shocks	+43·8	+ 11·2	29)	1929 Apr. 20	19
21 9 39 55	+43·8	+ 11·2	8	1929 Apr. 20	
21 9 46 56	+43·8	+ 11·2	14	1929 Apr. 21	
21 12 37 42	+35·0	− 38·0	40		12
22 8 25 33	+43·8	+ 11·2	42	1929 Apr. 21	
22 9 23 32	+43·8	+ 11·2	8	1929 Apr. 22	
22 10 1 43	+43·8	+ 11·2	4	1929 Apr. 22	
22 14 18 47	+43·8	+ 11·2	16	1929 Apr. 22	
22 14 37 0	+43·8	+ 11·2	6	1929 Apr. 22	
22 (3 shocks	+43·8	+ 11·2	7)	1929 Apr. 22	21
23 5 53 44	+43·8	+ 11·2	12	1929 Apr. 22	
23 14 16 3	+36·1	+140·0	14		52
24 4 59 15	+36·5	+ 65·5	7	1928 Aug. 2	
24 22 50 52	+43·8	+ 11·2	18	1929 Apr. 23	41

8 12 27 30	+38·0	+ 29·5	11	1926 Jan. 13	39
9					21
10 11 17 33	+50·5	+106·0	19		
10 17 17 28	−39·0	180·0	*32	1925 Oct. 21	16
11 8 10 40	−22·7	− 65·6	5		
11 19 22 48	+44·5	+ 11·0	59	1926 July 1	35
12 1 13 15	+44·5	+ 11·0	7	1929 May 11	
12 9 34 30	+12·8	− 91·0	*33	1929 Feb. 15	
12 17 1 2	+39·2	+ 10·0	14		25
13 6 32 22	+38·4	+ 57·7	11	1929 May 4	
13 9 24 30	+15·5	− 96·4	13	1928 July 8	
13 13 27 3	+38·0	+ 56·8	*70	1929 May 1	40
14					27
15 23 51 25	+50·1	+ 12·4	7		
15 (23 51 27	+50·8	+ 12·5	6†)		
15 (19 shocks	+50·8	+ 12·5	38)	1929 May 15	30
16 1 22 34	+36·5	+ 36·0	13	1928 Aug. 23	32
17 19 33 33	+32·0	+ 57·0	7	1923 May 25	36
18 1 2 0	+11·5	+ 42·0	37		
18 6 37 39	+39·0	+ 37·5	96		39
19 5 8 56	− 4·5	+131·0	*22	1926 Nov. 6	
19 6 33 18	+39·0	+ 37·5	7	1929 May 18	33
20 4 52 51	+51·2	−176·0	*90	1928 Nov. 15	
20 12 17 34	+44·5	+ 26·5	17	1928 Mar. 30	44
21 16 35 25	+31·8	+131·8	*119		
21 16 52 3	+31·8	+131·8	2	1929 May 21	
21 16 57 59	+31·8	+131·8	5	1929 May 21	
21 17 10 20	+31·8	+131·8	9	1929 May 21	
21 17 20 57	+31·8	+131·8	7	1929 May 21	
21 18 11 39	+31·8	+131·8	2	1929 May 21	
21 21 27 48	+31·8	+131·8	2	1929 May 21	40
22 0 26 12	−14·0	+166·5	*30	1926 Sept. 6	
22 20 6 5	−61·7	+152·6	*57		30
23 18 36 15	+57·5	+ 5·8	23		26
24 18 37 44	+29·3	+ 98·7	24		27
25 3 44 42	+18·5	−107·0	9		
25 11 59 37	− 9·3	− 76·6	*45†		21
26 8 42 12	− 3·2	+129·9	*48		

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *May*—contd.			
d. h. m. s.	°	°			
26 22 39 48	+50·2	−130·7	*137	1929 Mar. 1	20
27 19 18 35	+44·5	+ 11·0	7	1929 May 12	
27 23 55 48	+13·0	− 94·5	*32		45
28 4 49 0	−34·0	−109·7	19		
28 7 12 18	+44·0	+ 20·0	26	1919 Oct. 7	31
29 23 31 0	+57·5	+ 7·0	13		31
30 9 43 16	−34·7	− 68·0	*92		
30 10 54 42	−34·7	− 68·0	5	1929 May 30	
30 11 47 38	−34·7	− 68·0	3	1929 May 30	
30 12 10 43	−34·7	− 68·0	19	1929 May 30	28
31 0 10 2	+42·2	+143·8	*58		
31 14 51 55	−34·7	− 68·0	17	1929 May 30	17
		1929 *June.*			
1 7 43 36	− 6·7	+131·2	5†	1927 Nov. 6	
1 17 58 33	+27·5	+127·5	*57		24
2 21 38 28	+34·5	+137·2	*111†		28
3 20 29 37	+44·3	+ 67·3	*85		
3 (3 shocks	+44·3	+ 67·3	11)	1929 June 3	12
4 7 4 48	+44·3	+ 67·3	33†	1929 June 3	
4 15 15 55	+ 7·5	+126·0	*79†		69
5 9 6 36	+44·3	+ 67·3	28	1929 June 4	34
6 10 50 3	− 1·2	− 14·2	*69		
6 14 18 48	−34·0	+ 57·0	*29	1929 May 3	
6 15 43 24	− 3·0	+138·0	37	1928 Feb. 25	42
7 0 5 0	−53·0	− 65·5	14		
7 19 52 55	+32·5	+132·5	9		25
8 6 10 40	+ 5·5	+ 93·0	8	1929 Mar. 25	
8 12 25 2	+35·7	+134·8	5	1929 Feb. 20	29
9 1 2 45	+12·8	− 91·0	13	1929 May 12	

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *June*—contd.			
d. h. m. s.	°	°			
21 (11 shocks	−41·8	+172·2	11)	1929 June 20	11
22 15 30 12	−41·8	+172·2	*63	1929 June 19	
22 18 39 8	−41·8	+172·2	*39	1929 June 22	
22 (28 shocks	−41·8	+172·2	28)	1929 June 22	27
23 3 12 3	+ 8·3	+126·9	16	1929 June 21	
23 21 47 0	+ 8·3	+126·9	*37	1929 June 23	
23 (22 shocks	−41·8	+172·2	22)	1929 June 22	32
24 2 4 27	+37·1	+141·3	19	1929 June 13	
24 (12 shocks	−41·8	+172·2	12)	1929 June 23	26
25 6 12 30	−29·0	−112·3	15	1924 June 7	
25 9 13 14	−29·0	−112·3	22	1929 June 25	
25 (11 shocks	−41·8	+172·2	11)	1929 June 24	33
26 6 29 18	+50·2	+174·7	*25		
26 8 46 0	+35·3	+130·8	5	1925 Oct. 14	
26 16 49 6	+36·2	+142·2	*42	1928 Aug. 26	
26 (15 shocks	−41·8	+172·2	15)	1929 June 25	15
27 12 46 57	−54·0	− 29·6	*125†		
27 15 17 10	−54·0	− 29·6	4	1929 June 27	
27 22 39 0	+71·0	− 6·0	30		
27 (7 shocks	−41·8	+172·2	7)	1929 June 26	41
28 22 18 44	+39·0	+ 37·5	8	1929 May 19	
28 (7 shocks	−41·8	+172·2	7)	1929 June 27	48
29 1 39 36	+ 2·8	+ 96·0	10	1928 Dec. 14	
29 (6 shocks	−41·8	+172·2	6)	1929 June 28	8
30 2 44 34	+ 8·3	+126·9	*85	1929 June 23	
30 5 13 36	+ 8·3	+126·9	*25	1929 June 30	
30 (9 shocks	−41·8	+172·2	9)	1929 June 29	15
		1929 *July.*			
1					32
2 0 37 46	+ 9·5	+128·8	*21	1924 June 23	

9 9 7 48	+45·5	+151·2	*148	1922 Dec. 31	
9 23 15 12	+45·5	+151·2	*19	1929 June 9	35
10 0 18 4	+25·5	+ 98·0	18	1929 Jan. 19	
10 23 3 6	+71·0	+ 10·0	78		25
11 19 32 30	+31·8	+131·8	10	1929 May 21	12
12 9 39 54	+43·8	+ 11·2	6	1929 May 1	
12 11 42 56	− 4·0	+144·5	*72†	1920 May 13	
12 14 30 4	+25·5	+ 98·0	25	1929 June 10	22
13 0 12 9	+45·5	+151·2	*114	1929 June 9	
13 0 14 7	+45·5	+151·2	*42	1929 June 13	
13 0 25 45	+45·5	+151·2	*70	1929 June 13	
13 9 24 23	+ 8·3	+126·9	*119		
13 19 47 24	+ 8·3	+126·9	*52	1929 June 13	
13 20 23 17	+37·1	+141·3	18		
13 22 15 36	+41·5	+ 63·5	14		
13 23 0 25	+ 8·3	+126·9	*71	1929 June 13	40
14 23 13 5	+ 8·3	+126·9	*17	1929 June 13	35
15 8 58 12	+ 9·0	+123·7	*26		
15 16 1 48	+ 8·3	+126·9	*9	1929 June 14	
15 19 35 12	+ 8·3	+126·9	*39	1929 June 15	
15 21 7 40	+ 8·3	+126·9	*26	1929 June 15	48
16 22 47 18	−41·8	+172·2	*126		
16 (5 shocks	−41·8	+172·2	5)		54
17 6 45 3	+33·7	+135·2	7		
17 10 16 16	+ 8·3	+126·9	*67	1929 June 15	
17 (266 shocks	−41·8	+172·2	266†)	1929 June 16	22
18 14 10 25	+39·0	+ 75·0	13	1928 Apr. 25	
18 (68 shocks	−41·8	+172·2	68)	1929 June 17	53
19 3 25 33	−41·8	+172·2	19	1929 June 16	
19 7 30 35	+ 8·3	+126·9	*74	1929 June 17	
19 9 17 10	−41·8	+172·2	18	1929 June 19	
19 19 20 45	+25·5	+ 98·0	16	1929 June 12	
19 (28 shocks	−41·8	+172·2	28)	1929 June 19	32
20 18 22 25	− 8·7	+112·6	*38		
20 20 10 22	+ 8·3	+126·9	*29	1929 June 19	
20 (19 shocks	−41·8	+172·2	19)	1929 June 19	39
21 4 40 39	+ 8·3	+126·9	*29	1929 June 20	

3 0 52 55	+61·5	−146·0	*42		
3 8 25 45	+41·5	+ 22·0	35		
3 17 53 24	− 7·0	+150·0	*31	1927 May 3	
3 20 2 30	+34·0	+135·5	11	1928 Apr. 11	30
4 4 28 28	+63·2	−147·3	*55		
4 7 14 18	+55·7	− 35·5	29	1929 Mar. 3	
4 7 31 10	+55·7	− 35·5	7	1929 July 4	
4 7 56 32	+55·7	− 35·5	12	1929 July 4	76
5 5 7 43	+38·0	+135·0	5		
5 14 18 56	+51·0	−179·5	*126	1927 Aug. 1	
5 14 35 5	+51·0	−179·5	*25	1929 July 5	
5 22 36 9	+50·5	−178·3	*111		
5 23 9 34	+50·5	−178·3	*18	1929 July 5	31
6 2 3 40	+50·5	−178·3	*97	1929 July 5	
6 9 46 6	+13·9	− 46·4	*83		
6 13 22 4	+ 1·5	+121·0	7	1928 Feb. 23	33
7 6 16 10	+50·5	−178·3	13	1929 July 6	
7 9 27 9	+50·5	−178·3	17	1929 July 7	
7 21 23 3	+50·5	−178·3	*141	1929 July 7	24
8 0 42 40	−41·8	+172·2	4	1929 June 22	
8 2 4 43	+50·5	−178·3	*12	1929 July 7	
8 19 8 45	+50·5	−178·3	*36	1929 July 8	66
9 8 37 43	+50·5	−178·3	13	1929 July 8	
9 17 23 18	+ 8·3	+126·9	*16	1929 June 30	51
10 9 1 57	+37·5	+ 70·5	6	1924 Sept. 17	27
11 13 36 54	+51·2	−172·0	*15	1922 May 3	
11 20 56 58	+51·6	−179·0	*46		22
12 15 54 33	+62·8	−151·0	28		
12 17 58 58	+26·8	+130·6	*36		42
13 7 36 25	+37·0	+ 58·5	64		
13 12 50 54	+42·5	+ 19·0	36		
13 14 50 18	− 5·5	+148·0	*75		34
14 8 57 55	−33·2	−108·0	*35		
14 9 36 43	+48·8	+154·7	*112		43
15 7 44 7	+33·7	+ 49·4	*99		
15 8 58 4	−41·8	+172·2	25	1929 July 8	
15 14 29 36	−31·0	− 71·0	*14	1929 Apr. 16	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *July*—contd.			
d. h. m. s.	°	°			
15 22 45 40	+35·5	+142·0	6	1923 May 6	
15 23 37 22	+44·8	+ 14·7	13	1925 May 1	21
16 19 43 15	+28·7	+ 51·9	11	1928 Aug. 27	43
17 8 37 57	+51·0	−179·5	*83	1929 July 5	
17 10 49 28	+36·5	+140·5	8†	1929 Apr. 17	
17 19 52 12	−22·0	−160·5	24		29
18 21 1 58	+43·8	+ 11·2	38	1929 June 12	52
19 8 30 34	+44·0	+ 21·0	15	1927 Oct. 12	27
20					13
21 10 7 6	−15·0	−172·0	24	1925 Oct. 15	
21 13 15 54	+14·6	+124·1	*40		33
22					21
23 14 45 30	+ 4·0	+128·0	*19	1928 Mar. 9	
23 18 42 51	+63·8	− 23·8	*96		
23 20 4 10	+63·8	− 23·8	18	1929 July 23	26
24 2 34 6	+ 4·0	+128·0	*14	1929 July 23	43
25 0 17 17	+37·7	+ 57·8	47		
25 15 7 24	+42·0	+158·0	15		
25 22 57 10	−14·5	− 14·0	*36	1926 May 17	34
26 17 18 45	− 3·0	+ 24·0	18	1922 Apr. 16	
26 22 48 16	+35·5	+139·1	*113†		38
27 12 52 58	+ 8·0	− 40·5	28	1919 Apr. 21	25
28 6 54 24	+44·6	+ 10·6	13		
28 17 33 14	+35·5	+139·1	6	1929 July 26	23
29					36
30 3 53 48	+18·0	−100·0	16	1918 May 16	
30 7 43 34	+13·9	− 91·2	*29	1929 Mar. 1	17
31					11
		1929 *August*.			
1 5 1 48	+12·0	+ 93·5	*79		

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *August*—contd.			
d. h. m. s.	°	°			
19 10 39 42	− 5·0	+ 72·5	7		
19 20 44 32	+24·7	+121·7	*60†	1929 Aug. 19	
19 23 17 51	+38·0	+ 29·5	10	1929 May 8	19
20 16 38 20	+24·7	+121·7	*69†	1929 Aug. 19	
20 17 36 54	+10·5	− 87·0	*24		12
21 1 24 14	+41·0	+ 37·0	11	1916 Jan. 24	
21 9 26 32	+13·4	+121·5	*24		18
22 7 34 30	−20·6	+168·8	28	1929 Feb. 26	
22 16 32 24	−35·0	− 96·5	19		
22 19 40 45	− 3·7	− 21·2	*15		18
23					24
24					45
25					18
26					7
27					15
28 18 51 35	+41·0	+143·1	*97		14
29 10 9 42	−22·5	−177·5	18		
29 10 45 25	+ 5·6	+126·3	*8	1923 Oct. 4	
29 19 47 13	+24·7	+121·7	*35†	1929 Aug. 20	42
30					35
31 3 3 9	+34·0	+131·0	4	1926 Apr. 6	
31 3 7 36	+34·0	+131·0	7	1929 Aug. 31	
31 19 16 26	−11·5	− 14·7	27	1928 Apr. 3	14
		1929 *September*.			
1 3 18 8	− 8·0	+122·0	6	1928 Nov. 28	
1 9 42 18	+45·1	+147·2	11	1926 Feb. 6	64
2 5 51 57	+46·3	+ 14·0	25		
2 11 12 30	+ 8·3	+126·9	*68	1929 July 9	
2 20 16 8	+33·7	+135·2	5	1929 June 17	18

1	8 12 6	−15·0	+165·0	23	1924 Feb. 17	26
2						30
3	12 49 22	−17·0	−172·5	*47		
3	14 55 57	−10·7	+159·7	*42	1926 Sept. 17	
3	16 0 6	+34·4	+130·2	11		
3	18 45 35	+51·6	−179·0	31	1929 July 11	22
4	9 3 54	+36·5	+ 31·0	36	1927 June 5	
4	15 12 36	+36·5	− 36·0	14	1926 July 31	
4	22 16 33	−55·0	−124·0	31		15
5	14 21 24	−34·5	− 71·5	15	1929 Apr. 17	36
6	1 30 0	+72·0	− 8·5	37	1923 Sept. 10	
6	12 17 0	− 6·5	+107·5	*13	1926 Apr. 13	27
7	19 56 27	−55·0	− 27·5	16	1929 Mar. 28	
7	20 22 25	+35·0	+ 44·0	5	1926 Apr. 2	16
8	4 48 45	+35·5	+139·1	4	1929 July 28	
8	12 57 13	+21·0	+ 97·0	*111	1922 Dec. 24	
8	13 29 29	+33·5	+130·3	3†		
8	13 33 21	+33·5	+130·3	12	1929 Aug. 8	
8	14 38 41	+39·0	+ 17·5	9		13
9						28
10						24
11	10 8 16	+30·5	+ 54·5	10	1929 Jan. 21	28
12	11 24 51	+42·9	− 78·3	12		26
13						23
14	2 16 30	−66·5	+170·0	*41		
14	6 38 24	+36·1	− 3·9	29		
14	19 3 20	+46·0	−130·0	*22	1927 Mar. 28	35
15	19 56 16	+ 5·0	− 82·0	*63		19
16	13 21 35	+36·9	+139·8	10		
16	21 28 12	−16·3	+122·4	*37		
16	23 28 52	+80·5	+ 5·0	16		27
17	4 20 44	+44·5	+ 11·0	25	1929 May 27	
17	23 40 36	+16·3	− 99·0	*82		15
18	8 35 0	−10·5	+157·0	50	1928 Dec. 9	
18	9 6 9	+16·3	− 99·0	11	1929 Aug. 17	25
19	2 43 6	+24·7	+121·7	*111†		
19	2 53 27	+46·5	+ 13·0	9	1928 Nov. 16	

3	20 39 0	−31·0	− 71·0	10	1929 July 15	11
4	22 24 42	+43·0	+ 67·0	37		11
5						56
6						20
7						20
8	8 34 30	+30·2	+140·3	5	1928 Nov. 1	
8	17 10 45	+34·0	+141·5	18	1927 July 27	
8	22 54 16	+42·0	+ 36·9	9		44
9	3 28 15	+ 2·4	+ 98·8	19	1924 July 21	
9	18 57 45	+25·5	+ 98·5	13		29
10	20 22 34	−34·0	+ 57·0	*42	1929 June 6	15
11	22 18 42	+24·7	+121·7	*49†	1929 Aug. 29	4
12						44
13						26
14	0 15 36	+24·7	+121·7	16†	1929 Sept. 11	
14	2 12 0	− 8·2	+152·5	*23	1928 May 17	24
15	13 9 48	+39·0	+ 39·5	60		26
16	3 44 33	− 1·2	− 82·0	*9		
16	11 11 4	+47·1	+ 9·7	6		
16	17 19 4	+44·5	+ 11·0	20	1929 Aug. 17	37
17	19 17 25	+49·7	−132·0	*111		43
18						23
19	11 3 30	+ 8·0	+128·5	9		23
20	4 9 30	+30·5	+131·0	14	1927 Sept. 17	22
21	7 22 15	+34·4	+132·8	5		
21	18 54 11	+11·5	+126·2	16†		40
22						30
23						35
24	1 28 30	−17·0	−177·5	*21	1926 Feb. 12	
24	13 51 55	+36·5	+ 75·0	14	1928 Apr. 12	12
25						20
26	4 50 54	+19·5	−154·8	*27		
26	7 47 0	−34·5	+178·5	*23		44
27	23 16 3	+25·5	−110·5	*60	1925 Aug. 29	14
28	14 56 18	+48·0	+137·0	22		23
29						16
30	15 58 40	+34·3	+131·7	9		

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *September*—contd.			
d. h. m. s.	°	°			
30 20 13 12	+37·3	− 4·0	3	1928 Dec. 25	
30 21 35 45	+37·3	− 4·0	3	1929 Sept. 30	18
		1929 *October*.			
1					23
2 9 18 0	−54·0	− 29·6	28	1929 July 2	
2 11 6 0	−31·0	− 65·5	6	1928 June 30	
2 11 51 54	+28·7	+ 51·9	7	1929 July 16	43
3					22
4					28
5 2 34 35	−37·0	+ 77·5	*34		
5 16 59 51	+53·5	+158·5	*98	1929 Mar. 5	
5 19 0 45	+45·7	+142·0	*43		23
6 5 49 40	− 5·0	−108·0	19	1928 June 3	
6 7 51 23	+19·5	−154·8	*86	1929 Sept. 26	
6 13 12 27	−18·0	−179·5	32	1928 June 21	22
7 15 7 39	−21·5	−170·5	*37		12
8 17 15 50	−27·0	−176·0	*90		11
9 19 45 32	+33·5	+131·9	11	1928 Sept. 25	22
10 23 1 6	+41·2	+ 28·6	16	1923 Oct. 26	41
11					12
12 5 34 22	+46·4	+ 10·0	4	1927 Aug. 25	
12 6 3 9	+46·4	+ 10·0	6	1929 Oct. 12	
12 6 8 24	+46·4	+ 10·0	17	1929 Oct. 12	
12 6 50 8	+46·4	+ 10·0	3	1929 Oct. 12	
12 8 33 41	+46·4	+ 10·0	10	1929 Oct. 12	
12 8 34 12	+46·4	+ 10·0	7	1929 Oct. 12	
12 8 58 8	+46·4	+ 10·0	2	1929 Oct. 12	
12 9 57 36	+46·4	+ 10·0	16	1929 Oct. 12	21
13					14

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *November*—contd.			
d. h. m. s.	°	°			
5 10 6 4	+37·5	+ 45·5	8		
5 11 37 55	+ 9·0	+128·0	*59	1924 Sept. 27	30
6					20
7 5 22 15	+13·0	+124·7	6	1927 July 3	24
8 3 20 20	+ 3·0	− 85·0	22	1927 May 19	21
9 1 40 15	+50·0	−174·0	*47	1913 Apr. 30	23
10					31
11 7 36 15	+36·8	+ 26·5	18	1929 Mar. 27	34
12 20 7 15	−18·5	− 70·0	6		13
13 0 34 25	− 1·7	+122·7	*29	1927 Aug. 4	
13 1 29 30	+29·2	+140·5	7		17
14 15 34 48	+39·0	+ 24·8	18	1925 Mar. 17	
14 20 43 30	− 0·7	+119·7	15	1929 Jan. 7	10
15 18 50 25	+ 8·0	+143·0	*129†		28
16 13 3 36	+35·0	+ 78·0	6	1926 Aug. 6	
16 22 48 30	+27·5	+106·0	14		25
17 3 43 5	+ 6·5	+126·0	*122	1927 Apr. 16	29
18 5 40 21	+ 4·0	+128·0	*36	1929 July 24	
18 20 31 45	+44·6	− 55·9	*134†		
18 22 44 40	−27·6	− 66·3	4	1927 Feb. 16	
18 23 1 48	+44·6	− 55·9	*15†	1929 Nov. 18	30
19 2 1 18	+44·6	− 55·9	9†	1929 Nov. 18	20
20 5 54 32	+34·0	+134·8	19	1929 Oct. 26	
20 19 56 58	+27·5	+ 55·0	13	1929 Oct. 29	17
21					15
22					47
23 0 1 38	− 5·3	+136·2	*71		25
24					24
25					26
26					23
27					18

15	4	45	22	+38·0	+ 42·0	12	1926 Oct. 9	36
16	1	5	18	+39·7	+ 14·5	15		
16	20	27	24	+25·5	+ 98·5	*88	1929 Sept. 9	40
17								30
18	10	42	35	+25·5	+ 98·5	14	1929 Oct. 16	32
19	10	12	48	−23·2	− 69·0	*122†		
19	20	20	38	−23·2	− 69·0	*21†	1929 Oct. 19	19
20	16	8	17	+55·0	−160·0	*26	1924 May 6	28
21	10	33	35	−59·0	− 28·0	43		23
22	13	55	39	+19·5	+144·0	7	1922 Dec. 16	
22	18	38	30	+23·2	+120·6	20	1929 Jan. 2	
22	20	1	16	+44·5	+ 11·0	13	1929 Sept. 16	31
23	17	48	48	+37·0	+138·5	6	1926 Dec. 5	42
24	6	34	0	+22·5	+117·5	*69	1913 Jan. 8	
24	18	57	24	+32·7	+130·3	14		42
25								32
26	21	27	16	+34·0	+134·8	8	1928 July 7	17
27	16	42	57	+33·5	+ 48·0	17	1927 Nov. 15	
27	19	29	41	+29·0	+124·5	12	1923 Apr. 23	17
28								28
29	5	53	30	+27·5	+ 55·0	44	1926 Apr. 23	
29	8	57	35	+25·0	+ 51·5	10		
29	10	32	36	+27·5	+ 55·0	12	1929 Oct. 29	
29	11	48	20	+27·5	+ 55·0	15	1929 Oct. 29	
29	16	40	24	+44·6	+ 10·6	5	1929 July 28	
29	18	33	3	+26·0	+ 96·0	10	1927 Mar. 15	17
30								20
31								22

1929 *November.*

1	6	57	14	+46·0	+ 26·1	75		
1	16	3	2	+34·4	+130·2	5	1929 Aug. 3	33
2	1	32	34	+19·0	+120·5	*11	1928 Nov. 28	14
3								40
4	15	32	18	−11·2	+161·2	*26	1926 Apr. 16	
4	23	6	36	+44·2	+ 34·3	4		17
29								10
30								28

1929 *December.*

1								34
2								8
3	7	35	12	− 3·2	+135·6	*32	1929 May 7	15
4								56
5	6	29	31	+37·3	− 4·0	4	1929 Sept. 30	30
6	4	15	55	+36·1	+140·0	7	1929 Apr. 23	
6	11	37	24	−65·7	− 50·0	33		
6	16	46	38	−54·0	− 29·6	*82	1929 Oct. 2	
6	20	20	59	−54·0	− 29·6	*77	1929 Dec. 6	30
7	9	54	45	+36·0	+ 92·5	12		18
8								17
9	6	42	18	+18·4	− 94·3	14	1920 Apr. 19	
9	6	49	49	+ 4·9	+ 94·8	*106		41
10	17	55	3	+36·5	+ 70·5	10†	1929 Mar. 3	24
11	7	26	8	−21·0	− 67·0	6	1929 May 22	
11	12	43	30	+45·0	+ 14·8	8	1926 Oct. 21	32
12								30
13	4	45	12	+35·5	+ 14·5	69	1923 Sept. 18	
13	9	42	36	+28·0	+130·0	20	1928 Mar. 28	53
14								63
15	1	33	12	+63·0	− 36·0	41		
15	19	54	28	+18·0	+ 97·0	13	1921 Sept. 12	28
16	0	45	16	−56·3	+155·3	13		
16	11	25	30	− 5·7	+151·8	*43	1928 Sept. 11	21
17	10	58	30	+52·7	+171·5	*148		
17	12	12	1	+52·7	+171·5	18	1929 Dec. 17	
17	17	43	35	+52·7	+171·5	21	1929 Dec. 17	
17	21	27	18	− 6·0	+160·0	*31	1925 Mar. 25	30
18	6	58	28	+24·0	+123·0	56	1927 Mar. 15	83
19								51
20	10	27	2	+15·5	− 92·5	17	1927 May 9	
20	20	19	34	+41·5	+ 22·0	40	1929 July 3	37

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1929 *December*—contd.			
d. h. m. s.	°	°			
21					64
22					27
23					7
24 4 29 18	− 3·0	−172·0	40†		
24 15 52 42	0·0	+103·0	*10		
24 19 54 35	+37·5	+ 60·0	10		
24 22 5 27	+41·5	+ 49·0	6		43
25 0 33 18	+41·5	+ 49·0	4	1929 Dec. 24	
25 5 38 12	+46·3	+ 12·5	12		11
26					10
27 13 32 2	0·0	+125·0	33	1928 Sept. 24	21
28 1 22 48	−41·0	+148·0	21		
28 11 28 14	−56·0	+143·0	25		15
29 0 58 53	+37·5	+ 70·5	3	1929 July 10	
29 9 20 51	+54·0	+161·0	8	1927 Dec. 28	18
30					33
31 1 3 51	+11·0	+141·8	*60		
31 4 10 10	−51·0	+138·0	32		
31 4 43 30	− 5·5	+147·0	*23†	1927 Nov. 9	
31 22 9 15	− 7·0	+145·0	*19	1928 June 16	33
		1930 *January*.			
1					20
2					20
3					29
4					14
5 1 19 48	+49·7	+154·8	*80†	1929 Jan. 13	
5 18 52 23	+45·5	+149·4	*54		28
6 0 7 44	+43·5	+ 79·0	3	1928 Jan. 5	
6 23 50 0	−55·0	−131·0	12		11

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *February*—contd.			
d. h. m. s.	°	°			
5 13 28 22	+33·8	+129·5	10	1928 Aug. 22	25
6					13
7 2 40 49	+34·8	+135·7	5		
7 3 34 22	+34·8	+135·7	5	1930 Feb. 7	
7 3 34 38	+33·8	+129·5	7	1930 Feb. 5	
7 16 34 20	− 3·8	+ 98·8	*26		114
8 5 20 18	+38·5	+ 40·0	20	1915 May 19	
8 6 28 54	+39·5	+ 76·5	17		45
9					23
10					24
11 0 12 3	+34·0	+134·8	11	1929 Nov. 20	
11 (9 shocks	+34·0	+134·8	9)	1930 Feb. 11	39
12 6 21 30	−40·9	+177·1	*45	1920 Aug. 10	21
13					20
14 18 38 12	+36·0	+ 25·0	*96		
14 20 41 16	−21·5	−175·5	*56		30
15 1 23 59	+43·2	+147·2	11	1928 Oct. 31	
15 19 7 6	+28·7	+ 51·9	21	1929 Oct. 2	23
16					22
17					41
18 1 52 48	−61·0	− 25·0	*35	1926 May 26	
18 6 7 28	−15·5	+171·0	*14	1928 June 29	
18 16 59 6	− 3·0	+102·7	8		20
19					28
20 23 36 52	+37·4	+138·8	7	1929 Mar. 27	27
21					28
22 5 48 0	+37·4	+138·8	5	1930 Feb. 20	
22 11 21 46	+37·4	+138·8	6	1930 Feb. 22	
22 18 19 58	+35·7	+134·8	5	1929 June 8	34
23 10 13 48	+44·0	+146·2	9	1927 Dec. 30	
23 18 19 12	+39·0	+ 23·0	*75	1925 Apr. 12	34

7 17 27 42	+39·1	+ 71·6	9	1929 Mar. 27	6
8					25
9 19 38 38	+47·0	− 1·5	24		50
10 18 14 23	+31·0	+132·0	15	1927 May 18	
10 21 53 0	+48·0	+ 15·0	16		15
11 21 21 0	+30·2	+140·3	8	1929 Sept. 8	19
12 12			10†		31
13					41
14 22 1 19	−16·5	−171·5	*41		56
15 23 58 4	+35·0	+ 27·5	17	1929 Apr. 17	30
16 0 24 30	+32·0	−119·0	8	1918 June 21	27
17 11 10 21	−34·0	+ 57·0	*21	1929 Sept. 10	
17 16 54 30	+ 8·0	−106·3	15		21
18 7 4 7	− 5·7	+151·8	*53	1929 Dec. 16	31
19					16
20 7 11 46	− 7·0	+155·0	*23	1927 Feb. 1	13
21 3 41 57	+19·6	−106·5	6	1925 July 7	
21 18 23 55	− 8·0	+160·0	7	1925 Oct. 30	
21 22 15 2	+19·6	−106·5	6	1930 Jan. 21	42
22					13
23 10 53 50	+35·0	+ 27·5	20	1930 Jan. 15	33
24					25
25 1 38 15	+ 7·5	+126·0	*38	1929 June 4	
25 11 42 12	+36·1	+140·0	5	1929 Dec. 6	37
26 12 20 12	+17·0	+145·0	11		21
27					27
28 6 19 32	−12·0	+162·5	*19		22
29					30
30					22
31					20

1930 *February.*

1 19 4 0	+13·0	− 80·0	*18		
1 23 7 28	+36·1	+141·5	8		23
2 14 56 5	+51·7	+179·3	*83		29
3					31
4					25
5 0 30 6	+48·3	+152·0	16	1920 Apr. 11	
24 20 50 30	0·0	+122·4	*48	1929 Feb. 28	43
25 13 35 54	+45·8	+ 14·3	18		29
26 2 29 30	+31·0	−116·0	12	1926 Apr. 19	61
27 2 15 16	+ 4·0	+ 94·1	*22		
27 12 11 5	+31·0	+132·0	4	1930 Jan. 10	33
28 0 58 2	+15·2	− 45·8	*39		
28 9 31 4	+35·0	+139·5	6	1924 Mar. 5	
28 22 49 10	+25 5	+ 98·0	12	1929 June 19	67

1930 *March.*

1 5 35 9	+38·0	+ 76·5	10	1925 Dec. 7	
1 17 42 48	+35·5	+140·0	6	1928 May 31	
1 23 44 6	+31·0	−116·0	8	1930 Feb. 26	27
2 15 26 45	+25·5	+123·5	11		26
3 12 14 20	+34·0	+140·0	3	1924 Mar. 28	
3 13 4 12	+34·0	+140·0	2	1930 Mar. 3	
3 13 55 3	+34·0	+140·0	3	1930 Mar. 3	
3 18 50 32	+34·0	+140·0	6	1930 Mar. 3	
3 20 10 57	+34·0	+140·0	7	1930 Mar. 3	23
4 13 6 45	+37·5	− 11·5	5		37
5 5 13 3	+42·5	+ 19·0	11	1929 July 13	
5 23 55 54	+48·0	+ 18·0	26	1921 May 4	35
6 3 31 36	+26·5	+139·0	30†		
6 8 21 39	+34·5	+ 26·4	38		
6 9 18 30	+35·5	+ 25·0	57		
6 15 35 12	−33·2	−178·0	*67		35
7 6 41 2	+31·4	− 11·4	24		
7 10 52 8	+28·5	+131·0	*20		40
8 3 45 35	+ 9·8	− 78·0	*48		
8 19 39 36	+34·0	+139·5	6	1926 May 22	24
9 8 52 26	− 3·5	+ 72·0	14		
9 9 41 0	+40·0	+142·5	8	1929 Aug. 1	
9 10 54 34	+35·0	+139·5	8	1930 Feb. 28	37
10 16 27 30	+50·0	+149·0	85†	1928 May 8	
10 20 17 40	−18·5	+168·5	11	1927 Apr. 12	61
11 16 40 12	+39·2	+141·3	5		27
12 3 46 26	+35·0	+139·5	4	1930 Mar. 9	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *March*—contd.			
d. h. m. s.	°	°			
12 5 29 57	−18·5	+168·5	5	1930 Mar. 10	
12 19 29 30	+35·0	+139·5	7	1930 Mar. 12	67
13 8 38 12	+46·5	+102·0	6		37
14 5 19 24	+34·0	+140·0	6	1930 Mar. 3	36
15 3 56 38	+ 2·0	+126·0	9	1926 Jan. 6	
15 6 55 0	− 8·0	+105·0	*20	1928 Sept. 3	
15 9 13 30	+78·5	− 2·5	8		
15 9 33 45	+34·0	+140·0	7	1930 Mar. 14	17
16 4 59 40	+19·5	+120·0	15	1929 Mar. 20	22
17					32
18					17
19 1 16 38	+34·0	+140·0	6	1930 Mar. 15	20
20					38
21 14 24 5	+34·0	+140·0	8	1930 Mar. 19	22
22 8 50 30	+34·0	+140·0	21	1930 Mar. 21	
22 12 5 31	+35·7	+134·8	5	1930 Feb. 22	46
23 19 24 25	+26·5	+ 99·0	8	1928 Dec. 31	23
24					24
25					39
26 5 22 36	+34·0	+140·0	7	1930 Mar. 22	
26 7 12 8	− 7·8	+125·5	*113		
26 11 14 40	+36·5	+ 96·0	13		
26 11 32 11	− 7·8	+125·5	*41	1930 Mar. 26	
26 16 41 30	+34·0	+140·0	8	1930 Mar. 26	
26 19 11 48	+33·8	+132·5	5	1929 Jan. 4	
26 20 15 47	− 7·8	+125·5	*18	1930 Mar. 26	13
27 2 40 18	+45·3	+153·5	6	1928 Oct. 12	21
28					45
29 0 55 7	+39·0	+135·5	7	1926 June 29	25
30 0 26 45	+11·0	+140·0	*22		
30 5 7 23	+38·0	+135·0	5	1929 July 5	

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *April*—contd.			
d. h. m. s.	°	°			
21 10 19 12	+45·0	+152·1	*44	1921 Jan. 19	
21 11 50 56	−56·0	− 25·0	*68		
21 21 56 57	+40·5	+160·5	9	1927 Aug. 27	81
22					35
23 18 27 22	+54·0	−160·5	*22	1923 Aug. 3	
23 21 48 58	+45·5	+151·2	*99	1929 June 13	22
24 0 23 30	+44·7	+153·0	*32		20
25 9 16 8	+33·2	+131·0	5	1928 Dec. 21	
25 11 31 36	−55·7	+138·5	8		
25 12 31 50	+33·2	+131·0	6	1930 Apr. 25	
25 12 58 0	+33·2	+131·0	3	1930 Apr. 25	
25 15 4 44	+45·5	+151·2	*34	1930 Apr. 23	58
26 16 18 18	+51·7	+179·3	*112	1930 Feb. 2	96
27 1 46 44	+40·0	+ 12·5	12	1925 Sept. 24	
27 9 56 41	− 7·7	+106·5	12	1927 Sept. 8	
27 14 26 24	−33·5	+ 59·0	*63		
27 21 37 43	− 7·6	+128·3	*23†	1926 June 24	12
28 12 59 27	+32·0	+100·0	7	1919 Aug. 25	
28 18 34 41	+25·5	+ 98·0	74	1930 Feb. 28	22
29 11 33 50	−34·7	− 68·0	3	1929 May 30	32
30 16 6 4	−19·0	−177·0	*65	1929 Feb. 20	
30 23 21 20	+42·5	+ 15·5	10	1924 Apr. 11	21
		1930 *May*.			
1 0 57 47	+35·0	+142·0	*79†	1928 Dec. 21	
1 1 15 48	+35·0	+142·0	10	1930 May 1	
1 4 20 25	+35·0	+142·0	21	1930 May 1	
1 (52 shocks	—	—	52†)		47
2 1 41 30	−11·5	+168·0	*42		
2 6 1 40	−13·0	+170·0	*68		27
3 12 23 32	−13·0	+170·0	*10	1930 May 2	

30	8	26	15	−55·0	− 27·5	*46	1929 Aug. 7	
30	9	4	36	− 8·0	+105·0	4	1930 Mar. 15	
30	15	19	31	− 7·8	+125·5	*64	1930 Mar. 26	
30	20	9	26	+32·7	+131·9	9	1929 Mar. 15	22
31	12	33	55	+40·0	+ 24·0	*75	1923 Dec. 5	
31	23	45	12	+11·0	+140·0	9	1930 Mar. 30	19
					1930 *April.*			
1	14	4	36	+35·0	+139·5	8	1930 Mar. 12	31
2	4	14	35	+ 4·8	+126·0	*18	1928 June 29	
2	19	54	48	+ 4·2	+127·0	*25		33
3	6	32	58	+32·5	+ 47·0	9		
3	12	8	40	+32·5	+ 43·7	10		39
4	2	11	16	−37·0	+175·0	16	1923 Dec. 3	
4	9	25	9	− 9·0	+159·5	*24	1926 May 17	42
5	11	24	57	+55·2	+165·0	13	1924 Oct. 20	10
6								38
7	17	17	18	+42·8	+ 12·3	14	1929 Jan. 22	15
8								18
9	5	7	46	+39·7	+ 34·0	7	1928 Oct. 4	
9	5	27	49	+39·0	+ 39·5	30	1929 Sept. 15	
9	23	46	45	+36·5	+140·5	9†	1929 July 17	31
10	14	24	10	+39·5	+ 76·5	32	1930 Feb. 8	19
11								22
12								19
13								41
14								23
15	9	56	27	+28·0	+ 54·0	17		
15	10	32	2	− 2·7	+131·3	*18		38
16	13	44	54	+56·0	− 34·5	14	1927 Mar. 25	
16	14	30	44	+49·5	−130·5	23		
16	21	25	42	+38·0	+ 43·8	5		22
17	20	6	39	+37·1	+ 23·2	*81		28
18								20
19								48
20	1	43	40	−22·0	+172·0	8	1926 Sept. 4	
20	10	20	38	+39·0	+ 39·5	9	1930 Apr. 9	
20	16	22	18	−14·7	+166·0	*37		27

3	15	22	58	−13·0	+170·0	*11	1930 May 3	14
4								33
5	13	45	58	+17·3	+ 96·5	*131†		33
6	7	3	22	+37·0	+ 44·0	30		
6	22	34	27	+37·0	+ 44·0	*138	1930 May 6	55
7	4	47	46	+37·0	+ 44·0	2	1930 May 6	
7	4	58	40	+37·0	+ 44·0	3	1930 May 7	
7	5	24	24	+37·0	+ 44·0	2	1930 May 7	
7	5	42	30	+37·0	+ 44·0	4	1930 May 7	
7	9	29	30	+37·0	+ 44·0	6	1930 May 7	
7	10	58	25	+37·0	+ 44·0	3	1930 May 7	
7	11	31	42	+37·0	+ 44·0	4	1930 May 7	
7	13	47	48	+37·5	+ 45·5	11	1929 Nov. 5	
7	20	27	57	+34·0	+139·5	3	1930 Mar. 8	
7	20	41	9	+34·0	+139·5	5	1930 May 7	
7	22	42	43	+34·0	+139·5	3	1930 May 7	59
8	5	29	30	+37·5	+ 45·5	18	1930 May 7	
8	12	47	18	− 8·0	+117·2	*25		
8	13	35	0	−22·0	+174·0	*47	1929 Mar. 24	
8	14	23	32	+37·5	+ 45·5	6	1930 May 8	
8	15	5	21	+37·5	+ 45·5	13	1930 May 8	
8	15	35	24	+37·3	+ 44·8	*94		
8	22	45	2	+17·0	−112·0	8	1924 Mar. 26	
8	23	36	22	+37·3	+ 44·8	12	1930 May 8	77
9	1	43	0	+37·0	+ 44·0	6	1930 May 7	
9	2	52	36	+34·3	+139·7	7		
9	7	7	21	+34·1	+ 32·2	*63		
9	23	46	0	− 8·5	+117·5	*13		103
10	12	4	5	+33·7	+135·2	6	1929 Sept. 2	
10	21	43	22	+37·0	+ 44·0	21	1930 May 9	
10	22	11	8	+23·0	−107·0	10		
10	23	59	20	+37·0	+ 44·0	5	1930 May 10	107
11	11	30	36	+31·7	+ 77·0	10	1929 Jan. 14	
11	22	35	50	+27·5	+ 55·0	80	1929 Nov. 20	36
12	0	21	15	+27·5	+ 55·0	61	1930 May 11	
12	2	37	20	−20·6	+168·8	21	1929 Aug. 22	
12	12	26	50	+35·0	+139·5	9	1930 Apr. 1	50
13	20	14	14	+27·5	+ 55·0	13	1930 May 12	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1930 *May*—contd.			
13 23 56 32	+36·0	+139·0	8	1927 Dec. 31	147
14 0 1 19	+46·8	+ 12·3	29		
14 8 35 15	+33·6	+138·4	8	1927 Aug. 20	
14 19 32 9	+51·6	−179·0	19	1929 Aug. 3	
14 19 48 22	+25·0	+100·5	16	1925 Mar. 16	77
15 6 58 6	+36·0	+139·0	6	1930 May 13	
15 7 43 32	+36·0	+139·0	5	1930 May 15	
15 10 13 15	+36·0	+139·0	6	1930 May 15	
15 10 25 55	+36·0	+139·0	6	1930 May 15	
15 12 49 18	+36·0	+139·0	4	1930 May 15	
15 14 30 42	+36·0	+139·0	2	1930 May 15	
15 19 38 59	+35·0	+142·0	9	1930 May 1	48
16 1 43 24	+38·6	+ 15·8	6	1928 Mar. 7	
16 2 16 0	+20·0	+101·5	6	1926 Mar. 29	
16 2 41 21	+51·6	−179·0	*15	1930 May 14	
16 13 34 38	+33·6	+138·4	5	1930 May 14	
16 20 14 13	+34·9	+139·2	25		35
17 17 11 10	+36·0	+ 78·0	10		17
18 0 2 18	− 7·0	+147·0	*34†	1928 Aug. 28	
18 4 13 55	+48·6	+ 13·4	14		35
19 3 11 58	−57·6	− 27·0	25		
19 3 56 13	+35·5	+126·0	6		
19 15 3 54	+22·0	+120·5	*73	1928 Apr. 7	38
20 7 43 1	− 3·5	+146·5	*25	1929 Apr. 27	
20 11 15 3	+51·7	+179·3	*91	1930 Apr. 26	
20 22 11 23	+35·6	+140·8	9		33
21 8 8 59	+42·8	+ 12·3	14	1930 Apr. 7	
21 13 50 51	+37·0	+ 44·0	7	1930 May 10	
21 17 37 11	+34·0	+139·5	8	1930 May 7	
21 22 9 7	+41·5	− 30·5	47	1924 Aug. 28	70
22					35

T_0 (G.M.T.) d. h. m. s.	Lat. N. °	Long. E. °	Stns.	Former Occasions.	Minor Ents.
		1930 *June*—contd.			
15 21 8 11	−44·0	−118·0	*40		29
16 17 58 36	+39·8	+ 13·3	12		17
17 2 59 2	+37·0	+141·0	6	1927 Dec. 7	
17 17 2 48	+ 2·0	+126·0	4	1930 Mar. 15	
17 20 7 22	+42·5	+103·0	10		8
18 12 12 2	+37·3	+141·7	8	1929 May 7	
18 15 49 40	+43·6	−128·0	8		
18 20 45 42	+31·0	+131·8	8		
18 20 56 32	+ 8·0	+128·5	6	1930 June 11	23
19 13 7 27	− 5·6	+105·3	*46		
19 13 27 18	− 5·6	+105·3	*12	1930 June 19	34
20					31
21 9 47 29	+31·0	+131·8	10	1930 June 18	36
22 18 24 40	−45·5	− 80·5	*16		21
23 6 14 10	+35·5	+140·0	6	1930 Mar. 1	
23 19 34 35	− 5·5	+147·0	*39	1929 Dec. 31	20
24					19
25 0 49 0	+25·0	+ 77·5	8	1929 Apr. 10	
25 10 17 44	−15·3	− 75·8	*71		
25 12 6 14	+20·0	− 64·0	*38		
25 13 2 14	+44·7	+147·6	9	1925 Jan. 3	
25 21	—	—	18†		
25 21 21 45	−14·5	− 76·0	*92		56
26					54
27 5 28 20	+40·3	+ 76·3	4		30
28					21
29 0 25 12	+36·5	+140·5	8	1930 May 31	25
30					44
		1930 *July*.			
1 1 9 13	+51·5	−133·3	*43		17

23	9 48 20	+37·5	+ 45·5	33	1930 May 8	
23	16 38 12	+34·2	+139·6	*64†		
23	21 33 33	+37·5	+145·0	5		44
24	9 25 5	+37·0	+ 72·0	5	1925 June 20	
24	22 2 5	+44·6	+ 10·6	37	1929 Oct. 29	22
25						30
26						54
27	12 20 0	+37·5	+140·0	5	1928 May 20	39
28	19 31 55	+36·5	+140·5	9	1930 Apr. 9	33
29	8 30 39	+ 7·0	− 73·0	11		
29	17 14 55	+37·5	+ 45·5	37	1930 May 23	34
30	12 56 45	0·0	+125·0	14†	1929 Dec. 27	24
31	10 22 0	+49·0	−129·0	*23		
31	17 58 24	+36·5	+140·5	*65	1930 May 28	29
			1930 *June*.			
1	13 4 35	−19·0	+179·0	*62	1927 Apr. 27	59
2	1 52 9	+41·4	+ 0·3	13		28
3	18 9 20	+51·2	+148·4	*34†		
3	19 55 42	+28·5	+141·5	6	1928 Jan. 26	25
4	7 28 10	+37·9	+ 45·1	52		
4	9 50 35	− 6·5	+128·5	*80†		9
5	11 42 48	−16·5	+174·0	*80		
5	16 27 4	+25·5	+ 98·0	15	1930 Apr. 28	
5	21 58 25	+35·8	+ 30·3	26		27
6						37
7						18
8	15 45 26	+38·5	+144·5	6	1929 Mar. 31	
8	17 44 57	− 8·4	+155·8	8	1925 July 4	25
9	4 41 36	+43·5	+ 16·5	27	1923 Apr. 30	25
10						33
11	0 49 40	− 5·5	+150·0	*109		
11	10 24 0	+ 8·0	+128·5	8	1929 Sept. 19	
11	13 45 3	+23·0	+121·7	8	1928 Aug. 31	32
12	9 46 44	+42·6	−111·0	11		31
13	0 53 56	+50·5	−170·2	*73		16
14						23
15	7 33 3	−13·0	−162·8	18		

2	8 18 36	+35·7	+134·8	6	1930 Mar. 22	
2	21 3 44	+25·8	+ 90·2	*149		11
3	0 19 5	+25·8	+ 90·2	25	1930 July 2	
3	6 1 21	+25·8	+ 90·2	5	1930 July 3	42
4	13 38 22	+33·7	+135·2	4	1930 May 10	
4	16 33 43	+36·0	+141·0	8	1922 Nov. 8	
4	18 54 44	+25·8	+ 90·2	3	1930 July 3	
4	21 6 48	+44·6	+ 7·7	23	1927 Dec. 12	
4	21 34 0	+25·8	+ 90·2	6	1930 July 4	39
5	8 57 6	+37·3	+141·7	7	1930 June 18	
5	17 56 46	− 5·7	+151·8	*40	1930 Jan. 18	
5	23 11 52	+37·6	− 4·6	37		36
6						31
7	13 33 11	+13·9	− 91·2	*43	1929 July 30	
7	20 42 52	+13·9	− 91·2	6	1930 July 7	66
8	4 32 24	+25·8	+ 90·2	11	1930 July 4	
8	9 43 0	+25·8	+ 90·2	13	1930 July 8	
8	17 15 42	+28·7	+ 51·9	8	1930 Feb. 15	17
9	4 35 49	+37·0	+ 44·0	8	1930 May 21	40
10	12 34 30	+33·6	+138·4	8	1930 May 16	
10	13 0 44	+41·3	+ 14·4	17		52
11	7 6 34	+25·0	+ 93·5	23		25
12						37
13	0 59 24	+47·5	−112·0	15		
13	1 12 18	−58·0	− 67·5	32		
13	14 0 12	+25·8	+ 90·2	21	1930 July 8	
13	19 27 22	+38·1	+ 98·4	99		30
14	10 24 12	+36·2	+142·2	6	1929 June 26	
14	20 41 54	+38·0	+ 68·0	8		
14	22 40 44	+14·0	− 89·0	*101	1926 Mar. 24	● 12
15						45
16	16 28 0	+35·0	+135·5	5		26
17	14 34 44	+ 8·0	+ 94·0	*32	1927 May 17	
17	18 30 16	+15·6	− 97·8	12	1928 July 10	27
18						26
19	9 5 38	+37·5	− 0·5	5		
19	15 20 48	− 6·0	+113·0	13	1926 Nov. 19	
19	18 33 30	−32·9	− 68·3	5	1926 May 5	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *July*—contd.			
d. h. m. s.	°	°			
19 23 18 54	+42·3	+145·0	17		24
20 5 50 33	+41·5	+142·7	13	1929 Jan. 2	
20 11 6 20	+14·5	− 99·0	9		
20 11 21 15	+14·5	− 99·0	5	1930 July 20	
20 12 54 52	+14·5	− 99·0	7	1930 July 20	75
21 14 6 2	+ 7·5	+116·0	14		32
22 8 59 42	+ 7·2	+123·0	8	1928 Dec. 28	
22 19 25 58	+44·2	+147·4	*122†		30
23 0 8 43	+41·1	+ 15·4	*112		
23 5 30 38	+41·1	+ 15·4	13	1930 July 23	
23 13 53 20	+41·1	+ 15·4	28	1930 July 23	
23 18 53 16	+34·4	+105·8	11		100
24 8 18 24	+41·1	+ 15·4	10	1930 July 23	
24 12 3 37	+41·1	+ 15·4	8	1930 July 24	47
25 9 9 32	−42·5	+172·0	6	1929 Mar. 9	
25 15 51 28	+41·1	+ 15·4	9	1930 July 24	
25 19 46 33	+34·1	+ 32·2	31	1930 May 9	
25 21 34 12	+18·5	−104·5	14	1928 Apr. 27	41
26					36
27 15 1 30	+15·5	− 92·5	*16	1929 Dec. 20	
27 18 58 24	+13·9	− 91·2	*40	1930 July 7	46
28					27
29 6 24 6	+12·7	− 86·7	*32		11
30 6 41 36	+37·0	+137·0	5	1928 Feb. 7	27
31 0 7 30	+37·6	+ 72·6	7	1929 Mar. 13	
31 5 24 25	+41·1	+ 15·4	7	1930 July 25	23
		1930 *August*.			
1					51
2 16 6 9	−58·0	−135·0	*53		42
		1930 *August*—contd.			
d. h. m. s.	°	°			
25					63
26 12 39 22	+42·0	+144·4	17		22
27					42
28					25
29 8 27 40	+ 8·7	− 83·0	*34	1925 Jan. 28	
29 20 2 36	+44·2	+146·7	26†		54
30 10 3 49	− 8·5	+ 67·0	9	1929 Feb. 17	17
31 0 40 40	+33·9	−118·6	5†		
31 1 14 24	+15·5	+122·0	5	1928 Nov. 21	33
		1930 *September*.			
1 5 18 3	+25·5	+ 98·0	17	1930 Aug. 6	
1 17 43 17	+35·2	+ 81·1	45		24
2 15 51 14	+12·3	− 93·8	*7	1929 Apr. 27	
2 18 58 52	+29·4	+ 51·4	50		22
3 9 59 46	+38·1	− 1·2	6		23
4 4 17 52	+38·5	+143·0	17	1927 Aug. 29	9
5 10 13 56	+37·0	+ 72·0	12	1930 May 24	
5 16 20 38	+27·5	+ 55·0	24	1930 Aug. 23	
5 20 1 36	+34·9	+134·1	4		
5 21 23 49	+41·1	+ 15·4	7	1930 Aug. 15	17
6 21 36 5	+31·2	+ 61·6	5	1923 Nov. 29	23
7 10 56 23	+37·8	+ 25·0	7	1929 Apr. 17	15
8					27
9 15 30 54	+33·7	− 3·0	5		39
10 22 23 30	+34·0	+142·5	9	1924 Mar. 12	24
11 12 36 49	+37·5	+ 31·3	*78		
11 17 20 10	+36·5	+ 70·5	18†	1929 Dec. 10	64
12 8 18 33	+37·1	+ 23·2	25	1930 Apr. 17	
12 9 22 27	+37·1	+ 23·2	22	1930 Sept. 12	

3	22	5	51	+37·3	+ 44·8	25	1930 May 8	47
4	5	4	38	− 8·0	− 68·0	*71†		
4	12	20	30	+40·5	+ 43·8	10		
4	15	2	33	+42·4	+ 11·1	6	1921 July 5	28
5	0	11	0	+38·5	−128·5	8	1915 May 6	
5	0	22	55	+41·1	+ 15·4	14	1930 July 31	
5	23	23	0	+34·0	+ 27·0	32		19
6	7	28	30	+25·5	+ 98·0	8	1930 June 5	27
7	23	47	41	+23·2	+120·6	12	1929 Oct. 22	33
8								30
9	19	9	23	+33·6	− 6·2	33		
9	21	54	30	+33·6	− 6·2	8	1930 Aug. 9	
9	22	41	9	+39·2	+ 73·6	12		49
10	13	10	54	+34·5	+137·2	6†	1929 June 2	54
11								35
12								17
13	3	19	47	+33·6	− 6·2	5	1930 Aug. 9	
13	21	27	11	+53·5	+158·5	8	1929 Oct. 5	43
14								17
15	13	34	54	+41·1	+ 15·4	4	1930 Aug. 5	41
16	20	44	12	+45·6	+ 16·4	15	1918 Jan. 29	24
17	9	28	30	+35·2	+140·7	38		
17	12	29	32	+27·5	+ 55·0	52	1930 May 13	30
18	9	53	45	−55·0	− 27·5	*105	1930 Mar. 30	
18	19	42	11	+36·5	+141·5	16	1929 Apr. 16	43
19	12	40	22	+35·0	+139·5	10	1930 May 12	
19	17	41	36	+35·6	+140·8	23	1930 May 20	40
20	20	54	12	+24·5	+122·2	*98		29
21	1	33	5	+39·0	+ 14·5	6		
21	6	55	20	+37·0	+ 44·0	5	1930 July 9	
21	10	44	8	+41·2	+143·4	16		
21	15	6	0	+41·6	+146·9	11		29
22	0	44	54	+35·0	+ 27·5	13	1930 Jan. 23	
22	9	44	57	+44·0	+ 84·0	13		25
23	10	53	18	+27·5	+ 55·0	*87	1930 Aug. 17	
23	15	7	28	+ 3·0	+ 65·0	6	1926 Dec. 2	13
24	9	8	40	− 8·0	+157·0	*28	1926 Nov. 6	
24	10	51	20	+30·0	+100·0	15		20
12	13	33	54	+37·1	+ 23·2	8	1930 Sept. 12	42
13	17	58	58	+23·0	+ 96·0	10		
13	20	5	46	+37·1	+ 23·2	25	1930 Sept. 12	
13	23	17	20	−23·8	+172·5	22	1926 Aug. 25	27
14	3	1	0	−61·0	+150·0	36		
14	17	13	24	−14·3	+163·5	*41		24
15								39
16								36
17	3	14	43	+49·5	−130·5	11	1930 Apr. 16	
17	10	54	36	+37·9	+141·8	12		38
18								20
19	8	0	20	+34·0	+135·5	5	1929 July 3	24
20								49
21	8	34	13	−35·2	−179·5	5		
21	23	4	17	+25·5	+ 98·5	*107	1929 Oct. 18	27
22	1	31	24	−35·2	−179·5	*80	1930 Sept. 21	
22	4	54	50	+25·5	+ 98·5	18	1930 Sept. 21	
22	5	2	27	+16·0	−111·0	6		
22	7	11	27	+25·5	+ 98·5	9	1930 Sept. 22	
22	14	19	14	+25·3	+ 93·8	*85		
22	16	26	45	+38·8	+ 70·0	46	1926 June 30	65
23	10	15	21	+37·5	+ 70·5	12	1929 Dec. 29	
23	12	5	7	+27·5	+106·0	10	1929 Nov. 16	
23	20	35	38	+36·7	+ 21·0	9	1920 Dec. 10	
23	23	34	5	−25·5	− 65·5	*15		45
24	3	22	20	+32·3	+ 93·0	8		
24	7	38	2	+ 9·2	+127·5	*11		
24	12	6	51	+ 9·2	+127·5	*40	1930 Sept. 24	
24	15	47	15	+ 9·2	+127·5	5	1930 Sept. 24	
24	19	10	55	+44·6	+ 10·6	8	1930 May 24	26
25	18	6	23	−34·5	−179·2	34		
25	18	33	40	+25·5	+ 98·5	24	1930 Sept. 22	62
26	4	22	14	+13·9	− 91·2	3	1930 July 27	
26	19	55	42	+37·4	+137·9	9		41
27								18
28	5	57	51	+25·8	+128·0	9	1928 May 31	
28	9	51	51	+34·5	+139·5	15		20
29	4	52	43	+31·6	+130·6	22†		

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *September*—contd.			
d. h. m. s.	°	°			
29 9 58 42	+32·5	+ 97·5	6	1924 Jan. 26	
29 13 29 0	+26·8	+ 66·5	16		17
30 4 55 14	+36·5	+140·5	6	1930 June 29	
30 13 5 0	+ 9·0	+ 94·0	8		
30 21 20 48	− 4·5	+146·5	*104		21
		1930 *October*.			
1 2 53 17	+17·0	+122·0	29	1927 Jan. 12	31
2 0 41 30	+ 8·0	+136·2	*24		
2 10 1 18	+42·3	+142·4	22		
2 15 33 12	+35·8	+ 52·1	32		27
3 18 9 10	+ 2·0	+135·5	19		28
4					22
5 12 4 20	+35·5	+140·0	4	1930 June 23	
5 18 37 6	−18·0	+170·1	11	1920 Aug. 29	24
6 18 8 18	+37·0	+ 58·5	5	1929 July 13	38
7 2 27 20	+25·0	+ 98·5	10	1930 Sept. 25	
7 20 53 6	+35·8	+ 52·1	17	1930 Oct. 2	
7 23 27 15	+47·4	+ 10·5	42†		22
8 0 28 48	+47·4	+ 10·5	9	1930 Oct. 7	
8 10 19 21	−13·5	+169·0	*104		23
9 4 33 40	+39·3	+ 18·0	11	1929 Jan. 17	
9 4 51 36	+39·3	+ 18·0	9	1930 Oct. 9	
9 21 30 30	+21·0	+ 60·0	13		19
10 0 37 18	+25·5	+ 98·5	32	1930 Oct. 7	18
11 3 6 22	+72·5	− 12·0	61	1927 Nov. 19	22
12 8 57 52	+35·0	+142·0	8	1930 May 15	
12 15 6 43	+39·3	+ 69·7	9†		45
13					28
14					24
15 22 19 7	+47·7	+ 7·6	12		58

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *October*—contd.			
d. h. m. s.	°	°			
30 10 35 58	+43·6	+ 13·5	7	1930 Oct. 30	
30 10 41 47	+43·6	+ 13·5	3	1930 Oct. 30	
30 10 56 36	+43·6	+ 13·5	5	1930 Oct. 30	
30 11 0 44	+43·6	+ 13·5	1	1930 Oct. 30	
30 11 6 0	+43·6	+ 13·5	1	1930 Oct. 30	
30 11 34 10	+43·6	+ 13·5	3	1930 Oct. 30	
30 12 13 44	+43·6	+ 13·5	2	1930 Oct. 30	
30 13 12 20	+43·6	+ 13·5	5	1930 Oct. 30	
30 13 23 47	+43·6	+ 13·5	1	1930 Oct. 30	
30 13 40 59	+43·6	+ 13·5	2	1930 Oct. 30	
30 13 47 10	+43·6	+ 13·5	3	1930 Oct. 30	
30 13 49 56	+43·6	+ 13·5	3	1930 Oct. 30	
30 16 11 22	+43·6	+ 13·5	4	1930 Oct. 30	
30 16 30 26	+43·6	+ 13·5	3	1930 Oct. 30	
30 17 0 38	+43·6	+ 13·5	6	1930 Oct. 30	
30 17 3 31	+43·6	+ 13·5	5	1930 Oct. 30	
30 22 0 50	+43·6	+ 13·5	2	1930 Oct. 30	
30 23 56 32	+43·6	+ 13·5	3	1930 Oct. 30	49
31 10 24 6	−11·0	+162·3	*42		
31 21 32 0	+42·5	+ 71·0	3		
31 21 35 20	+42·5	+ 71·0	4	1930 Oct. 31	
31 23 16 43	+55·3	+ 12·8	6		103
		1930 *November*.			
1 8 40 54	+43·6	+ 13·5	5	1930 Oct. 30	
1 8 48 56	+43·6	+ 13·5	5	1930 Nov. 1	
1 9 40 41	+43·6	+ 13·5	5	1930 Nov. 1	
1 9 50 11	+43·6	+ 13·5	4	1930 Nov. 1	
1 10 19 46	+43·6	+ 13·5	6	1930 Nov. 1	
1 17 21 0	+43·6	+ 13·5	2	1930 Nov. 1	
1 19 55 35	+43·6	+ 13·5	6	1930 Nov. 1	

16	20	46	12	−14·5	+175·0	*14		
16	21	32	29	+36·3	+136·3	23		
16	21	36	3	+36·3	+136·3	37	1930 Oct. 16	20
17	1	29	50	+13·0	−105·0	7		
17	8	46	37	−32·0	− 71·0	*76		
17	17	15	42	+43·8	+ 15·7	11	1928 Feb. 11	23
18	1	2	20	+29·4	+ 51·4	6	1930 Sept. 2	
18	4	23	8	+36·3	+136·3	5	1930 Oct. 16	14
19	2	43	3	+35·0	− 5·0	5	1926 Oct. 15	
19	11	4	45	+51·8	−171·0	10		34
20	2	7	47	+36·3	+136·3	4	1930 Oct. 18	20
21	5	25	24	+33·1	+132·3	8		
21	19	5	54	+36·5	− 23·5	21		11
22	18	6	5	− 5·7	+151·8	*24	1930 July 5	21
23	8	56	0	−14·5	−179·5	*44		37
24	0	51	37	+44·5	+ 11·0	22	1929 Oct. 22	
24	10	47	16	+10·3	+ 42·7	25		
24	20	15	11	+18·3	+146·8	*161		
24	22	21	57	+36·2	+139·6	8		32
25	12	3	18	+61·7	−154·2	*46		
25	16	28	46	+11·5	+ 42·0	11	1929 May 18	
25	17	41	55	+11·5	+ 42·0	8	1930 Oct. 25	
25	23	34	25	+37·9	+ 45·1	17	1930 June 4	41
26	7	14	14	+44·5	+ 11·0	28	1930 Oct. 24	
26	7	30	42	+44·5	+ 11·0	26	1930 Oct. 26	
26	13	45	9	+34·0	+135·5	7	1930 Sept. 19	29
27	23	28	41	+11·5	+ 43·5	22	1929 Jan. 22	38
28	21	10	22	+18·3	+146·8	*96	1930 Oct. 24	22
29	12	29	36	+19·0	+149·0	5		
29	14	27	19	+34·2	+135·2	6		27
30	7	13	13	+43·6	+ 13·5	92	1928 May 30	
30	7	34	20	+43·6	+ 13·5	1	1930 Oct. 30	
30	7	49	6	+43·6	+ 13·5	4	1930 Oct. 30	
30	8	12	40	+43·6	+ 13·5	29	1930 Oct. 30	
30	8	29	10	+43·6	+ 13·5	6	1930 Oct. 30	
30	8	44	10	+43·6	+ 13·5	3	1930 Oct. 30	
30	9	5	4	+43·6	+ 13·5	6	1930 Oct. 30	
30	10	13	10	+43·6	+ 13·5	5	1930 Oct. 30	

1	22	9	11	+43·6	+ 13·5	15	1930 Nov. 1	57
2	0	37	35	+43·6	+ 13·5	1	1930 Nov. 1	
2	1	27	20	+43·6	+ 13·5	4	1930 Nov. 2	
2	3	20	53	+43·6	+ 13·5	4	1930 Nov. 2	
2	5	22	20	+43·6	+ 13·5	4	1930 Nov. 2	
2	5	25	13	+43·6	+ 13·5	5	1930 Nov. 2	
2	8	18	24	+43·6	+ 13·5	9	1930 Nov. 2	
2	10	5	6	+43·6	+ 13·5	3	1930 Nov. 2	
2	16	38	8	+54·0	−160·5	*12	1930 Apr. 23	36
3	18	36	50	− 3·5	+149·5	*26		22
4	4	32	33	+22·5	+120·5	5		
4	15	38	2	+24·3	+ 97·9	25		17
5								18
6								26
7	5	56	52	+42·0	+ 42·0	16		14
8	3	22	39	+ 3·5	+122·5	*69†		
8	4	1	57	+33·7	+135·2	6	1930 July 4	38
9	19	8	42	− 0·7	+131·8	*125		45
10	8	30	33	− 0·7	+131·8	5	1930 Nov. 9	
10	13	35	36	+36·3	+141·2	9		
10	13	44	12	− 2·5	+138·0	*88	1917 May 23	22
11	8	29	45	+24·5	+122·2	*29	1930 Aug. 20	50
12	6	7	3	+44·5	+ 11·5	13	1928 June 9	
12	19	10	16	+50·7	−168·8	*31		34
13	23	5	3	− 0·7	+131·8	17	1930 Nov. 10	15
14								18
15	0	52	52	+19·5	+146·5	10		38
16	20	46	30	+34·1	+ 32·2	10	1930 July 25	41
17	12	3	33	− 2·0	+152·3	*30		
17	15	15	46	+35·0	+132·5	9	1926 Dec. 1	16
18								35
19	1	9	35	+36·5	+140·5	4	1930 Sept. 30	19
20	6	56	11	+43·6	+ 13·5	14	1930 Nov. 2	36
21	2	0	30	+40·0	+ 19·5	80		
21	4	1	24	+40·0	+ 19·5	13	1930 Nov. 2	
21	9	49	58	+35·1	+139·0	6		
21	10	16	56	+35·1	+139·0	4	1930 Nov. 21	
21	12	17	33	+35·1	+139·0	6	1930 Nov. 21	

CATALOGUE OF EARTHQUAKES, 1925–1930—*contd.*

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *November*—contd.			
d. h. m. s.	°	°			
21 12 55 50	+35·1	+139·0	4	1930 Nov. 21	26
22 0 25 50	+40·0	+ 19·5	7	1930 Nov. 21	
22 13 56 52	−27·5	−176·8	*26	1928 Dec. 12	24
23 15 53 36	−14·5	+ 64·0	7		26
24 6 6 48	− 2·0	− 74·5	*23		
24 6 45 44	+34·0	+135·5	7	1930 Oct. 26	
24 19 43 13	+47·0	+ 13·2	6	1927 Jan. 18	67
25 6 26 37	+35·1	+139·0	6	1930 Nov. 21	
25 7 5 57	+35·1	+139·0	8	1930 Nov. 25	
25 7 50 18	+35·1	+139·0	6	1930 Nov. 25	
25 9 34 22	+35·1	+139·0	3	1930 Nov. 25	
25 12 13 30	+35·1	+139·0	3	1930 Nov. 25	
25 14 23 21	+35·1	+139·0	6	1930 Nov. 25	
25 19 2 55	+35·1	+139·0	*162	1930 Nov. 25	
25 19 29 13	+35·1	+139·0	3	1930 Nov. 25	
25 19 46 20	+35·1	+139·0	3	1930 Nov. 25	59
26 1 6 36	+35·1	+139·0	6	1930 Nov. 25	
26 4 52 17	+35·1	+139·0	7	1930 Nov. 26	
26 8 42 36	+35·1	+139·0	6	1930 Nov. 26	
26 12 41 48	+35·1	+139·0	3	1930 Nov. 26	
26 15 9 54	+11·0	+135·0	7		35
27					12
28 7 32 57	+18·5	−107·0	*43		32
29					18
30 0 35 0	+36·0	+ 86·0	10		
30 21 30 46	+18·5	−107·0	28	1930 Nov. 28	24
		1930 *December*.			
1					31
2 4 21 38	+41·9	+143·7	10		

T_0 (G.M.T.)	Lat. N.	Long. E.	Stns.	Former Occasions.	Minor Ents.
		1930 *December*—contd.			
d. h. m. s.	°	°			
11 7 51 40	+41·0	+ 16·0	10	1928 Oct. 17	24
12 2 53 12	+25·0	+100·5	13	1930 Dec. 9	
12 13 54 28	+32·9	+130·8	3	1929 Feb. 9	
12 16 2 0	+32·9	+130·8	6	1930 Dec. 12	
12 19 43 0	+32·9	+130·8	5	1930 Dec. 12	52
13 2 35 27	−61·0	+148·0	8		
13 14 22 53	+42·3	+142·4	*44†	1930 Oct. 2	
13 16 28 27	+ 8·0	+ 94·0	16	1930 July 17	16
14					50
15 5 22 12	+35·6	+140·8	5	1930 Aug. 19	
15 15 59 34	+23·2	+120·6	11	1930 Dec. 8	16
16 8 19 25	+36·0	+ 71·0	11		
16 19 50 1	+35·1	+139·0	6	1930 Dec. 7	44
17					25
18					31
19					10
20 14 2 32	+34·8	+132·9	29		
20 14 23 9	+34·8	+132·9	6	1930 Dec. 20	
20 14 43 11	+34·8	+132·9	18	1930 Dec. 20	
20 23 26 49	+34·8	+132·9	9	1930 Dec. 20	22
21 12 14 33	+34·8	+132·9	30	1930 Dec. 20	
21 12 18 0	+34·8	+132·9	10	1930 Dec. 21	
21 13 9 30	+34·8	+132·9	8	1930 Dec. 21	
21 13 17 2	+34·8	+132·9	8	1930 Dec. 21	
21 14 9 43	+34·8	+132·9	5	1930 Dec. 21	
21 14 51 32	+20·4	+122·2	*108†		
21 16 30 31	+34·8	+132·9	8	1930 Dec. 21	
21 17 38 19	+34·8	+132·9	8	1930 Dec. 21	
21 20 48 8	+34·8	+132·9	7	1930 Dec. 21	
21 23 51 53	+23·5	+120·9	29		37
22 0 8 21	+23·6	+120·2	*30		

2	7	1	26	+25·5	+ 98·5	53	1930 Oct. 10	
2	13	28	51	+40·0	+ 19·5	30	1930 Nov. 22	27
3	15	42	14	+15·0	+ 97·0	6		
3	16	36	20	+17·3	+ 96·5	10	1930 May 5	
3	18	51	51	+18·2	+ 96·4	*140		20
4	4	16	51	+35·0	+135·5	5	1930 July 16	
4	6	18	39	+23·0	+ 97·0	8	1926 Nov. 21	29
5	5	56	48	+33·5	+ 46·5	6	1927 Nov. 12	
5	19	6	54	+41·7	+141·6	10		
5	20	31	51	+34·4	+134·8	17		23
6	7	3	21	+51·2	−172·0	*40	1929 July 11	29
7	4	2	0	+35·1	+139·0	3	1930 Nov. 26	
7	5	50	28	+35·1	+139·0	6	1930 Dec. 7	
7	6	5	50	+36·5	+141·5	7	1930 Aug. 18	40
7	7	12	40	+35·1	+139·0	3	1930 Dec. 7	
7	13	35	21	+35·1	+139·0	3	1930 Dec. 7	
7	15	34	24	+35·1	+139·0	3	1930 Dec. 7	
8	6	20	4	+23·2	+120·6	33	1930 Aug. 7	
8	8	1	5	+23·2	+120·6	*59	1930 Dec. 8	
8	17	21	20	−29·0	−174·0	*41	1928 Nov. 29	37
9	0	27	30	+25·0	+100·5	5	1930 May 14	
9	19	16	6	+19·5	−104·5	13		48
10	10	31	30	+39·5	+ 39·4	67		27

22	3	23	27	+35·0	+132·5	8	1930 Nov. 17	
22	4	19	50	+23·2	+120·6	22	1930 Dec. 15	
22	23	7	8	+35·0	+132·5	5	1930 Dec. 22	32
23	2	9	21	+35·0	+132·5	6	1930 Dec. 22	
23	4	6	42	+35·0	+132·5	6	1930 Dec. 23	
23	5	20	31	+23·6	+120·2	8	1930 Dec. 22	
23	7	32	21	+28·5	+140·5	5	1929 Apr. 10	
23	10	46	42	+35·0	+132·5	8	1930 Dec. 23	
23	21	35	36	− 1·3	+143·4	*28	1927 May 13	
23	23	55	8	+43·1	+143·4	30†	1929 Mar. 11	15
24	6	2	50	−25·0	− 66·0	20		
24	14	27	43	+34·5	− 4·0	6	1927 Sept. 12	21
25	12					10†		
25	13	7	24	−33·0	− 11·0	*28		
25	13	49	16	+42·1	+ 69·3	3		
25	23					11†		24
26								15
27								21
28								14
29	20	57	4	+35·5	+140·0	5	1930 Oct. 5	17
30								36
31	20	15	3	− 3·0	+143·5	*13	1929 Mar. 31	16

NOTES TO 1925.

Jan. 28d. 18h. Focal depth +0·010. See shock 30d. 17h. Should the T_0 be increased by 30s. ?

Feb. 9d. 5h. Residuals suggest an origin further N.

Feb. 9d. 14h. See note in Summary, p. 43.

Feb. 10d. 8h. 10h. 12h. 21h. Epicentre −21·0° +171·5° was computed, but the old epicentre was retained.

Feb. 18d. 11h. An alternative solution is given.

Mar. 1d. 2h. Focal depth +0·010. Felt in Canada and the Eastern States. See papers by E. A. Hodgson, also *Jour. Roy. Astron. Soc. Canada*, 1928, October.

Mar. 16d. 10h. Note in *Bull. Volcan.* nos. 9 and 10 (1926), p. 226.

Mar. 16d. 14h. Many large negative residuals, especially in S. near $\triangle=30°$.

Mar. 25d. 12h. Should T_0 be increased by 30s. ?

Apr. 12d. 19h. An alternative solution is given.

Apr. 16d. 19h. There are a number of records 29m. later than T_0, which may belong to another shock.

Apr. 25d. 13h. It seems possible that this may be two shocks.

Apr. 26d. 8h. An alternative solution is given with *high* focus −0·030.

May 5d. 18h. See *Bull. Seis. Soc. Amer.*, vol. xvii, no. 3, p. 147.

May 23d. 2h. See investigation by K. Suda, *Seis. Bull. Imp. Marine Obs. and Kobe Meteor Obs., Kobe, Japan*, vol. i, no. 3, Oct. 1925 ; also T. Matuzama's paper in *Bull. Equake. Res. Inst., Tokyo*, vol. v.

May 27d. 20h. There is some evidence of this being a double shock.

June 21d. 3h. An origin −0·5° would fit the records better.

June 28d. 1h. See investigations by P. Byerly, *Bull. Seis. Soc. Amer.*, vol. xvi, no. 4, 1926.

July 7d. 8h. The effect of this shock is masked by the one following.

Aug. 11d. 17h. +2°−12° would suit some stations better.

Aug. 12d. 6h. Note on possible *high* focus.

Aug. 26d. 16h. D should read +0·995 and E +0·105.

Sept. 11d. 4h. 6h. 9h. De Bilt gives +45·2° +14·7° for shock I. and +45·0° +14·9° for shock II. III. is entered tentatively.

Sept. 14d. 9h. Several assumptions of an error of 1 min. must be made if this is to be regarded as a repetition of Sept. 1d.

Sept. 24d. 13h. Some readings suggest at least two shocks, separated by about 20s.

Sept. 25d. 8h. The position −5·6°+102·3° deduced from the residuals would suit the observed times better.

Sept. 29d. 17h. Note and alternative solution given, the alternative gives +0·005 deep focus.

Oct. 13d. 17h. Focal depth +0·005. See note in Summary, p. 266.

Oct. 25d. 4h. It is not easy to reconcile the observations.

Oct. 30d. 11h. Alternative epicentre given.

Nov. 13d. 12h. Some stations indicate a T_0 about 20s. earlier : see note to Nov. 14d. (8h. 10h. 14h.).

Nov. 14d. 8h. 10h. 14h. All three shocks, stations within 45°, indicate T_0 about 20s. earlier. See shock Nov. 13d. 12h.

Nov. 16d. 11h. Some indication of a focal depth.

Dec. 6d. 16h. Probably a double shock. See note in the Summary, p. 305.

Dec. 10d. 16h. 20h. Only the earliest record, which may be P, is given for each station.

Dec. 18d. 18h. Focal depth +0·030. See note in Summary, p. 310.

Deep focus has also been applied to the following quakes :

Jan. 30d. 17h. +0·010. Mar. 8d. 11h. +0·030. Mar. 15d. 13h. and 15h. +0·015. Mar. 21d. 15h. +0·010. Mar. 26d. 10h. +0·040. Mar. 29d. 21h. +0·010. Apr. 19d. 15h. +0·045. May 14d. 7h. +0·020. May 15d. 18h. +0·050. May 27d. 2h. +0·050. June 7d. 23h. +0·045. June 20d. 13h. +0·040. June 23d. 16h. +0·025. Sept. 23d. 20h. +0·020. Oct. 5d. 4h. +0·020. Oct. 20d. 9h. +0·050.

A list of readings from Hukuoka received too late, will be found on p. 323.

Notes to 1926.

Jan. 1d. 21h. Felt by S.S. *Essequito* in Lat. 23° 26′ S., Long. 70° 40·5′ W.
Feb. 1d. 1h. Focal depth +0·025. See note in Summary, p. 27.
Feb. 7d. 2h. Focal depth +0·040. Alternative solution.
Feb. 8d. 15h. See note to Feb. 15d. 2 h. in Summary, p. 44.
Feb. 9d. 0h. Focal depth +0·090. See note in Summary, p. 38.
Feb. 15d. 2h. Focal depth +0·015. See note in Summary, p. 44.
Mar. 7d. 20h. An alternative solution.
Mar. 18d. 14h. This may be two shocks.
Mar. 25d. 19h. An alternative solution with focal depth +0·020 is given.
May 20d. 7h. Suggested by Batavia. But +5·5°+124·5° as on 1918. Sept. 5d. would suit the records better.
June 5d. 9h. Focal depth +0·035. See note in Summary, p. 137.
June 19d. 11h. Epicentre given in *U.S. Coast and Geodetic Survey Report*, p. 55; but most stations would be better suited by an epicentre further E., as on 1925 Sept. 10d.
June 20d. 6h. Focal depth +0·020. See note in Summary, p. 149.
June 24d. 21h. Focal depth +0·020. An alternative solution given with focal depth +0·030.
June 26d. 19h. See note in Summary, p. 155.
June 29d. 14h. Focal depth +0·020. See note in Summary, p. 167.
June 29d. 18h. Epicentre given by *U.S. Coast and Geodetic Survey Report*, p. 56.
July 26d. 18h. Focal depth +0·050. See notes in Summary, pp. 177, 211.
July 30d. 13h. See paper by H. Jeffreys in *Geophy. Supp. M.N.R.A.S.*, vol. i, p. 484, June 1927.
Aug. 5d. 2h. See note in Summary, p. 225.
Aug. 6d. 16h. See note in Summary, p. 234.
Aug. 9d. 3h. Large negative residuals near △=35·0° are noteworthy.
Aug. 15d. 3h. See paper by H. Jeffreys in *Geophy. Supp. M.N.R.A.S.*, vol. i, p. 489, June 1927.
Sept. 7d. 12h. Focal depth +0·020. See note in Summary, p. 279.
Sept. 9d. 17h. See note in Summary, p. 281.
Sept. 16d. 17h. Focal depth +0·020. See note in Summary, p. 293.
Sept. 19d. 20h. See note to 9d. 17h.; difficulties are here increased by a local European shock; three alternative solutions are given.
Sept. 30d. 5h. Focal depth +0·080. See note in Summary, p. 308.
Oct. 3d. 19h. A long series of [P] is noteworthy.
Oct. 8d. 19h. See note in Summary, p. 324.
Oct. 22d. 12h. See *Bull. Seis. Soc. Amer.*, vol. xviii, no. 3, p. 153; paper by G. D. Mitchell.
Nov. 5d. 7h. Focal depth +0·020. See note in Summary, p. 373.
Dec. 9d. 12h. See note in Summary, p. 397.
Dec. 10d. 8h. Several stations suggest a change of T_0 to about 20s. later.
Dec. 16d. 0h. See note in Summary, p. 401.
Dec. 18d. 14h. See note in Summary, p. 406.
Dec. 20d. 10h. See note in Summary, p. 408.
Dec. 25d. 15h. See note in Summary, p. 412.

Deep focus has also been applied to the following quakes:

Jan. 15d. 14h. +0·060. Mar. 16d. 17h. +0·020. Apr. 1d. 16h. +0·045. Apr. 13d. 2h. +0·020. May 26d. 9h. +0·020. Sept. 10d. 10h. +0·013. Sept. 10d. 19h. +0·030. Sept. 11d. 12h. +0·013. Sept. 17d. 1h. 2h. 5h. +0·020. Sept. 29d. 12h. +0·040. Oct. 30d. 13h. +0·070. Nov. 6d. 9h. +0·015. Nov. 6d. 9h. 53m. +0·015.

A list of readings for Kew received too late, will be found on pp. 416–426 in the Summary.

Notes to 1927.

Jan. 11d. 19h. For La Paz △ read 9·9°.
Jan. 12d. 0h. A revised epicentre +15·0°+119·7° was issued separately in the Summary.

Jan. 12d. 21h. See note in Summary, p. 11.

Jan. 15d. 14h. Focal depth +0·060, paper by K. Wadati in *Geophy. Mag. Tokyo*, vol. ii, no. 1, p. 10, 1929 March.

Jan. 21d. 8h. See note in Summary, p. 17.

Mar. 3d. 1h. See special note about P[S] on p. 64 in the Summary by H. H. Turner.

Mar. 7d. 9h. See paper in *Bull. Equake. Res. Inst. Tokyo*, vol. iv, p. 179 (1928), by A. Imamura, also paper by E. A. Hodgson, *Bull. Seis. Soc. Amer.*, vol. xxii, no. 4 (1932).

Apr. 1d. 19h. Focal depth +0·070. See note in Summary, p. 117.

Apr. 14d. 6h. Focal depth +0·015. See *Bol. d. Serv. Sismol. de la Univ. di Chile*, vol. xix, 1927, paper by P. Loos.

Apr. 28d. 2h. Focal depth +0·025. See note in Summary, p. 147.

May 17d. 21h. Focal depth +0·060. See note in Summary, p. 173.

May 22d. 1h. The residuals suggest a focus rather deeper than normal.

May 22d. 21h. Focal *height* −0·005.

May 22d. 22h. Focal *height* −0·005. See note in Summary, p. 185.

May 23d. 2h. Focal *height* −0·005.

May 23d. 13h. An alternative solution given with focal *height* −0·005.

May 23d. 23h. 'Notes de Seismologie' of the Observatoire de Zi-ka-wei, No. 9, paper by P. E. Gherzi ; see note in Summary, p. 190.

May 24d. 11h. See note in Summary, p. 192.

May 28d. 17h. See *Bull. Seis. Soc. Amer.*, Sept. 1927, paper by P. Byerly.

June 1d. 10h. 9m. Should read 19h. 9m.

June 5d. 17h. See note in Summary, p. 206.

June 20d. 14h. A slight depth of focus is probable.

July 12d. 21h. Focal depth +0·015. See note in Summary, p. 250.

July 15d. 3h. Focal depth +0·030. See note in Summary, p. 253.

July 22d. 20h. An alternative solution is given.

Aug. 8d. 18h. See note in Summary, p. 294.

Aug. 12d. 0h. Focal depth +0·090. See note in Summary, p. 302.

Aug. 20d. 23h. See note in Summary, p. 315.

Aug. 24d. 8h. See paper by T. Matuzawa in *Bull. Equake Res. Inst. Tokyo*, vol. vi, 1929.

Sept. 23d. 13h. Focal depth +0·005. See note in Summary, p. 360.

Oct. 12d. 7h. *For* 24·0° N. *read* 25·0° N. in Summary, p. 383.

Oct. 27d. 1h. Paper by T. Matuzawa in *Bull. Equake. Res. Inst. Tokyo*, vol. v, 1928 Aug.

Nov. 16d. 21h. Focal depth +0·020. See note in Summary, p. 432.

Nov. 19d. 7h. Focal depth +0·060. See note in Summary, p. 438.

Nov. 19d. 23h. Paper by A. E. Mourant in *Geophy. Supp. M.N.R.A.S.*, vol. ii, no. 7.

Dec. 18d. 19h. See note in Summary, p. 461.

Dec. 30d. 12h. See note in Summary, p. 470.

Dec. 31d. 5h. Papers in *Geophy. Mag. Tokyo*, vol. ii, no. 1, and *Bull. Equake. Res. Inst. Tokyo*, vol. vii, pt. 2.

Deep focus has also been applied to the following quakes :

Jan. 20d. 10h. +0·010. Feb. 1d. 17h. +0·020. Apr. 3d. 13h. +0·015. Apr. 6d. 18h., 19h. 4m., 19h. 15m., and 20h. +0·080. Apr. 9d. 16h. +0·010. Apr. 13d. 13h. and 14h. +0·020. Apr. 17d. 9h. +0·020. Apr. 19d. 17h. +0·010. Apr. 24d. 11h. +0·020. May 2d. 11h. +0·015. June 3d. 7h. +0·025. June 18d. 2h. +0·050. July 4d. 13h. +0·050. Aug. 1d. 11h. +0·050. Aug. 8d. 0h. +0·020. Aug. 24d. 18h. +0·015. Sept. 3d. 19h. +0·005. Sept. 30d. 10h. +0·015. Oct. 2d. 3h. +0·030. Nov. 6d. 15h. +0·030. Nov. 9d. 1h. +0·040. Nov. 15d. 8h. +0·010. Nov. 17d. 20h. +0·025. Nov. 17d. 22h. +0·020. Nov. 26d. 12h. +0·030.

Notes to 1928.

Jan. 5d. 21h. Focal depth +0·080. See note in Summary, p. 8.

Jan. 6d. 19h. Focal *height* −0·015.

Jan. 10d. 2h. Focal *height* −0·015.

Mar. 20d. 2h. Focal *height* −0·005.

Mar. 21d. 3h. Focal *height* −0·005. An alternative solution given without focal depth.

Mar. 27d. 8h. Paper by A. Cavasino, see *Boll. della Soc. Sismol. Ital.*, vol. xxviii, fasc. 3–4 (1928–1929).

Mar. 29d. 5h. Focal depth +0·060. See note in Summary, p. 96.

Apr. 13d. 23h. Read G= −0·030.

Apr. 18d. 19h. A revised epicentre +41·8°+25·0° was issued after receiving a publication in the Bulgarian language, dealing with earthquakes 1928–1931; this epicentre was printed separately and sent out with the *I.S.S.* 1928, July–Sept. quarter.

May 8d. 4h. Focal depth +0·070. See note in Summary, p. 154.

May 16d. 7h. An alternative solution.

July 8d. 11h. Read G= −0·030.

Aug. 15d. 17h. Focal depth +0·080. See note in Summary, p. 285.

Aug. 16d. 3h. Focal depth +0·070. See note in Summary, p. 286.

Aug. 24d. 21h. Focal depth +0·040. See note in Summary, p. 298.

Aug. 30d. 20h. Paper by W. Hilber, 'Die Herdform des Schwabischen Bebens am 30 Aug., 1928.'

Sept. 2d. 16h. See note in Summary, p. 311.

Oct. 25d. 12h. Phases confused with next earthquake (12h. 36m. 9s.). See note in Summary.

Nov. 29d. 17h. Read 29·0° S.

Dec. 13d. 19h. Paper by B. Gutenburg; see Gerland's *Beit. zur Geophy.* (1929, Bd. 23, S. 22–32) *Das Rheinlandbeben von* 13 *Dez.* 1928.

Dec. 14d. 1h. Read 1h. 58m. 24s.

Deep focus has also been applied to the following quakes:

Feb. 18d. 14h. +0·015. Mar. 13d. 18h. +0·015. Apr. 16d. 19h. +0·005. May 26d. 8h. +0·020. June 7d. 6h. +0·070. Aug. 10d. 15h. +0·035. Aug. 12d. 8h. +0·030. Aug. 23d. 1h. +0·070. Sept. 7d. 2h. +0·020. Sept. 21d. 13h. +0·040. Oct. 21d. 16h. +0·015. Dec. 19d. 15h. +0·040.

Notes to 1929.

Jan. 24d. 20h. Felt by S.S. *Manhattan* at 12° 50′ N., 91° 2′ W.

Mar. 7d. 1h. Focal depth +0·010. See note in Summary, pp. 86–7.

Jan. and Feb. Late readings from Karlsruhe given in Summary, p. 125.

May 15d. 23h. An alternative solution.

June 4d. 7h. See note in Summary, p. 226.

June 17d. With epicentre −41·8°+172·2°. Christchurch gives 33 S phases and Wellington 233 phases, either iP, iS, or i; these two stations give repetitions to the end of the month.

Aug 8d. 13h. 29m., 13h. 33m. Both epicentres from *Geophy. Mag. Tokyo*, vol. iv, no. 4.

June 27d. 12h. Paper by E. Tams in *Zeitschrift für Geophysik*, vol. iv, no. 8.

Nov. 18d. 20h., 23h. and 19d. 2h. Epicentre given is +44·55° −55·95°; this has been contracted to +44·6° −55·9°. See Summary, p. 474.

Dec. 24d. 4h. See note in Summary, p. 509.

Deep focus has also been applied to the following quakes:

Jan. 13d. 0h. +0·015. Feb. 1d. 17h. +0·025. Feb. 26d. 9h. +0·005. Mar. 3d. 3h. +0·035. Mar. 7d. 5h. +0·010. Mar. 10d. 14h. +0·025. Mar. 17d. 12h. +0·050. Apr. 8d. 10h. +0·090. Apr. 17d. 18h. +0·015. May 25d. 11h. +0·040. June 1d. 7h. +0·025. June 2d. 21h. +0·050. June 4d. 15h. +0·060. June 12d. 11h. +0·020. July 17d. 10h. +0·015. July 26d. 22h. +0·010. Aug. 19d. 2h. +0·010. Aug. 19d. 20h. +0·010. Aug. 20d. 16h. +0·010. Aug. 29d. 19h. +0·010. Sept. 3d. 12h. +0·020. Sept. 11d. 22h. +0·010. Sept. 14d. 0h. +0·010. Sept. 21d. 18h. +0·020. Oct. 19d. 10h. +0·015. Oct. 19d. 20h. +0·015. Nov. 15d. 18h. +0·010. Dec. 10d. 17h. +0·025. Dec. 31d. 4h. +0·020.

A list of readings for Karlsruhe, received too late, will be found on p. 125.

NOTES TO 1930.

Jan. 12d. 12h. European shock with no definite determination.
May 1d. 0h. G—·454 *read* G—·452.
May 1d. Local shock recorded at Tyosi, probably +35·0° +142·0°.
May 5d. 13h. See *Geol. Survey of India*, vol. lxv, pt. 2.
June 3d. 18h. Focal depth +0·065. T_0 should read 18h. 9m. 20s.
June 25d. 21h. An indeterminate shock recorded by European stations.
Aug. 31d. See paper in *Bull. Seis. Soc. Amer.*, vol. xxii, no. 2, p. 138.
Oct. 7d. 23h. See *Geophy. Supp. M.N.R.A.S.*, vol. iii, no. 3, p. 138.
Oct. 12d. 15h. *For* 37·3° N. *read* 39·3° N. in Summary, p. 325.
Dec. 25d. 12h. A local European shock giving no definite determination.
Dec. 25d. 23h. A local European shock distinct from that at 12h.
Deep focus has also been applied to the following quakes :

Jan. 5d. 1h. +0·015. Mar. 6d. 3h. +0·060. Mar. 10d. 16h. +0·090. Apr. 9d. 23h. +0·015. Apr. 27d. 21h. +0·020. May 18d. 0h. +0·015. May 23d. 16h. +0·015. May 30d. 12h. +0·040. June 4d. 9h. +0·060. July 22d. 19h. +0·020. Aug. 4d. 5h. +0·080. Aug. 10d. 13h. +0·050. Aug. 29d. 20h. +0·020. Sept. 11d. 17h. +0·025. Sept. 29d. 4h. +0·030. Nov. 8d. 3h. +0·075. Dec. 13d. 14h. +0·020. Dec. 21d. 14h. +0·025. Dec. 23d., 23h. +0·015.

CATALOGUE OF EARTHQUAKES, 1918–1924.

Erratum.

P. 53. January 5d. 4h. *For* +5·5° *read* —5·5°.

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. W. G. BICKLEY, Prof. R. A. FISHER, Dr. J. HENDERSON, Dr. E. L. INCE, Dr. J. O. IRWIN, Dr. J. C. P. MILLER, Mr. F. ROBBINS, Mr. D. H. SADLER, Dr. A. J. THOMPSON, Dr. J. F. TOCHER and Dr. J. WISHART).

General activity.—Seven meetings of the Committee have been held, in London.

Dr. W. G. Bickley was co-opted in December.

The grant of £100 was increased by the Council to £150, and has been expended as follows :

	£	s.	d.
Preparation of copy for roots of J_0 and J_1 . .	1	0	0
Calculation of roots of Y_0 and Y_1 . . .	4	0	0
Proof-reading of Volume VI	23	0	0
Differencing of printed sheets of Volume VI .	35	0	0
Calculations of the functions J_2 to J_{20} . .	73	6	0
Secretarial and miscellaneous expenses . .	13	14	0

Cunningham Bequest.—The proof-reading of Volume V, containing the prime factors of all numbers up to 100,000, took longer than was anticipated. The volume has now been passed for press.

Tables for cyclotomy and trinomial congruences, offered by Prof. L. E. Dickson, have been accepted for publication.

Bessel functions.—Volume VI, described in the last report, is now in press, and will be published shortly.

It has been found that the remaining Bessel functions will require at least two further volumes, the first of which, containing about 300 pages, will tabulate the higher integral orders (up to $n = 20$) of the four functions J_n, Y_n, I_n, K_n. The calculations for $J_n(x)$, up to $x = 25$, are now practically complete ; work on the other functions is also in hand.

Reappointment.—The Committee desires reappointment, with a grant of £200, the greater part of which would be devoted to calculations for the next volume of Bessel functions.

THERMAL CONDUCTIVITIES OF ROCKS.

Report of Committee appointed to investigate the direct determination of the Thermal Conductivities of Rocks in mines or borings where the temperature gradient has been, or is likely to be, measured (Dr. Ezer Griffiths, F.R.S., *Convener* ; Dr. E. C. Bullard, Dr. H. Jeffreys, F.R.S., Mr. E. M. Anderson, Prof. W. G. Fearnsides, F.R.S., Prof. A. Holmes, Dr. D. W. Phillips, Dr. J. H. J. Poole, Mr. W. Campbell Smith).

The rate of outflow of heat per unit area of the earth's surface is the product of the thermal conductivity and the vertical temperature gradient, and can therefore be found if these two quantities are known. Different determinations by experiment and observation have, however, given substantially different results, and the variation requires explanation. The rate of outflow of heat is an important geophysical quantity connected with the amount of radioactivity within the earth, but has been determined in practice by taking scattered measurements, averaged by methods that are little better than a guess. Unfortunately, there seems to be no case where the temperature gradient and the conductivity have actually been measured in the same rocks. The possibility that there is a systematic difference between the rocks whose conductivities have been ascertained, and those where the gradient has been measured, therefore remains untested, and so does the possibility of a real variation of the heat outflow from place to place.

The work of the Committee during this year has been wholly exploratory. Two meetings have been held, and a long report on the existing determinations of temperature gradient has been drawn up by Dr. D. W. Phillips. It appears that much work has recently been done in the United States, Central Europe and Russia. Temperature gradients appear to be related to geological structure, and have therefore been used to some extent in prospecting. This is reasonable, because theoretically a body of high conductivity near the surface should make an easy path for the heat, and a high gradient would be found above it. This is a three-dimensional effect, which will arise only for inequalities with horizontal extents small in comparison with the depth of the main sources of heat, and near the edges of larger ones. Some other anomalies have been traced to the presence of intrusions that have not yet had time to cool down, and others to the disturbance produced by the last glacial period. These variations will have to be allowed for in any accurate determination of the heat flow at great depths.

The Committee desires to send forward the following recommendations to the Committees of Sections A and C :

(1) Casual collection and examination of rocks to determine conductivities can add little to what is already known. The collection of material for study should be done while mines or borings are actually being made, and

the conductivities should be compared with the strata temperatures measured in the same places.

(2) A first series of experiments should be made to determine the conductivity and temperature gradient in rocks that are homogeneous for some tens of feet beneath the surface, as in the area of the outcrop of the Gault near Cambridge.

(3) Members are asked to get into touch with mining undertakings at places where deep borings are being made, and to arrange for the collection of specimens and the determination of underground temperatures before disturbing conditions can have opportunity and time to become effective.

The Committee asks for reappointment with a grant of £35.

QUANTITATIVE ESTIMATES OF SENSORY EVENTS.

Second Interim Report of Committee appointed to consider and report upon the possibility of Quantitative Estimates of Sensory Events (Prof. A. Ferguson, *Chairman*; Dr. C. S. Myers, F.R.S., *Vice-Chairman*; Mr. R. J. Bartlett, *Secretary*; Dr. H. Banister, Prof. F. C. Bartlett, F.R.S., Dr. Wm. Brown, Dr. N. R. Campbell, Prof. J. Drever, Mr. J. Guild, Dr. R. A. Houston, Dr. J. C. Irwin, Dr. G. W. C. Kaye, Dr. S. J. F. Philpott, Dr. L. F. Richardson, F.R.S., Dr. J. H. Shaxby, Mr. T. Smith, Dr. R. H. Thouless, Dr. W. S. Tucker).

(1) Experimental investigation and research into the records have been continued, and interim reports have been received of the work being carried out at Cardiff and Cambridge.

(2) These reports and certain aspects of the theory of measurement have been discussed by correspondence.

(3) Before the accumulated information can be reduced to report form in a satisfactory manner, it seems desirable that experimental work in progress should be carried somewhat farther, and that a report on research being made into the records of previous work should be available.

(4) The Committee therefore asks to be re-appointed without grant.

PHOTOGRAPHS OF GEOLOGICAL INTEREST.

Twenty-seventh Report of the Committee (Profs. E. J. Garwood, *Chairman*; and S. H. Reynolds, *Secretary*; Messrs. G. Macdonald Davies, J. F. Jackson, J. Ranson, Prof. W. W. Watts, and Mr. R. J. Welch).

In the present report 308 photographs are listed, bringing the number in the collection to 8,711.

The present series includes an interesting set from Cornwall contributed by Mr. E. H. Davison, and some beautiful whole plate photographs illustrating coast erosion near Sidmouth given by Mr. Harold Preston, also sets from Lundy Island by Mr. O. D. Kendall, from Dorset by Dr. W. J. Arkell, from Nottingham by Prof. H. H. Swinnerton, and from Donegal by Dr. W. J. McCallien. Dr. E. Greenly has presented an interesting series of the pillow lavas of Newborough, Anglesey, taken by Mr. J. Trevor Owen, and Mr. J. Ranson some from the Isle of Man and a group illustrating the Brimham rocks, Harrogate. The Hon. Secretary contributes sets from Devon, Durham, Northumberland, the Ardnamurchan peninsula, and the North of Scotland.

The transfer of H.M. Geological Survey Office and Museum from Jermyn Street to South Kensington has involved a corresponding transfer of the Committee's collection of photographs, which is now housed in the new Survey Library, and is far more easy to refer to than was the case at Jermyn Street.

During the period of transfer the collection, through the kindness of Prof. P. G. H. Boswell, was housed at the Imperial College, South Kensington, and the opportunity was taken thoroughly to overhaul it and the card catalogue. The Committee are greatly indebted to Prof. Watts for the help he gave in this matter and in particular for the large amount of time he devoted to checking the card catalogue.

Some years ago Mr. F. W. Reader presented to the Committee the large collection of geological negatives made by his late brother, Mr. T. W. Reader. A second valuable collection of negatives has since been received as a gift from Mr. C. J. Watson. Executors may sometimes be glad to know that the Committee is glad to accept any collection of geological negatives. In past times several important collections have unfortunately been destroyed, probably through executors being unaware of their importance.

In the previous report (London, 1931) the fact is mentioned that a new (second) series of geological photographs (issues D and E) was ready. Although the publication of this new series has not resulted in any financial loss to the Committee it has scarcely justified itself, the demand being vastly less than in the case of the first series (issues A, B, C), brought out by Prof. Watts. Of the second series there were sold to the end of 1934 :

Issue D prints 17 sets, lantern slides 25 sets.
Issue E prints 17 sets, lantern slides 26 sets.

The number contrasts lamentably with that of the 193 subscribers (see 1904 report) who undertook to support the first series. The unfortunate result was not due to neglect of advertising.

An attempt was made to extend the knowledge of the Committee's work among Geographers by the publication in 1932 of an article in *Geography*, and by an exhibition at the meeting of the Museums Association in Bristol in 1934. At the latter meeting the following circular was issued altering the conditions of sale of the photographs published by the Committee : 'Hitherto these have been sold only in sets. This practice has probably checked the sale, as many of the subjects included, though interesting to geologists, do not appeal to geographers. It is proposed therefore to allow purchasers to select from the whole series of published photographs those which interest them. Such subjects may be obtained from the Hon. Secretary at the following rates :

Prints, half plate, unmounted	15*s*. a dozen
Prints, half plate, mounted on cards . .	20*s*. ,,
Whole plate prints or enlargements, unmounted	2*s*. each
Whole plate prints or enlargements, mounted	2*s*. 6*d*. each
12 × 10 enlargements, unmounted . .	3*s*. each
Lantern slides	20*s*. a dozen

Full descriptions, often illustrated by diagrams, are issued with all prints and lantern slides.'

LIST OF ADDITIONS TO THE COLLECTION.

CORNWALL.—Photographed by E. H. DAVISON, M.Sc., School of Mines, Camborne. P.C.

8404.	B. 25.	Kennack Sands, Lizard.	Epidiorite cutting gabbro intrusive in bastite serpentine. 1932.
8405.	B. 24.	Kennack Sands, Lizard.	Epidiorite dykes cutting serpentine. 1932.
8406.	B. 30.	Kennack Sands, Lizard.	Epidiorite cutting gabbro intrusive in bastite serpentine. 1932.
8407.	E. 30.	Kennack Sands, Lizard.	Granite cutting serpentine with pseudophite at contact. 1932.
8408.	1017.	Priest's Cove, Cape Cornwall, St. Just.	Granite-slate contact. 1934.
8409.	1008.	Balleswidden clay pit, St. Just.	Granite capping china clay deposit. 1934.
8410.	1007.	Porthledden, St. Just.	Aplite vein in slate. 1932.
8411.	36.	Goonvean china clay pit, St. Stephens.	Tramway to waste dump. 1932.
8412.	35.	Goonvean china clay pit, St. Stephens.	Washing clay. 1932.
8413.	42.	St. Erth, quarry near school.	Porphyry dyke with overlying Pliocene sands. 1932.
8414.	G. 3.	Crackington Haven, near Boscastle.	Culm quartzite showing ridges simulating false bedding but due to movement.
8415.		Crackington Haven, near Boscastle.	Outcrop on beach of thrust plane traversing Culm quartzite and shale.
8416.	38.	Tremearne cliff, Porthleven.	Aplite cutting Devonian slate. 1932.
8417.	A. 1.	Tremearne cliff, Porthleven.	Pegmatite sills in Devonian slate. 1932.
8418.	39.	Tremearne cliff, Porthleven.	Large felspars in pegmatite. 1932.
8419.	52.	Tortoise rock, Carn Brea, Redruth.	Horizontal jointing in granite. 1932.
8420.	51.	Bosleake qu., Carn Brea, Redruth.	Granite with aplite vein. 1932.
8421.	37.	Mousehole, near Penzance.	Raised Beach on granite. 1932.

Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

8422.	32·51.	Cawsand, Plymouth.	Dyke cutting Devonian. 1932.
8423.	32·52.	Cawsand, Plymouth.	Dyke cutting Devonian. 1932.
8424.	32·54.	Cawsand, Plymouth.	Inlet eroded along dyke. 1932.
8425.	32·55.	Cawsand, Plymouth.	Surface of felsite intrusion. 1932.

8426.	32·56.	Cawsand, Plymouth.	Surface of felsite intrusion forming raised shore-platform. 1932.
8427.	32·57.	Cawsand, Plymouth.	Surface of felsite intrusion forming raised shore-platform. 1932.

DEVON.—Photographed by W. J. ARKELL, M.A., D.Phil., Hurstcote, Cumnor, near Oxford. ¼.

8428.	X.	Pinhay Bay.	Blue and White Lias section.
8429.	Y.	Pinhay Bay.	Blue and White Lias section.
8430.	Z.	Between Pinhay and Lyme Cobb.	Blue Lias section.

Photographed by O. D. KENDALL, M.A., The University, Bristol. ¼ pl. enlargement.

8431.	1.	Lundy, mid-west coast.	Ravine in granite due to breakaway along line of joint. 1931.
8432.	2.	Lundy, mid-west coast.	Ravine in granite due to breakaway along line of joint. 1931.
8433.	3.	Lundy, S.W. corner of island.	Close set vertical joints in granite. 1931.
8434.	4.	Lundy, west side.	Well-jointed granite. 1931.
8435.	5.	Lundy, S.E. end.	Cave in slaty series. 1931.
8436.	6.	Lundy, N.W. coast.	Precipitous cliff. 1931.
8437.	7.	Lundy, E. coast.	Sea cave worn along joint in granite. 1931.
8438.	8.	Lundy, north end with lighthouse.	

Photographed by HAROLD PRESTON, Venayr, Sidmouth. ¼.

8439.	A.	Ladrum, near Sidmouth.	Marine erosion of Triassic sandstone.
8440.	B.	Ladrum, near Sidmouth.	Sea stacks of Triassic sandstone.
8441.	C.	Ladrum, near Sidmouth.	Marine erosion of Triassic sandstone.
8442.	D.	Ladrum, near Sidmouth.	Sea stacks of Triassic sandstone.
8443.	E.	Ladrum, near Sidmouth.	Marine erosion of Triassic sandstone.

Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

8444.	32·79.	Lundy, mid-west side.	Granite coast. 1931.
8445.	32·75.	Lundy, S.E. end.	Dyke in slate. 1931.
8446.	32·74.	Lundy, S.E. end.	On right granite, on left slaty rocks. 1931.
8447.	32·77.	Lundy, S. end.	Granite cliff. 1931.
8448.	33·3.	Dawlish.	Permian breccia showing honeycomb weathering. 1933.
8449.	33·4.	Dawlish.	Permian breccia showing honeycomb weathering. 1933.

8450.	33·8.	Dawlish.	Sea stacks of Permian. 1933.
8451.	33·9.	Budleigh Salterton.	Pebble beds. 1933.
8452.	33·10.	Budleigh Salterton.	Pebble beds. 1933.
8453.	33·11.	Budleigh Salterton.	'Cornstone' in Trias. 1933.
8454.	33·16.	Dunscombe cliff, Sidmouth.	Cretaceous on Trias. 1933.
8455.	34·9.	Bolt Tail.	Coast formed of 'Green schists.' 1934.
8456.	34·10.	Bolt Tail.	Coast formed of 'Green schists.' 1934.
8457.	34·12.	Bolt Head.	Rugged weathering of mica schist. 1934.
8458.	34·15.	Bolt Head from W.	1934.
8459.	34·18.	Thurlestone.	Rock fall. 1934.
8460.	34·18.*	W. of Thurlestone.	Shore platform. 1934.
8461.	34·19.	Start Point.	Coast formed of 'Green schists.' 1934.
8462.	34·20.	Start Point.	Coast formed of 'Green schists.' 1934.
8463.	34·22.	Start Point.	Coast formed of 'Green schists.' 1934.
8464.	34·14.	Prawle Point.	Mica schist. 1934.
8465.	34·16.	Near Prawle Point.	Raised-beach platform. 1934.
8466.	34·24.	Near Prawle Point.	Raised-beach platform. 1934.

DORSET.—Photographed by W. J. ARKELL, M.A., D.Phil., Hurstcote, Cumnor, near Oxford. $\frac{1}{4}$.

8467.	A.	Hounstout and Emmit Hill, from St. Alban's Head	Kimeridgian and Portlandian section.
8468.	B.	Hounstout and Emmit Hill.	Kimeridgian and Portlandian section.
8469.	C.	Hounstout.	Kimeridgian and Portlandian section.
8470.	D.	St. Alban's Head.	Portlandian section and slipped material.
8471.	E.	W. Weare Cliff, Portland.	Purbeck and Portland section.
8472.	F.	W. Weare Cliff, Portland.	Kimeridgian and Portlandian section.

Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. $\frac{1}{4}$.

8473.	31· 1.	Portland Bill.	Raised beach on Portlands. 1931.
8474.	31· 2.	Portland Bill.	Raised beach on Portlands. 1931.
8475.	31· 3.	Portland Bill.	Raised beach on Portlands. 1931.
8476.	31· 5.	Portland Bill.	Blow-hole. 1931.
8477.	31· 8.	Black Nore, Portland.	Purbeck section. 1931.
8478.	31·10.	N. of Black Nore, Portland.	Chert beds in Portland stone. 1931.
8479.	31·11.	N. of Black Nore, Portland.	Foundering of cliff. 1931.
8480.	31·14.	Nothe, Weymouth.	'Fucoids' in Nothe beds. 1931.
8481.	31·17.	Sandsfoot Castle, Weymouth.	'Fucoids' in Sandsfoot beds. 1931.

8482.	31·23.	Lulworth Cove, E. side.	'Broken beds.' 1931.
8483.	31·28.	Lulworth, fossil forest.	Lower Purbeck section. 1931.
8484.	31·30.	Lulworth, fossil forest.	Lower Purbeck section. 1931.
8485.	31·32.	Lulworth, fossil forest.	Lower Purbeck section. 1931.
8486.	31·33.	Lulworth, fossil forest.	Lower Purbeck section. 1931.

Durham.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. ¼.

8487.	31·101.	Fulwell.	Cannon-ball concretions in Magnesian Limestone. 1931.
8488.	31·102.	Fulwell.	Concretions in Magnesian Limestone. 1931.
8489.	31·103.	Fulwell.	Concretions in Magnesian Limestone. 1931.
8490.	31·108.	Claxheugh, section by the Wear.	Well-bedded Lower Limestone resting on Yellow Sands. 1931.
8491.	31·110.	Roker.	Cannon-ball limestone on shore. 1931.
8492.	31·111.	Roker.	Cannon-ball limestone on shore. 1931.
8493.	31·112.	Blackhall Rocks.	Superposed caves. 1931.
8494.	31·113.	Blackhall Rocks.	Brecciated Magnesian Limestone. 1931.
8495.	31·114.	Blackhall Rocks.	Stack of normal Magnesian Limestone resting on 'brecciated beds.' 1931.
8496.	31·115.	Blackhall Rocks.	Cliff showing alternation of breccia and normal limestone. 1931.
8497.	31·116.	Blackhall Rocks, N. end.	Brecciated Magnesian Limestone 1931.
8498.	31·117.	Blackhall Rocks, N. end.	Caves worn in 12 ft. brecciated bed. 1931.
8499.	31·118.	Blackhall Rocks.	Brecciated bed 12 ft. thick. 1931.
8500.	31·121.	Marsden Bay, near S. end.	Middle Magnesian Limestone showing alternation of hard calcareous beds and soft magnesian beds. 1931.
8501.	31·123.	Marsden Bay.	Lot's Wife, a stack of gash-breccia. 1931.
8502.	31·124.	Marsden Bay.	Typical gash filled with breccia. 1931.
8503.	31·126.	Marsden Bay, N. end.	Typical cellular breccia of Middle Magnesian Limestone. 1931.
8504.	31·127.	Coast ¼ mile S. of Frenchman's Bay.	Brecciated Middle Magnesian Limestone resting on Lower Limestone. 1931.
8505.	31·129.	Trow Rocks, 1 m. S. of South Shields.	Cellular breccia showing local lamination. 1931.
8506.	31·131.	Trow Rocks, 1 m. S. of South Shields.	Cellular breccia at base of Middle Magnesian Limestone. 1931.
8507.	31·89.	Copt Hill, near Stanhope.	Quarry in Whin Sill. 1931.

Gloucester.—Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. ¼.

8508.	32·70.	Aust Cliff.	Erosion of Severn Alluvium. 1932.
8509.	32·72.	Aust Cliff.	General view of South part of section showing projections in relation to faults. 1932.
8510.	34·75.	Aust Cliff.	Section near S. end showing downthrow due to faults. 1934.
8511.	34·77.	Aust Cliff.	Gypseous series near N. end. 1934.
8512.	34·78.	Aust.	View from top of cliff showing Trias resting on Carb. Lst. 1934.
8513.	34·79.	Aust.	View from top of cliff showing Trias resting on Carb. Lst. 1934.
8514.	32·39.	Plump Hill, Mitcheldean.	Upper Low. Lst. Shale Quarry. 1932.
8515.	32·41.	Plump Hill, Mitcheldean.	Whitehead Limestone Quarry. 1932.
8516.	32·42.	Plump Hill, Mitcheldean.	Whitehead Limestone Quarry. 1932.
8517.	32·43.	Plump Hill, Mitcheldean.	Lowest bed of Whitehead Limestone. 1932.
8518.	32·44.	Plump Hill, Mitcheldean.	Lower Dolomite Quarry. 1932.
8519.	32·47.	Cement Stone Quarry, Mitcheldean.	General view. 1932.
8520.	31·51.	Milkwall, near Coleford.	Quarry near Easter Pit showing limestone band in Drybrook Sandstone. 1931.
8521.	31·53.	Milkwall, near Coleford.	Small quarry near Easter Pit. 1931.
8522.	31·55.	Cement Stone Quarry, Mitcheldean.	Seen from near entrance. 1931.
8523.	31·59.	Scully Grove Quarry, Mitcheldean.	General view. 1931.

Photographed by J. E. Livingstone, The University, Bristol. 1934.

8524.		Scully Grove Quarry, Mitcheldean.	Weathered surface, block of Whitehead Limestone. 1934.

Hampshire (Isle of Wight).—Photographed by J. Ranson, 174 Willows Lane, Accrington. ¼.

8525.	M.	Landslip near Niton.	From W.
8526.	N.	Culver Cliff.	From S.
8527.	O.	Compton Bay.	Sun cracks in Wealden.

Photographed by S. H. Reynolds, M.A., Sc.D., The University, Bristol. ¼.

8528.	32· 1.	S.E. of Niton.	The 'Cliff' formed by the Chert beds of the Upper Greensand, with the undercliff below. 1932.
8529.	32· 2.	S.E. of Niton.	Chert beds of the Upper Greensand. 1932.
8530.	32· 3.	S.E. of Niton.	The 'Cliff' with undercliff below. 1932.
8531.	32· 4.	S.E. of Niton.	Chert beds of the Upper Greensand forming the 'Cliff.' 1932.
8532	32· 5.	Ventnor Downs from W.	Chalk Downs.
8533.	32·35.	Gore Cliff W. of the landslip.	The 'Cliff' with undercliff below. 1932.
8534.	32·14.	N. of Sandown.	Coast erosion. 1932.
8535.	32·15.	N. of Sandown.	Coast erosion. 1932.
8536.	32·18.	N. of Sandown.	Coast erosion. 1932.
8537.	32·37.	N. of Sandown.	Coast erosion. 1932.
8538.	32·13.	N. of Sandown.	Foundering of Wealden. 1932.
8539.	32·17.	S. of Culver Cliff.	Slipping of Gault. 1932.
8540.	32·22.	Headon Hill.	Oyster bed, Middle Headon. 1932.
8541.	32·23.	Headon Hill.	Lignite bed, Upper Headon. 1932.
8542.	32·25.	Top of cliff E. of Atherfield Point.	Wind erosion of Lower Greensand. 1932.
8543.	32·26.	Top of cliff E. of Atherfield Point.	Wind erosion of Lower Greensand. 1932.
8544.	32·27.	Near Atherfield Point.	Slipping. 1932.
8545.	32·29.	Alum Bay.	Recession of cliff by subaerial erosion. 1932.
8546.	34·86.	Puckaster Cove, Ventnor	Slipping. 1934.
8547.	34·87.	Above Binnel Bay, Ventnor.	Greensand cliff with outcrop of Gault below. 1934.
8548.	34·88.	Above Binnel Bay, Ventnor.	Greensand cliff. 1934.
8549.	34·90.	Binnel Bay, Ventnor.	Ruins of breakwater. 1934.
8550.	34·91.	Woody Bay, Ventnor.	Two cliffs of highly dipping and slipped Upper Cretaceous. 1934.
8551.	34·92.	E. of S. Laurence station, Ventnor.	Chert beds of Upper Greensand. 1934.

Leicestershire.—Photographed by H. H. Gregory, B.A., 67 Princess Road, Leicester. 5 × 4.

8552.	1.	Bardon Hill, near Coalville.	General view of country N.W. from Bardon Hill summit.
8553.	2.	Bardon Hill, near Coalville.	Trias Marl on Charnian.
8554.	3.	Bardon Hill, near Coalville.	General view of quarry.

NORTHUMBERLAND.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

8555.	31·75.	Bamborough Castle.	Transgression of Whin Sill, 1931.
8556.	31·76.	Bamborough Castle.	Whin Sill and underlying sediments. 1931.
8557.	31·83.	Dunstanborough Castle.	Outcrop of Whin Sill. 1931.
8558.	31·84.	Dunstanborough Castle.	Outcrop of Whin Sill. 1931.
8559.	31·85.	Dunstanborough Castle.	Whin Sill with underlying sediments. 1931.
8560.	31·86.	Dunstanborough Castle.	Whin Sill with underlying sediments. 1931.
8561.	31·92.	Near Homesteads.	Whin Sill escarpment. 1931.
8562.	31·90.	Little Mill, near Alnwick.	Quarry in Whin Sill intrusive in Acre Limestone. 1931.
8563.	31·91.	Little Mill, near Alnwick.	Whin Sill showing contact at base with Acre Limestone. 1931.
8564.	31·93.	Cullernose Point, near Alnwick.	Cliff formed by Whin Sill. 1931.
8565.	31·94.	Cullernose Point, near Alnwick.	Cliff formed by Whin Sill. 1931.
8566.	31·95.	Cullernose Point, near Alnwick.	Big sandstone blocks included in the Whin Sill. 1931.

NOTTINGHAMSHIRE.—Photographed by H. H. SWINNERTON, D.Sc., University College, Nottingham. ¼ and ½.

8567.	1.	Hempshill, near Bulwell.	Bunter and Permian section. ¼. 1910.
8568.	2.	Bulwell.	Copious spring issuing from junction of Permian Marl and Bunter. ¼. 1910.
8569.	3.	Mapperley Park, Nottingham.	Section of Keuper Sandstone (Waterstones). ¼. 1910.
8570.	4.	Mapperley Park, Nottingham.	Rippled surface of Keuper Sandstone with reptilian tracks. ¼. 1910.
8571.	7.	E. of Trowell.	Road cutting showing coal-seam and effect of soil creep. ½. 1910.

Photographed by W. SUTCLIFFE, University College, Nottingham. ¼.

8572.	5.	Brick-pits, Docket Head, near Arnold.	Salt pseudomorphs in Keuper Marl. 1910.
8573.	6.	Arnold.	Facetted pebbles. 1910.

SOMERSET.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

8574.	32·60.	Cheddar.	The gorge from above.
8575.	32·63.	Portishead, S. of Woodhill Bay.	Irregular Cornstone development in O.R.S. 1932.
8576.	32·67.	Portishead, S. of Woodhill Bay.	Trias conglomerate unconformable on O.R.S.

8577.	32·64.	Portishead, S. of Woodhill Bay.	O.R. conglomerate overlying sandstone with irregular Cornstone. 1932.
8578.	32·65.	Portishead, S. of Woodhill Bay.	O.R.S. conglomerate with sandstone above. 1932.
8579.	32·66.	Portishead, S. of Woodhill Bay.	Trias conglomerate unconformable on O.R.S. 1932.
8580.	32·67.	Portishead, Battery Point.	Trias conglomerate unconformable on Carboniferous Limestone. 1932.
8581.	00·20.	Middle Hope (Woodspring).	Fallen block of raised beach. 1900.
8582.	32·85.	Middle Hope (Woodspring).	Rocks above the lava, western igneous section. 1932.
8583.	32·86.	Middle Hope (Woodspring), S. side.	Infilling of breccia. 1932.
8584.	32·87.	Spring Cove, Weston-super-Mare.	Agglomerate enclosing lava-spheroid. 1932.
8585.	32·88.	Spring Cove, Weston-super-Mare.	Limestone in spaces between calcite-veined lava-spheroids. 1932.
8586.	33·17.	Clevedon.	Mud flats S. of Church Hill. 1933.
8587.	33·18.	Salthouse, Clevedon.	Chert in Z. beds. 1933.
8588.	33·27.	Near Knightstone, Weston-super-Mare.	Honeycomb weathering by spray of calcareous sandstone. 1933.
8589.	30·55.	E. Quantockhead, Watchet.	Lias section. 1930.
8590.	30·57.	E. Quantockhead, Watchet.	Jointing in Lias limestone. 1930.
8591.	30·58.	E. Quantockhead, Watchet.	Jointing in Lias limestone. 1930.
8592.	31·67.	Coast E. of Watchet.	Lias cliffs and shore-platform. 1931.
8593.	31·68.	Coast E. of Watchet.	Lias cliffs and shore-platform. 1931.
8594.	31·71.	Coast W. of Watchet.	Keuper with gypsum. 1931.
8595.	31·72.	Coast W. of Watchet.	Keuper with gypsum. 1931.

WARWICKSHIRE.—Photographed by W. H. LAURIE, Geological Department, The University, Birmingham, and presented by Prof. L. J. WILLS, M.A., D.Sc. ½.

8596.	Nuneaton, Messrs. Stanley Bros. Pit.	Middle Coal Measures overlain by Boulder Clay.
8597.	Near Nuneaton, Born's Windmill Hill Quarry.	Base of Cambrian resting on Markfieldite.

YORKSHIRE.—Photographed by the *Yorkshire Post*, Leeds, and presented by T. SHEPPARD, M.Sc., Municipal Museum, Hull. 10 × 8.

8598.	Danes' Dyke, Flamborough.	Slipped mass of Boulder Clay.

Photographed by J. Ranson, 174 Willows Lane, Accrington. ¼.

8599.	Brimham rocks, near Harrogate.	Wind erosion.
8600.	Brimham rocks, near Harrogate.	Wind erosion.
8601.	Brimham rocks, near Harrogate.	Wind erosion.
8602.	Brimham rocks, near Harrogate.	Wind erosion.
8603.	Brimham rocks, near Harrogate.	Wind erosion.
8604.	Brimham rocks, near Harrogate.	Wind erosion.
8605.	Brimham rocks, near Harrogate.	Wind erosion.
8606.	Brimham rocks, near Harrogate.	Wind erosion.

Isle of Man.—Photographed by J. Ranson, 174 Willows Lane, Accrington.

8607.	Langness, near Castleton.	Manx slate.
8608.	Langness, near Castleton.	Manx slate.
8609.	Langness, near Castleton.	Manx slate.
8610.	Langness, near Castleton.	Manx slate with quartz veins.
8611.	Langness, near Castleton.	Carboniferous basal conglomerate on Manx slate.
8612.	Langness, near Castleton.	Carboniferous basal conglomerate on Manx slate.

WALES.

Anglesey.—Photographed by (or for) E. Veil Baynes, 39 Roland Gardens, London, S.W. 7. 10 × 8.

8613.	Marienglas.	Rock table of Carboniferous Limestone.

Photographed by J. Trevor Owen, County School, Swansea, 1901, and presented by E. Greenly, D.Sc., Aethwy Ridge, Bangor.

8614.	A.	Newborough dunes.	Folded Tyfry beds.
8615.	B.	Newborough dunes.	Spilitic lava with interstitial jasper.
8616.	C.	Newborough dunes.	Spilitic lava with interstitial jasper.
8617.	D.	Newborough dunes.	Spilitic lava, smaller type of ellipsoid.
8618.	E.	Newborough dunes.	Spilitic lava, larger type of ellipsoid.
8619.	F.	Newborough dunes.	Spilitic lava, larger type of ellipsoid.
8620.	G.	Newborough dunes.	Schistocity developing in ellipsoidal spilite.

Cardiganshire.—Photographed by J. Challinor, M.A., University College of Wales, Aberystwyth. 2 × 2.

8621.	60.	Clarach Bay, Aberystwyth.	Dissected anticline.
8622.	174.	Quarry 5 m. S. of Aberystwyth.	Bedding and jointing in Aberystwyth grits.
8623.	264.	N. of Port-erwyd.	Pot holes in the bed of the Rheidol.

8624.	387.	Between Aberystwyth and Clarach.	Bedding of Aberystwyth grits in plan on shore.
8625.	837.	Between Clarach and Wallog.	Differential erosion of Aberystwyth grits on shore.
8626.	854.	Near Gwbert.	Stacks of well-bedded and jointed Bala mudstone.
8627.	1365.	Llanon.	Boulder clay platform with old coast behind.
8628.	1413.	North of Aberystwyth.	Cliffs and shore platform of Aberystwyth grits.
8629.	1448.	2½ m. S. of Aberystwyth.	Blocks of Aberystwyth grits collecting at foot of dip-slope.
8630.	1459.	Allt Wen, Aberystwyth.	Cliff face formed by dip-slope.
8631.	1463.	Wallog.	Shore platform, sea cliff and coastal slope.
8632.	1543.	Cwm Tydi, S. of Aberystwyth.	Confused bedding in Aberystwyth grits.
8633.	1565.	Banks of Rheidol, Capel Bangor.	Bedded glacial clay.

GLAMORGAN.—Photographed by F. F. MISKIN, 46 Windsor Road, Penarth.

8634.	4273 and 4199.	Flat Holm.	Folded Carb. Limestone.

Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

8635.	02·20.	Bacon Hole, Gower.	1902.
8636.	32·89.	Flatholm.	Marine erosion. 1932.
8637.	32·90.	Flatholm.	Dip of Limestone. 1932.
8638.	33·25.	Steepholm.	General view. 1933.

SCOTLAND.

ARGYLL.—Photographed by J. F. N. GREEN, B.A., 51 Alexandra Grove, London, N. 12. ¼.

8639.	S. side Kilmory Bay, Knapdale.	Pitching folds of quartzite interbedded in phyllite.

Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

ARDNAMURCHAN. 1931.

8640.	31·144.	Kilchoan.	Cone-sheet W. of jetty.
8641.	31·145.	Kilchoan.	Cone-sheet W. of jetty.
8642.	31·149.	Kilchoan.	Cone-sheet cutting Lias W. of jetty.
8643.	31·151.	Mingary Castle.	Sills in Lias.
8644.	31·152.	Kilchoan.	Lias shale and sill near jetty.
8645.	31·154.	Mingary Castle.	Large sill cutting highly calcareous Trias.

8646.	31·156.	E. of Mingary Castle.	Plexus of small intrusions in Trias.
8647.	31·157.	Mingary Castle.	Small cone-sheet.
8648.	31·159.	S.W. end of Ardnamurchan.	Gabbro coast with pre-glacial raised-beach platform.
8649.	31·160.	W. of Maclean's Nose.	Big sill in Moines.
8650.	31·161.	W. of Maclean's Nose.	Raised sea-cave in Moines.
8651.	31·162.	W. of Maclean's Nose.	Basalt on Trias on Moines.
8652.	31·164.	Maclean's Nose.	Agglomerate.
8653.	31·165.	Maclean's Nose.	Agglomerate.
8654.	31·166.	Maclean's Nose.	Agglomerate.
8655.	31·167.	Maclean's Nose.	Agglomerate.
8656.	31·168	Maclean's Nose.	Agglomerate.
8657.	31·169.	Maclean's Nose.	Agglomerate.
8658.	31·170.	Maclean's Nose.	Sill cutting agglomerate.
8659.	31·171.	Maclean's Nose.	Dyke cutting sill.
8660.	31·172.	E. side of Ben Hiant.	Dykes cutting bedded basalt above Lias section.
8661.	31·173.	N. of Maclean's Nose.	Columnar quartz-dolerite.
8662.	31·174.	1½ m. N.W. of Kilchoan.	Glaciated gabbro.
8663.	31·175.	1½ m. N.W. of Kilchoan.	Glaciated gabbro.
8664.	31·178.	Ben-na-Seilg.	Glaciated gabbro country.
8665.	31·181.	Ben-na-Seilg, N.E. of lochans.	Dyke cutting gabbro.
8666.	31·185.	Sanna.	Glaciated gabbro country.
8667.	31·186.	Sanna.	Glaciated gabbro country.
8668.	31·188.	Faskadale.	Agglomerate.
8669.	31·190.	Achateny.	Large mass of sediment in agglomerate.
8670.	31·191.	E. of Achateny.	Agglomerate stack.
8671.	31·176.	N.W. of Kilchoan.	Granophyre veining gabbro.
8672.	31·177.	N.E. of Kilchoan.	Granophyre veining gabbro.
8673.	31·182.	Top of Ben-na-Seilg.	Granophyre veining gabbro.
8674.	31·183.	Ben-na-Seilg.	Granophyre veining gabbro.
8675.	31·184.	Top of Ben-na-Seilg.	Granophyre veining gabbro.

BANFF.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼. 1934.

8676.	34·64.	Boyndie Bay.	Andalusite mica schist.
8677.	34·65.	Sandsend.	Contorted Sandsend Limestone.
8678.	34·65.	W. of Whitehills.	Folded and thrust gritty limestone of the Whitehills group.
8679.	34·71.	Cullen.	Vertical quartzite.
8680.	34·72.	Cullen.	Stacks of O.R.S. rising from raised shore platform.
8681.	34·73.	E. of Cullen.	Hornblende schist crags.

BERWICK.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼. 1931.

8682.	31·131.	N. of Berwick-on-Tweed.	Sea caves in Calciferous Sandstone.
8683	31·132.	N. of Berwick-on-Tweed.	Current bedded Calciferous Sandstone.

8684. 31·133. N. of Berwick-on-Tweed. Marine erosion of Calciferous Sandstone.
8685. 31·134. N. of Berwick-on-Tweed. Marine erosion of Calciferous Sandstone.

Photographed by ? P.C.

8686. North of Berwick-on-Tweed. Marine erosion of Calciferous Sandstone.

ELGIN.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼. 1934.

8687. 34·68. Spynie brick pit, Elgin. Glacial marine boulder clay overlain by peat on which rests a littoral marine deposit.
8688. 34·69. Quarrywood Hill, Elgin. Quarry in Permian.
8689. 34·70. Quarrywood Hill, Elgin. Quarry in O.R.S.

FORFAR.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼.

8690. Near Arbroath. Honeycomb weathering by spray.

INVERNESS. SKYE.—Photographed by ABRAHAMS, Keswick. P.C.

8691. W. ridge, Sgurr nan Gillian, Cuillins. Dolerite dykes cutting gabbro.

SUTHERLAND.—Photographed by S. H. REYNOLDS, M.A., Sc.D., The University, Bristol. ¼. 1934.

8692. 34·49. Head of Loch Glencoul, Inchnadamff. Glencoul thrust in middle distance, Pipe rock in foreground.
8693. 34·50. Head of Loch Glencoul, Inchnadamff. Glencoul thrust with over- and underlying strata.
8694. 34·52. Head of Loch Glencoul, Inchnadamff. Islands traversed by Glencoul thrust.
8695. 34·56. Traligill burn, Inchnadamff. Stream falling into swallet.
8696. 34·57. Traligill burn, Inchnadamff. Caves in Cambrian.
8697. 34·60. Knockan cliff, Elphin. Moine thrust.
8698. 34·32. Helmsdale, Kimeridgian section. Boulder bed resting with transgressive base on shale.
8699. 34·35. Helmsdale, Kimeridgian section. Boulder bed.
8700. 34·37. Helmsdale, Kimeridgian section. Boulder bed.

8701.	34·39.	Helmsdale, Kimeridgian section.	Discordance between boulder bed and underlying shale.
8702.	34·40.	Helmsdale, Kimeridgian section.	Giant boulder of O.R.S. in Kimeridgian.
8703.	34·41.	Helmsdale, Kimeridgian section.	Giant boulder of O.R.S. in Kimeridgian.
8704.	34·45.	S. of Helmsdale.	'Cloud burst' effect.

IRELAND.

DONEGAL.—Photographed by W. J. McCALLIEN, D.Sc., The University, Glasgow.

8705.	A.	Fahan, Lough Swilly.	Fahan slates, bedding dipping left to right, cleavage vertical but folded.
8706.	B.	Culdaff.	Slates showing cleavage and bedding.
8707.	C.	Culdaff.	Spheroidal weathering in coarse grit.
8708.	D.	Culdaff.	Bedding of slates dips gently, cleavage steeply from left to right.
8709.	E.	Culdaff.	Isoclinally folded limestone bed in slate.
8710.	F.	Portaleen.	Recumbent fold in Dalradian schist.
8711.	G.	Fahan, Lough Swilly.	Slates showing cleavage and bedding.

ARTEMIA SALINA.

Report of the Committee appointed to investigate the progressive adaptation to new conditions in Artemia salina (Diploid and Octoploid, Parthenogenetic v. *Bisexual).*—(Prof. R. A. FISHER, F.R.S., *Chairman*; Dr. F. GROSS, *Secretary*; Dr. J. GRAY, F.R.S., Prof. J. S. HUXLEY, Sec. Z.S., Dr. E. S. RUSSELL, O.B.E., Prof. D. M. S. WATSON, F.R.S.).

THE following forms of *Artemia salina* have been tested for resistance against sodium arsenite: Diploid-bisexual races from California (C), from Formentera in Spain (F), and from Cagliari (Cg); octoploid-parthenogenetic forms from Estang de Berre (E), and from Marguerita di Savoia (M).

The experiments were conducted under environmental conditions, which were kept as constant as possible with regard to room temperature, food—a pure culture of a marine *Chlamydomonas* spec.-purity of glass dishes, culture medium ('Erdschreiber' = sterilised sea-water + 2·5 per cent. soil extract + small amounts of $NaNO_3$ and Na_2HPO_4), etc.

The animals were kept in pairs, or singly in the case of parthenogenetic females, and the nauplii at the age of 1–4 days were transferred for 24 hours into 95 cc. culture medium + 5 cc. of a vivid green *Chlamydomonas* culture + different amounts of an $\frac{1}{10}$ N sodium arsenite solution. After 24 hours the surviving nauplii were counted, washed in sterile sea-water and then placed in fresh culture medium with fresh food. In the first experiments the surviving nauplii were counted and transferred daily into fresh medium. Comparisons with controls showed that the effect of arsenic treatment ceases on the third day after treatment. After three days the mortality of treated nauplii is quite small and does not exceed that of the controls. Therefore the percentage of survivals after this period has been taken as a measure of resistance.

The response of different broods of the same parentage was found to be significantly heterogeneous in some cases. Whether this irregularity is due to unequal resistance in different broods, or to differences in the conditions on which they were tested, has not yet been established. Changes in the stock solution of sodium arsenite are not likely to occur. The possibility that differences in the composition of the soil extract might be the reason for the irregularities and that the method could be improved by using sterile sea-water without soil extract for the 24-hour tests was explored. Although *Artemia* does not breed well in sea-water, the nauplii do not suffer to any visible degree if kept therein for 24 hours. (Traces of soil extract are introduced by 5 cc. of the *Chlamydomonas* culture which can be only grown in 'Erdschreiber.') These experiments show in two cases out of seventeen considerable differences in the number of survivals in 'Erdschreiber' and in sea-water which most probably have been caused by the presence and absence of soil extract respectively. But some tests show that, using sea-water only, the whole source of heterogeneity has not been removed.

The data indicate, however, that when sufficient numbers are used, reliable resistance curves can be obtained. It is further clear that parallel families in the bisexual races show consistently different powers of resistance. With respect to any increase in resistance due to treatment and selection the data so far are necessarily very inadequate. Two comparisons seem worth making. In the parthenogenetic line E4, we may compare the aggregate responses of 322 nauplii from untreated parents with those of 408 from treated parents.

Percentage Survival.

Strength.	Untreated.	Number Tested.	Treated.	Number Tested.
	%		%	
0·38	100	31	—	—
0·40	100	31	—	—
0·41	79	48	—	—
0·42	67	12	—	—
0·43	53	81	100	29
0·46	43	53	100	29
0·50	20	66	38	110
0·52	—	—	23	86
0·53	—	—	2	45
0·55	—	—	20	64
0·56	—	—	9	45
		322		408

A second comparison may be made for the bisexual lines C1, C2, C7 and C9, all of which have some broods after one and some after two generations treatment. Of these 1,120 have had one generation treatment and 824 two generations.

Strength.	One Generation. %	Number Tested.	Two Generations. %	Number Tested.
0·30	98	40	—	—
0·35	43	54	—	—
0·37	90	40	—	—
0·40	62	314	63	30
0·43	—	—	63	27
0·44	73	33	—	—
0·45	58	259	65	49
0·46	—	—	79	63
0·47	15	97	97	36
0·48	—	—	65	54
0·49	26	78	67	30
0·50	37	135	51	105
0·51	—	—	39	52
0·52	—	—	75	99
0·53	—	—	48	104
0·54	—	—	57	21
0·55	—	70	34	154
		1,120		824

In both cases it is difficult to avoid the conclusion that the strength of poison needed to produce a given death-rate has been increased by at least 10 per cent., and probably more for the bisexual material. Many of the individual percentages are based on quite small numbers, but the series are distinctly more irregular than homogeneous material would give.

Another result of the tests hitherto made is that, in spite of the irregularity in the response to arsenic treatment, there appears to exist a difference in the susceptibility between the diploid bisexual and the octoploid parthenogenetic forms; the latter have a considerably wider range of resistance than the former. In the bisexual races the 50 per cent. point of survival lies well under 0·5 per cent. arsenite, whereas in several lines of the octoploid parthenogenetic races 100 per cent. of the nauplii survive this strength, and even 0·6 per cent.

The Committee ask to be reappointed.

BIOLOGICAL MEASUREMENTS.

Report of Committee appointed to revise the leaflet on Biological Measurements and to consider what steps should be taken to increase the use made of the archives for the reception of such measurements now established at the British Museum (Natural History), South Kensington (Prof. J. S. Huxley, *Chairman*; Prof. R. A. Fisher, F.R.S., *Secretary*; Dr. W. T. Calman, F.R.S., Dr. J. Gray, F.R.S.).

The Committee have revised and enlarged the leaflet on Biological Measurements, first issued in 1927, of which the first edition has been exhausted. The leaflet is now published separately from this Report, and is obtainable price 6*d*., or 7*d*. post free, from the offices of the British Association, Burlington House.

The following journals now include in their notice to contributors information as to the archives for the reception of bodies of provisional data established at the British Museum (Natural History), South Kensington. We are glad to say that the archives established at the Royal Society of Edinburgh have been maintained and are also prepared to receive such data. For the convenience of editors and contributors it is to be hoped that other journals liable to receive papers containing, or based on, extensive numerical observations will follow their example :—

Annals of Applied Biology.
Annals of Botany.
Instructions to Authors (Leaflet issued by the Publications Committee of the Zoological Society of London).
Journal of Experimental Biology.
Journal of the Linnean Society.
Journal of Pathology and Bacteriology.
Journal of the Malocological Society.
Proceedings of the Royal Society.
Quarterly Journal of Microscopical Science.

ZOOLOGICAL RECORD.

Report of Committee appointed to co-operate with other Sections interested and with the Zoological Society, for the purpose of obtaining support for the 'Zoological Record' (Sir Sydney Harmer, K.B.E., F.R.S., *Chairman*; Dr. W. T. Calman, F.R.S., *Secretary*; Prof. E. S. Goodrich, F.R.S., Prof. D. M. S. Watson, F.R.S.).

The grant of £50 was paid over to the Zoological Society on May 2, 1935, as a contribution towards the cost of preparing and publishing Vol. LXX of the *Zoological Record* for 1933. The statement of the 'Record Fund' in the report of the Council of the Zoological Society for 1934 shows that the balance had fallen from £2,317 18*s.* 2*d.* to £2,070 5*s.* 3*d.*, the loss on Vol. LXX having increased considerably over that of the preceding year. While such fluctuations are to be expected from year to year, it is evident that the support of the contributing societies is still essential for the continuation of the *Zoological Record.* The Committee accordingly asks for reappointment, with the renewal of the grant of £50.

FRESHWATER BIOLOGICAL STATION, WINDERMERE.

Report of Committee appointed to aid competent investigators nominated by the Committee to carry out definite pieces of work at the Freshwater Biological Station, Wray Castle, Windermere (Prof. F. E. Fritsch, F.R.S., *Chairman*; Mr. J. T. Saunders, *Secretary*; Miss P. M. Jenkin, Dr. C. H. O'Donoghue, *from Section D*; Dr. W. H. Pearsall, *from Section K*).

The grant of £75 from the British Association has been used to assist the following work at Wray Castle :

Miss Humphries has investigated the fauna of the mud at depths below

3 metres in Lake Windermere. She has determined the larvæ of some of the Chironomidæ by rearing them and submitting the adults to Dr. F. W. Edwards (British Museum, Natural History) for identification.

Dr. M. Rosenberg has prepared cultures of planktonic diatoms and is investigating the life histories of these algæ.

Mr. R. Misra has investigated the chemical composition of lake muds and the associated aquatic vegetation.

SOIL RESOURCES OF THE BRITISH EMPIRE.

Report of Committee appointed to co-operate with the Staff of the Imperial Soil Bureau to examine the soil resources of the Empire (Sir JOHN RUSSELL, O.B.E., F.R.S., *Chairman*; Mr. G. V. JACKS, *Secretary*; Dr. E. M. CROWTHER, Dr. W. G. OGG, Prof. G. W. ROBINSON, Prof. C. B. FAWCETT, Mr. H. KING, Dr. L. D. STAMP, Mr. A. STEVENS, Dr. S. W. WOOLDRIDGE).

IT has not been possible to arrange a meeting of the Committee during the past year, but it is intended to take advantage of the presence at the International Congress of Soil Science of the leading soil scientists of the Empire to ascertain the present position of surveys of soil resources in the different countries, and to learn from them the most suitable directions along which the future work of the Committee may be conducted.

INLAND WATER SURVEY.

Third Report of Committee appointed 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 (Vice-Adml. Sir H. P. DOUGLAS, K.C.B., C.M.G., *Chairman*; Lt.-Col. E. GOLD, D.S.O., F.R.S., *Vice-Chairman*; Capt. W. N. MCCLEAN, *Secretary*; Mr. E. G. BILHAM, Prof. W. S. BOULTON, Dr. BRYSSON CUNNINGHAM, Prof. C. B. FAWCETT, Prof. W. G. FEARNSIDES, F.R.S., Mr. W. T. HALCROW, Prof. A. FERGUSON, Mr. H. J. F. GOURLEY, Dr. EZER GRIFFITHS, F.R.S., Mr. T. SHIRLEY HAWKINS, O.B.E., Prof. G. HICKLING, Dr. MURRAY MACGREGOR, Mr. W. J. M. MENZIES, Mr. H. NIMMO, Dr. A. PARKER, Mr. D. RONALD, Capt. J. C. A. ROSEVEARE, Dr. BERNARD SMITH, F.R.S., Mr. C. CLEMESHA SMITH, Dr. L. DUDLEY STAMP, Mr. F. O. STANFORD, O.B.E., Mr. A. STEVENS, Mr. R. C. S. WALTERS, Brig. H. ST. J. L. WINTERBOTHAM, C.M.G., D.S.O., Dr. S. W. WOOLDRIDGE).

I. ABERDEEN MEETING AND REAPPOINTMENT OF THE COMMITTEE WITH THE INCLUSION OF SECTION C.

THE Second Report of the Committee was presented at the Aberdeen Meeting, in September 1934, and the following resolution was approved by the four sections, A (Mathematical and Physical Sciences), C (Geology), E (Geography), and G (Engineering) :

'That the British Association awaits with great interest the result of the careful consideration which His Majesty's Government has promised to give to the question of an Inland Water Survey, and trusts that the Government will be favourable to the establishment of an organised survey of the water resources of the country on a scientific basis.'

At Section C, a discussion took place on Underground Water, introduced by Prof. W. S. Boulton, who said that he favoured the strengthening of the Association's Committee on Inland Water Survey by the inclusion of Section C, rather than the setting up of another Committee to deal with underground water measurement and records and other problems.

At Section G there was a paper on the organisation of river-flow measurements on the Aberdeenshire Dee, and there were visits to the gauging site to see the gauging apparatus in use. (The records for 1934, for this river, resulting from this survey, were published in April of this year.)

The then President of the Institution of Water Engineers, Mr. R. F. Baker, wrote as follows:

'In the allotment and control of water affecting many conflicting interests, it is advisable that the correct data as to rainfall, storage and flow should be available. This involves systematic measurement and records, which should be under the direction and supervision of a national authority so that the data may be on accepted lines, applicable to the consideration of the various problems involved.'

The Water Engineer of Aberdeen, Mr. T. F. Henderson, said that if the British Association could institute an Inland Water Survey Association, they would have the everlasting appreciation of the engineering profession.

This Second Report was published by the British Association in November, including the note of the resolution passed by the sections, and at the end of October notification of the reappointment of the Inland Water Survey Committee was received from the Secretary of the British Association.

II. Joint Sub-Committee of the British Association and Institution of Civil Engineers.

This joint Sub-Committee met on October 11 and 19. The following resolution was sent to the Council of the British Association, together with two memoranda:

'It is understood that the Council of the British Association will meet early in November and at their meeting will consider the resolution which was passed by Sections A, C, E and G at the Aberdeen Meeting relative to the Inland Water Survey Committee's Report. Assuming that the resolution is adopted, this Committee hopes that the Council will submit it, at an early date, to His Majesty's Government, and it is suggested by this Committee that at the same time the two attached memoranda should be forwarded so that His Majesty's Government may have a clear indication of the requirements as visualised by the Inland Water Survey Committee.'

Memorandum No. 1.

It is suggested that the survey should be organised and controlled by the Department of Scientific and Industrial Research, and that a Committee consisting of twelve persons should be formed: six to be selected from the Department of Scientific and Industrial Research and other Government

Departments interested, and six from the British Association, the Institution of Civil Engineers, and such other bodies as they may decide to invite ; in addition, a Chairman to be nominated by the Committee of the Privy Council for Scientific and Industrial Research and a Secretary from the Department of Scientific and Industrial Research.

Memorandum No. 2.

The object of the survey is to ascertain the quantity of water present in surface and underground resources, and to compile records which would be made available to the public. The Committee would not deal in any way with the use and allocation of water.

The functions of the Committee would be :

1. The division of the country into suitable areas for observation and record.
2. The standardisation of apparatus and methods of observation, and the issue of instructions for the guidance of operators.
3. The establishment of efficient gauges and measuring apparatus at convenient points on rivers and watercourses.
4. The general direction of operations, including :
   - (*a*) Gauge readings of the rise and fall of water levels in rivers and streams ;
   - (*b*) Measurements of stream and river flow ;
   - (*c*) Level readings of lakes and reservoirs ;
   - (*d*) Compilation of lists of springs, wells and underground water resources, with records of yield ;
   - (*e*) Calculation of discharges of rivers and streams, with compilation of tables therefrom ;
   - (*f*) Taking of profiles of lake and river beds.
5. The assemblage, collation and publication of the records and results obtained from the various local centres.
6. Other matters connected with or arising out of the foregoing.

This joint Sub-Committee met again on November 15, when Prof. P. G. H. Boswell intimated to them that the Council of the British Association were in touch with the Ministry of Health and had invited the co-operation of the Council of the Institution of Civil Engineers in support of the two resolutions passed at the British Association meeting at Aberdeen. The second resolution, with reference to the registration of wells, was given verbally by Prof. Boswell.

III. Statement on Inland Water Survey in the House of Commons.

On December 7, in answer to a question by Lt.-Col. Acland-Troyte, Sir Hilton Young, the Minister of Health, made the following statement :

'After consultation with the Department of Scientific and Industrial Research and other Departments concerned, and with their co-operation, the Secretary of State for Scotland and I have decided that a comprehensive inland water survey shall be undertaken for Great Britain. The information required for the purposes of the survey will be obtained by the Departments from water undertakers, catchment boards, and other qualified bodies and persons. In cases where records are desirable but are not now kept, measures will be undertaken to encourage the keeping of the necessary records. A Water Survey Committee, composed of persons outside Government Departments, will be appointed to advise on the survey and on the progress of measures undertaken. In the constitution of the Committee attention will be paid to the inclusion of both scientific and practical experience. It will be open to the Water Survey Committee to make recommendations on any further measures which they consider necessary for the purposes of the survey, and, particularly in the annual report, to state their views on the survey and to set out the conclusions to be drawn from the information received. Preliminary work has already been put in hand, and I hope shortly to announce the members of the Committee.'

The joint Sub-Committee of the British Association and Institution of Civil Engineers met on December 12, following the statement of Sir Hilton Young.

It was reported that the Council of the Institution of Civil Engineers had agreed to the request from the Council of the British Association to support them on the lines of the two resolutions aforementioned, passed at the Aberdeen Meeting of the British Association, and that the Council of the British Association had received from the Government the official copy of Sir Hilton Young's statement in the House.

At the direction of the joint Sub-Committee, the Secretary wrote to the Secretary of the British Association as follows, and received the following reply:

To O. J. R. Howarth, Esq.,
Secretary, British Association. 12th December, 1934.

Inland Water Survey.

Joint Sub-Committee of British Association and Institution of Civil Engineers Committees.

Dear Sir,—I am desired by the Chairman of this Committee and of the British Association Research Committee, appointed at Aberdeen, to inquire of the British Association if any reply to their resolution and memoranda sent to you on the 19th October may be expected, he having had no official communication to date from the British Association, although certain Press notices and a report of Sir Hilton Young's speech appearing in Hansard of the 7th December, 1934, lead him to believe that certain action by the Government may be expected in the near future.

An early reply will be appreciated.

Yours faithfully,
(Sgd.) W. N. McClean,
Honorary Secretary.

To Capt. W. N. McClean,
Parliament Mansions,
Victoria Street, S.W. 1. 14th December, 1934.

Dear Sir,—In regard to the resolution and memoranda forwarded by you on October 19. The following are extracts from the Council Minutes.

Nov. 2.

'The General Secretaries were instructed to consult the Institution of Civil Engineers and to co-operate with it in any action on the above resolution' (which had been circulated, with memoranda. This was done, and the I.C.E. expressed willingness to co-operate).

Dec. 7 (unconfirmed).

'It was reported that the I.C.E. wished to co-operate with the Association in forwarding to H.M. Government the resolution and recommendations proposed concerning the Inland Water Survey, but in view of a statement by the Minister of Health it was resolved that no further action be taken at present.' (The I.C.E. has been informed accordingly.)

I return with thanks your copy of Parliamentary Debates containing the statement referred to.

Yours faithfully,
(Sgd.) O. J. R. Howarth,
Secretary.

IV. Appointment of Inland Water Survey Committee by the Ministry of Health.

On February 6, 1935, *The Times* reported as follows :

Inland Water Survey.

Advisory Committee appointed.

The Minister of Health and the Secretary of State for Scotland have appointed a Committee to advise on the Inland Water Survey for Great Britain, on the progress of the measures undertaken and on further measures required, and, in particular, to make an annual report on the subject.

The members are :

Col. Sir Henry Lyons (Chairman), Sir Charles Bird, Prof. W. S. Boulton, Mr. G. Dallas, Mr. G. J. Griffiths, Lieut.-Col. F. Hibbert, Sir Clement Hindley, Mr. S. R. Hobday, Mr. W. A. Millar, Mr. D. Paul, and Mr. B. Verity.

The Secretary of the Committee is Mr. I. F. Armer, and any communications relating to the work of the Committee should be addressed to him, at the Ministry of Health, Whitehall, S.W. 1.

In constituting the Committee the object has been not to appoint representatives of organisations or interests, but to obtain a body of men of different classes of experience serviceable for the work to be undertaken.

On February 11, 1935, a meeting of the joint Sub-Committee was held. The appointment of the Government Committee was noted. It was also noted that the Council of the Institution of Civil Engineers had adopted the report of their Committee and had now appointed certain members of the Council, in lieu of that Committee, to deal with matters connected with Inland Water Survey. It was agreed that the joint Sub-Committee, therefore, ceased to exist.

V. Work of Main British Association Committee.

On February 22, by the kind permission of the President and Council of the Institution of Civil Engineers, a meeting of the British Association Committee was held in the Council Room of the Institution. Seventeen members or their representatives, and representatives of the Institution of Civil Engineers who had acted on the joint Sub-Committee, were present, and regrets for non-attendance were received from other members.

It was resolved :

'That the Council of the British Association be invited to forward Memorandum No. 2 to the Secretary of the Government Committee on Inland Water Survey.'

As a result of this resolution, on February 28, Sir Percy Douglas wrote to Prof. W. W. Watts, the President of the British Association, enclosing Memorandum No. 2 (see p. 326).

The following letter and enclosure were received from the Secretary of the British Association :

To Capt. W. N. McClean,
Parliament Mansions,
Victoria Street, S.W. 1.

Burlington House,
London, W. 1.
4th March, 1935.

Dear McClean,—I am directed by the President to thank the Chairman of the Inland Water Survey Committee for his communication of February 28th, and a copy of the letter which has been addressed to the Ministry of Health, enclosed herewith, will show him and your Committee that the Council has taken the action desired. A copy of this letter has also been sent to the Institution of Civil Engineers.

Yours very truly,
(Sgd.) O. J. R. Howarth,
Secretary.

To The Private Secretary,
The Ministry of Health,
Whitehall, S.W. 1.

Burlington House,
London, W. 1.
4th March, 1935.

Sir,—(1) I am directed by the Council of the British Association to request that there may be conveyed to the Minister a sincere expression of the Council's gratification that the Minister has caused to be appointed a Committee to deal with the question of an Inland Water Survey, a course which the British Association, in co-operation with the Institution of Civil Engineers, had the honour to urge upon H.M. Government through a deputation which the Minister was good enough to receive.

(2) As you are aware, the British Association has a Committee on this subject, which has presented two reports, and has now forwarded a brief memorandum of which I have the honour to enclose a copy by direction of the Council.

(3) I am further directed to bring to your notice a resolution which was put forward at the last annual meeting of the Association by the Section of Geology, and has been adopted by the Council, recommending 'That the Government be urged to make compulsory the registration of wells, borings and excavations exceeding 100 feet in depth, under conditions similar to those for the notification and registration of shafts and boreholes for mineral, contained in the Mining Industry Act of 1926.'

I am, Sir,
Your Obedient Servant,
(Sgd.) O. J. R. Howarth,
Secretary.

It was further resolved at the meeting of the Main Committee on February 22 :

'That a small Sub-Committee be appointed consisting of the Chairman and one representative from each British Association Section, to draw up a report for consideration by the Committee, framed in such a way as to leave it open for each representative to take the same viewpoint to his sectional Committee and to get a new Committee appointed with new terms of reference' ;

and the Committee appointed the following 'Sections' Sub-Committee:

Col. E. Gold (Section A), Prof. W. S. Boulton (Section C), Dr. L. Dudley Stamp (Section E), Mr. W. T. Halcrow (Section G), the Chairman and the Secretary.

VI. Report of the 'Sections' Sub-Committee.

This Sub-Committee met on March 11, at which meeting all members were present, and the following recommendations were agreed:

'1. The Sub-Committee recommends that at the Norwich Meeting of the British Association in September next, the various sections represented on the Inland Water Survey Committee be informed that the main purpose of that Committee, as defined in its terms of reference, appears to have been achieved by the reports of this Committee already published and by the appointment of the Inland Water Survey Committee by the Minister of Health and the Secretary of State for Scotland.'

'2. Nevertheless, the Sub-Committee is of opinion that valuable work may still be done by a British Association Committee, and it recommends that the present Committee be continued or a new Committee appointed with fresh terms of reference.'

'3. The Sub-Committee suggested that these terms of reference might include the following:

> 'To assist generally in promoting research into the inland water resources of the country on such lines as may best achieve this object.'

Col. E. Gold wrote, on March 28, suggesting that paragraph 3 should be modified to read:

> 'To assist generally in promoting research into the inland water resources of the country, and in particular into underground water supply and river flow.'

STRESSES IN OVERSTRAINED MATERIALS.

Report of Committee on Stresses in Overstrained Materials (Sir Henry Fowler, K.B.E., *Chairman*; Dr. J. G. Docherty, *Secretary*; Prof. G. Cook, Prof. P. B. Haigh, Mr. J. S. Wilson).

The Committee has directed particular attention to overstrain in mild and moderately high-tensile steels as used in current structural and general engineering practice in bridges, buildings, high-pressure pipe lines and other applications in which safety depends directly on the avoidance of undue plastic overstrain in the ductile metal.

The results of a number of investigations carried out on its behalf have been published in the Report of the Committee for 1931, and in the following papers:

- 'The Yield Point and Initial Stages of Plastic Strain in Mild Steel subjected to Uniform and Non-uniform Distributions of Stress,' by Prof. G. Cook, D.Sc. (*Phil. Trans. A.*, ccxxx, 103–147).
- 'The Elastic Limit of Metals Exposed to Tri-axial Stress,' by Prof. G. Cook, D.Sc. (*Proc. Roy. Soc. A.*, cxxxvii (1932), 559).
- 'The Stresses in Thick-walled Cylinders of Mild Steel Overstrained by Internal Pressure,' by Prof. G. Cook, D.Sc. (*Proc. I. Mech. E.* (1934), cxxvi, 407).

'The Effect of Fluid Pressure on the Permanent Deformation of Metals by Shear,' by Prof. G. Cook, D.Sc. (*Inst. of Civil Eng., Selected Engineering Paper* No. 170).

'The Lower Yield-Point in Mild Steel,' by Prof. B. P. Haigh, D.Sc. (Section G, British Association, Aberdeen, September 1934).

The Committee has considered these investigations together with other work bearing on the subject, particularly in relation to the requirements of the engineering profession and industry for present and future developments. The need for reconsideration arises in part from the increasing use of electric and other methods of welding in lieu of riveting in structural and general practice. While the practice of welding eliminates certain difficulties and dangers, it leaves the problem of plastic overstrain more prominently in the position of the limiting factor in design in many cases of economic importance. In such circumstances, it appears desirable that current methods of design should be adapted to recognise the danger of plastic strain in a more definite and formal manner, so that the margin of safety of a structure under its working loads may be judged by direct comparison with the overloads that would be required definitely to produce undue plastic overstrain in the ductile metal.

The investigations carried out by the Committee confirm the view that has long been held by many engineers, that the elastic-limit in the case of mild or moderately high-tensile structural steel is unsuitable for use as a reference value for purposes of design. The value depends unduly upon the method of testing adopted ; and when special precautions are observed to ensure that scientific accuracy is attained, the value appears to be much higher than is generally believed, and misleading for general application.

The yield-point of the material is considered to afford a more reliable basis for design in cases where plastic overstrain is regarded as the limiting factor ; but the yield-point also—as now generally measured in accordance with current standard specifications—is open to the objection that the value also varies according to the method of testing and probably with the rate of application of load in the tensile test.

The so-called 'lower yield-point' has been studied with particular attention and is considered to afford the most satisfactory and reliable basis for the comparison of structural steels and for the design of structures in which plastic overstrain must be limited ; and it is recommended that a specification of the lower yield-point should be adopted for the use of those who may desire to use it. At present, although the lower yield-point is already used by many who have experience of its advantages, no specification for its measurement appears among the British Standard Specifications for yield-point.

The advantages of the lower yield-point, as a basis for the comparison of different structural steels and as a basis for design, may be summarised as follows :

(1) In samples of mild or moderately high-tensile structural steel the value of the lower yield-point is readily determined in any ordinary tensile testing machine without the use of an extensometer or other sensitive or costly equipment.

(2) Consistent values are obtained without any undue change in the current procedure for tensile testing, and are likewise obtained when the method of procedure is varied within limits to permit of changes to suit local conditions.

(3) Although the value depends perceptibly upon the rate of straining adopted in the test, the variations that may be found when the rate

is restricted during a brief stage of the test are only slight, and not of practical importance.

(4) The determination of the lower yield-point during the course of an ordinary tensile test should not add greatly to the total time required for the test.

(5) In structural members such as tie-bars, columns, beams, tubes and the like, of mild steel or moderately high-tensile steel, subject to determinate conditions of loading, the overloads required to cause undue plastic overstrain are readily calculated in terms of the lower yield-point of the steel employed.

(6) In welded structures comprising members subject to determinate loading, the calculated overloads required to cause undue plastic overstrain are closely confirmed in tests, when the joints between the members are of reasonable design.

(7) In welded structures of complex design the margin between the actual load and the calculated overload (at which undue plastic overstrain may be expected to occur in the light of calculations based on the lower yield-point of the steel) affords a serviceable guide to the designer.

In view of these considerations based upon investigation and experience, it is considered that the tensile lower yield-point offers advantages that justify its more general application in connection with structural design in mild and moderately high-tensile steel; but its application at present is restricted by the lack of an accepted British Standard Specification.

A draft of such a specification is submitted for consideration:

> ' After yield has commenced in a tensile test on a standard piece (comprising a portion that is tolerably uniform in section) and before it has spread along the whole of the portion of uniform section, the load shall be readjusted to a new, steady value (being reduced if necessary) so that yield spreads along the uniform portion while the machine continues to elongate the piece slowly (at a rate not exceeding $\frac{1}{16}$ in. per minute). The stress value deduced by dividing the readjusted load by the initial cross-sectional area of the uniform portion of the test-piece shall be known as the lower yield-point.'

Recommendation.—The Committee recommends that the desirability of adding a specification of the lower yield-point to the specifications of other properties of mild and moderately high-tensile steel, be brought to the notice of the British Standards Institution.

* * * * *

The terms of reference ' to investigate the stresses in overstrained materials ' were extremely wide. The Committee has investigated one important aspect of the problem. They do not ask to be reappointed, but suggest that further investigation of some of the special problems involved deserves serious consideration.

EARTH PRESSURES.

Tenth Interim Report of Committee on Earth Pressures (Mr. F. E. Wentworth-Shields, O.B.E., *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, F.R.S., Dr. R. E. Stradling, C.B., Mr. E. G. Walker, Mr. J. S. Wilson).

Since their last report, the Committee have had a meeting at the Building Research Station, Garston, at which Dr. Stradling and his staff fully explained the work which has been carried out during the past year on soil classification and soil mechanics.

The work is summarised in the attached 'Note on Soil Physics,' which was circulated to members of the Committee before the meeting. Briefly, it may be said that the work of the Research Station has been to obtain samples of soil in an undisturbed condition at various depths and to examine their properties such as water content, mechanical analysis, plasticity, shrinkage, etc., with the view to classifying them, and also their mechanical properties, such as compression and shear strength.

The Committee feel that investigation of this kind is an important step towards the estimation of such properties as the pressure and resistance of soils, which they have set out to try to ascertain, and consider it most important that this work should be carried on, and that either they or some Committee of Engineers should keep in touch with this work, so as to be fully acquainted with the results.

The Committee would, therefore, ask to be reappointed.

Note on Soil Physics.

In July 1934, the Committee of Earth Pressures considered two reports issued from the Building Research Station, the first by Professor Jenkin on 'The Mechanics of Granular Materials,' and the second, which was in the nature of an appendix to the first, on 'The Experimental Investigations of the Mechanics of Clay,' which described in detail the experimental methods developed by Prof. Jenkin.

Prof. Jenkin's work was essentially a fundamental investigation into the mechanics of granular material and his later work was directed towards the investigation of the properties of Kaolin. Although the aspect of the investigation has now been changed, advantage is being taken of the experimental methods and technique which he developed and the valuable ideas which he formulated on the dilatancy and compactibility of clays are being kept in mind.

In the present programme of work the method of approach to the problem is less of the nature of a fundamental investigation and is inclined more towards the practical application of the results of laboratory tests. In consequence experiments are not confined to one material, and all types of soil as they occur in nature are being examined. The term soil covers a wide range of materials which exhibit large variations in their mechanical properties. Because of this fact one of the first objects of the work is to develop a system of soil classification by means of which soils can be divided into broad groups according to their mechanical characteristics. Broadly speaking, the mechanical properties of a soil depend upon the following factors:

(*a*) The nature of the raw constituents which go to make up the soil.
(*b*) The 'structure' of the soil, or the way in which the soil particles are arranged in the soil skeleton.
(*c*) The water content.

As a means of preliminary soil classification, a method of characterising a soil by identifying its raw constituents has been followed. This method, which was developed by American workers, is based essentially on physical tests of an empirical nature. Although it is both rapid and useful, it is by no means wholly acceptable as a final method of soil classification. Work is now in progress with the object of developing a classification system based upon the experimental measurement of mechanical properties. For this purpose tests such as those developed by Prof. Jenkin for the measurement of compressive strength, consolidation and shear strength are being employed.

In parallel with this work investigations are being made into the influence on the mechanical characteristics of the structure of the soil as it occurs in its natural condition. For this research an apparatus has been devised and developed by means of which it is possible to obtain undisturbed soil cores of 4 in. diameter down to depths of approximately 12 ft. The tests mentioned above are being employed to investigate the mechanical properties, and interesting results have been obtained.

The second important object of the investigation is to correlate the results obtained in the laboratory with observations of actual structures. With this object in view, observations are being taken of :

(*a*) The settlement of a building both during and after construction.
(*b*) Seasonal fluctuations in the level of road slabs.
(*c*) Examination of failures in building structures which have occurred as the result of settlements.
(*d*) Examination of a failure in a retaining wall due to an embankment slide.

Experiments are being performed on samples of soil collected from these sites and with the accumulation of data it is hoped that correlation may be possible.

KENT'S CAVERN.

Report of Committee appointed to co-operate with the Torquay Natural History Society in investigating Kent's Cavern (Sir A. Keith, F.R.S., *Chairman* ; Prof. J. L. Myres, O.B.E., F.B.A., *Secretary* ; Mr. M. C. Burkitt, Dr. R. V. Favell, Miss D. A. E. Garrod, Mr. Lacaille).

The following report has been received from the excavators :

'Excavations were resumed on October 22, 1934, and have been continued to the end of May 1935. For the past three seasons this work has been carried on in the " Vestibule " of the North Entrance, and the present excavated area occupies the centre of this chamber.

'This season's digging has proved very remunerative in the quantity and large size of the animal relics. Several of the bones are remarkably free from injury and gnawing by carnivores. One would naturally expect that large portions of the beasts slain outside would be dragged into the entrance and partially devoured, before taking smaller morsels into the lairs farther in the cave. Apparently the " floor " was then composed of large rock fallen from the roof and walls, at all angles, and this could account for some of the bones having disappeared between the crevices, and thus escaping the jaws of the hyænas.

'Very few bones exhibited any trace of being water-rolled, but most were covered with a rough earthy stalagmitic coating, and others had been smashed by rock falls, whilst a great many were much disintegrated. Only two or three coprolites have been met with this season, and very few have been found in the "Vestibule" hitherto.

'The presence of man contemporary with the animals has been indicated by ten implements, flint chips and a small piece of bone curiously bored. These were distributed at various levels from a depth of 11 to 14 ft. below the datum line of the original stalagmitic floor. A fine ovate chert axe of Mousterian aspect was secured at the 14-ft. level, and at 12 ft. 6 ins. a quartzite pounder was dug up. The other flint implements and chips, at various levels, are probably of the Aurignacian culture. Amongst the unusually fine specimens excavated during the season may be mentioned the tibia of an Irish deer, which is believed to be the largest bone ever found in the Cavern, a radius, a very long rib of a rhinoceros, a well-preserved tooth of a mammoth, and the whole of the incisors of a horse.

'F. Beynon, Arthur H. Ogilvie.'

The Committee desires to be reappointed, with a further grant. None of the ground excavated this season has been filled in again, and next season it will be possible to go deeper ; skilled quarrymen will be required, and expenses will be heavier than heretofore.

CAVE DEPOSITS ON MT. CARMEL.

Report of Committee to carry out the Excavation of Palæolithic Cave Deposits on Mt. Carmel, Palestine (Prof. J. L. Myres, O.B.E., F.B.A., *Chairman* ; Mr. M. C. Burkitt, *Secretary* ; Miss G. Caton-Thompson, Miss D. A. E. Garrod).

The Committee has received the following report from Miss D. A. E. Garrod, who has been in charge of this excavation throughout :

Wady Mughara Expedition.

'The 1934 season lasted from March 28 till August 29, excavation being carried on continuously during this time in the cave known as the Tabūn (" Oven ").

'The members of the staff were as follows : Miss D. A. E. Garrod ; Miss A. H. Fuller (representing the American Society for Prehistoric Research), Assistant Excavator ; Miss J. Crowfoot (in charge of records) ; Miss E. Dyott (camp manager). Miss Fuller was obliged to leave early in July, and her place was to have been filled by Mrs. Waddington. Mrs. Waddington, however, went down with malaria after three days' work and was not able to rejoin us. The last seven weeks of the season were therefore short-handed.

'Miss D. M. Bate, of the British Museum (Natural History), spent three weeks in camp during May and June, and helped with the palæontological side of the work.

'The object of this season's work was to enlarge the trench and sounding, dug in 1933 in the terrace and outer chamber of the Tabūn, so as to expose the bed-rock over as large an area as possible. The excavation was divided into two main parts:

'(*a*) The 1933 excavation had left a long strip of deposit (surface area approximately 4 m. × 11 m.) in place along the S.W. wall of the outer chamber and terrace. In this strip excavation had been carried just below the base of Layer C (Lower Mousterian), *i.e.* 2·40 m. below datum. This area was labelled *Locus W*.

'(*b*) A fresh area was excavated on the slope of the terrace, immediately to the N.W. of the 1933 trench. After the superficial deposit (Layer A) had been cleared, the surface of the archæological layers was found to run from 2 m. to 8 m. below datum. In spite of the steep slope of the deposit, Layers C and D (Levalloisian) were found to be still in place over the greater part of this area, but they petered out towards the base of the slope. Layer B was absent, having petered out within the limits of the 1933 trench. This area was labelled *Locus N*.

'*Locus W*.—All through Layer D the deposit was extremely hard, and flints were sparse. A fair amount of animal bone was obtained, especially against the S.W. rock wall. Artefacts and fauna corresponded with those found in 1933, the industry being in the Levalloisian tradition with a high proportion of points and triangular flakes, while the animal remains point to a warm, damp period.

'The surface of Layer E (Acheuleo-Mousterian) was reached at 4·60 m. below datum on the outer edge of the Locus, but it rose to 4 m. below datum against the S.W. rock wall.

'In 1933 Layer E was subdivided into E*a*, E*b*, E*c* and E*d*. This year's work, while confirming a gradual modification in the industry throughout the layer, showed that the typological divisions were very much less clearly marked than the finds made in the 1933 trench had led me to suppose. In particular, the diminution in size of the implements in E*b* turned out to be illusory, as did the localisation of La Micoque hand-axes in E*c*. These hand-axes did, indeed, appear round about this level, but their arrival and disappearance was much more gradual than in the 1933 trench. Another interesting point was that the proportion of hand-axes to flake implements was much greater in *Locus W* than elsewhere. Stores of hand-axes were found in different places all through Layer E.

'My hope that animal bones would prove to be more abundant against S.W. rock wall than in the 1933 trench was justified, and we now have a good idea of the fauna of the Acheuleo-Mousterian stage. Both rhinoceros and hippopotamus are present, so it seems clear that this stage falls within the warm, damp period already known in C and D. A new and important find was a large portion of a tusk of elephant—the first Pleistocene elephant recorded from the Near East. Unfortunately no molars were found, so it will not be possible to identify the species. This tusk was found in E*c* at 7·70 m. below datum.

'From the surface of E*a* downwards the S.W. rock wall sloped sharply away, so that by the time E*d* was reached *Locus W* had approximately doubled its area. As the wall continued to recede it became evident that it would be impossible to excavate the whole area in one season and with the funds at our disposal. Another disconcerting feature was that the base of E*d* plunged very steeply to the S.W.: this was made clear by the work that was being carried on concurrently in *Locus QQ*, which remained about

4 m. ahead of that in *Locus W* for the greater part of the time. As animal bones had ceased to appear against the S.W. rock wall, I decided to cut out this part of the excavation ; a platform 4 m. in width was therefore left in place against the rock wall from 8·65 m. below datum downwards. The remaining area was then excavated to 10 m. below datum, when it became apparent that even this reduced scheme was too ambitious. A second platform 4·75 m. in width was therefore cut, and work on the reduced strip of *Locus W* was carried to 12·60 m. below datum, after which it was amalgamated with the main part of the excavation under the label *Locus QW*.

'The surface of Layer F (Upper Acheulean) was reached at 9·30 m. below datum on the extreme outer edge of *Locus W*, but it plunged steeply to 12 m. below datum on the inner side.

'*Locus N*.—The excavation of the N.W. slope of the terrace so as to bring it to the same depth as the 1933 trench occupied five weeks. Layers C and D were found to be comparatively thin in this area, and only a small amount of material was obtained from them. In Layer E*a* flints were less abundant than in other Loci, but some good animal bones were obtained. When the level of the 1933 trench was reached at 6·40 m. below datum in the upper part of Layer E*b*, work was extended so as to include the area of this trench. In 1933 a large sounding had been made in the floor of the excavation (6·40 m. below datum to bed-rock) ; this was Sounding Q, and the area now remaining to be excavated lay on three sides of this, the fourth (S.E.) side being left to form the base of the great control section in the inner chamber of the cave. The area lying round three sides of Sounding Q was labelled *Locus QQ*, and was excavated concurrently with *Locus N*.

'In *Locus N*, Layer F (Upper Acheulean) was reached at 9 m. below datum. Some good hand-axes were found, and although larger bones were rare, a large number of small bones (rodents, birds, etc.) were collected, and Miss Bate thinks these may give interesting results.

'At 10·90 m. below datum the excavation of *Locus N* was brought to an end, as a massive buttress projecting from the N.E. rock wall, which gradually spread outward as the trench grew deeper, now ran right across the excavation, forming a barrier of rock between *Locus N* and *Locus QQ*. The material obtained from *Locus N* at this level was very sparse, and its continued excavation would have made access to *Locus QQ* very difficult.

'*Locus QQ*.—As I have already said, *Locus QQ* was excavated concurrently with *Locus N*. The material obtained from it closely resembled that obtained from Sounding Q last year. The most notable find was a human molar, which lay close to the N.W. rock wall in the upper part of E*b*, at 6·50 m. below datum. With the exception of birds and rodents, animal bones were much more sparse than in *Locus W*.

'The surface of Layer F (Upper Acheulean) was reached at 9 m. below datum on the N.E. side of the area, but on the N.W. and S.W. sides the base of E*d* showed the beginning of a deep plunge to the S.W.

'Layer G (Tayacian) was reached at 10·60 m. below datum on the N.E. side, but it sloped steeply away to the S.W. It rested immediately on bed-rock, which in its turn sloped so steeply that one could not definitely say that the floor of the cave had been reached at any point. Flints were very sparse in Layer G, and show exceedingly poor workmanship. No bones were found.

'At 12·60 m. below datum *Locus QQ* and the remaining strip of *Locus W* were amalgamated as *Locus QW*, and worked as a single area.

'*Locus QW*.—The steep slope of the rock and its overlying deposits greatly complicated the task of excavation in this area, but I was helped by the fact that the stratification showed up quite clearly in the S.E. wall of the trench. The bed-rock sloped downwards from 12·60 m. to 15·50 m. below datum over more than three-quarters of the Locus, but was never reached in the extreme S.W. strip.

'Layer G (Tayacian) showed a maximum thickness of 3·50 m., but thinned out very rapidly to the S.W. The S.W. side of the Locus was occupied exclusively by Layer F, which here descended nearly vertically. A considerable number of good hand-axes came from this restricted area, but no bones were found.

'Excavation was brought to an end on August 25, at 15·50 m. below datum, as the S.W. strip of the trench was now too narrow to allow of further digging. Layers F and G at this point plunge very steeply indeed to the S.W., and it is plain that a large swallow-hole lies under the unexcavated part of *Locus W*. It seems probable that this hole was already more or less filled with deposit at the time that Layer G was laid down, and that the subsidence of G, F and the base of E is due to subterranean drainage, which at some time during the Acheuleo-Mousterian occupation of the cave caused the deposits filling the swallow-hole to filter away, and drew the existing archæological layers into the swallow-hole in their place.

'The excavation of this swallow-hole would involve two or three more seasons at least, and as it is doubtful whether the results would justify the expenditure of so much time and money, the excavation of the Tabūn may be considered as complete for purposes of publication.

'D. A. E. GARROD.'

The Committee asks to be reappointed, with a further grant, in order to make adequate arrangements for the publication of this very important piece of work.

DERBYSHIRE CAVES.

Thirteenth Interim Report of Committee appointed to co-operate with a Committee of the Royal Anthropological Institute in the exploration of caves in the Derbyshire district (Mr. M. C. BURKITT, *Chairman*; 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).

WORK during the current year has been confined to Creswell Crags, where Mr. Leslie Armstrong, F.S.A., has continued his excavations and reports as follows:

'Since the presentation of my last report the excavation of the section in the rear of the main chamber, then in progress, has been completed, and a typical vertical section, showing the entire stratification of the cave deposits, a total thickness of 19 ft., is now exposed to view.

'The work upon this section has been carefully carried out so as to facilitate the permanent preservation of this section and to prevent, as far as possible, any slipping of the face. As now exposed, it is crowned by a layer of hard crystalline stalagmite, from 9 to 12 in. in thickness, which has been left projecting from 1 to 2 ft. beyond the face of the underlying deposit, in order to reveal the nature of the layer sealing the cave-earth and also provide protection to the exposed face beneath against erosion by dripping water. The excavation has been carried out in a series of steps, arranged to synchronise with the main divisions of the stratification, by which means valuable horizontal exposures have been obtained of the two slab layers which, throughout the cave, have consistently separated the Mousterian (1) and (2), and Mousterian (2) and (3) levels, and additional security given thereby to the intervening vertical faces. In front of this type section, a pit has been formed and the bed-rock of the cave left exposed therein for a horizontal distance of 6 ft.

'As instructed by the Cave Committee, I have approached the Ancient Monuments Committee for Derbyshire with a view to the early scheduling of the Pin Hole Cave, and preservation of the type section, as an Ancient Monument. If the support of the Council of the Association can be secured by the Cave Committee, through Section H, the attainment of this desirable object would be considerably assisted.

'My excavations in the Pin Hole commenced at a point 23 ft. from the entrance, where those of the 1875 excavations, by the Rev. Magins Mello, had terminated. It is clear, from his published account of the work, that only the upper cave-earth was removed in 1875, and that merely the top of the lower deposit had been superficially examined by him. Having regard to the two important Mousterian occupation levels, the presence of which the present excavations have revealed in the lower cave-earth, I considered that the work here could not be looked upon as satisfactorily completed without a critical examination of the deposits in the entrance, left intact by Mello, and therefore, upon ceasing work on the rear section, activities were transferred to the entrance, where, at the time of writing, excavations are still in progress. A length of 13 ft. has been examined and, as anticipated, only superficial disturbance of the deposit has previously taken place and extended, at most, down to the uppermost of the two layers of fallen slabs. Both Mousterian (1) and (2) levels are found to be present. Traces of occupation by man or animals were at first scanty, but have become more plentiful as the work has extended further towards the interior and agree in character with the findings already recorded. Amongst the artifacts found here, a fine side scraper, in quartzite, from the Mousterian (2) level, is the most noteworthy. No additions have been made to the list of recorded fauna.

'*Mother Grundy's Parlour*.—A further area of this site has been excavated and valuable additions made to both the fauna and the artifacts. These confirm the conclusions reached in 1924 (Armstrong, *J.R.A.I.*, **55**, 1925), but in the light of the evidence since obtained in the Pin Hole excavations, I am of opinion that the quartzite implements, occurring in the yellow cave-earth of the base level, may be assigned, on their technique, to a Mousterian (3) occupation. The gradual development of the Aurignacian culture and its emergence into the microlithic, also the continuous occupation of this site until the coming of a microlithic culture, has been further demonstrated.

'The following additions have been made to the fauna of the respective zones previously recorded :

	Base.	Lower Middle.	Middle.	Upper Middle.
Hyæna (*H. spelæa*) . .			×	
Wolf		×	×	
Lion (*Felis spelæa*) . .		×		
Reindeer (*Cervus tarandus*) .			×	
Pig			×	×

'The presence of reindeer in the Middle Zone was previously indicated by only one fragment of antler, occurring near the bottom of the zone. A further fragment of antler and two teeth have been recovered from the middle and near the base of the zone respectively.

'The work carried out in 1934–35 has been made possible through a grant from the Derbyshire Archæological Society, generously provided for the specific purpose of completing the Pin Hole excavations; which is gratefully acknowledged. Other work has been financed privately.

'*The Boat House Cave.*—Through lack of funds, it has unfortunately been impossible to take advantage of the opportunity available for the examination of this promising cave. A considerable amount of "dead" work is necessary there before the relic bed can be reached: in order to remove the material of the lake embankment, which at present occupies the front of the cave and blankets the deposits to a depth of 6 ft. For this work the employment of additional labour is imperative and it will be necessary to return the material and re-form the bank, on completion.

'A grant of £25 is, therefore, earnestly requested for the initiation of this new work.'

SUMERIAN COPPER.

Sixth Interim Report of Committee appointed to report on the probable sources of the supply of Copper used by the Sumerians (Mr. H. J. E. Peake, *Chairman*; Dr. C. H. Desch, F.R.S., *Secretary*; Mr. H. Balfour, F.R.S., Mr. L. H. Dudley Buxton, Prof. V. Gordon Childe, Mr. O. Davies, Prof. H. J. Fleure, Sir Flinders Petrie, F.R.S., Dr. A. Raistrick, Dr. R. H. Rastall).

(Report by the Secretary.)

A short report was submitted to the Committee at the Aberdeen meeting of the Association, but was not ready in time for printing on account of the late arrival of specimens. The matters contained in it have therefore been incorporated into the present report, which thus covers the work of two years. A much larger number of specimens has been received during the past twelve months. Mr. W. H. Withey has performed many of the analyses, whilst Miss I. H. Hadfield has used the methods of micro-chemical analysis for objects of which only a very small quantity of drillings was available. Museum curators may be interested to know that a full quantitative analysis of a copper or bronze object can be made on one-twentieth of a gramme of material, so that a sufficient quantity of drillings may be obtained from a very small drilled hole on the under side of an object.

In the earlier reports, many of the specimens were indicated only by British Museum numbers, sometimes with the addition of 'early' or 'late.' In the full publication of Sir Leonard Woolley's results from Ur,[1] the analyses carried out by the Committee, with a few additions, are tabulated in chronological order by Dr. Plenderleith. It thus appears that the single object of the al 'Ubaid period so far found is of nearly pure copper; that of eleven objects from the Royal cemetery, nine are bronze, whilst two contain only small proportions of tin, that both copper and bronze occur in the Sumerian period, but that objects of the Sargonid period are either of copper or contain a very small proportion of tin. A bar of copper is described as of the 'Sumerian revival, *c.* 2500 B.C.'

[1] Ur Excavations. II. The Royal Cemetery, 1934.

Several vessels obtained by Sir Leonard Woolley from the Jemdet Nasr level at Ur have now been analysed, with the following results :

	1. Per cent.	2. Per cent.	3. Per cent.	4. Per cent.
Copper . .	48·18	55·59	55·66	67·23
Nickel . .	trace	0·02	—	0·075
Arsenic . .	0·65	0·20	0·39	0·93

Tin was absent.

On account of the highly corroded state of these specimens, it was not considered safe to calculate the composition of the original metal, but all may be described as arsenical copper. The first two contained much chloride, and were embedded in soil containing large quantities of soluble chlorides and sulphates, but no trace of tin, which might have been extracted from the metal, was found. Specimens 1 and 2 contained sulphur, indicating a pyritic ore, but this was absent from 3 and 4. The amount retained by the metal would be accidental, and liable to vary greatly in successive casts.

A copper rod sent with one of the vessels (Jemdet Nasr level), and marked PG Pit W. JNG, was less corroded, and gave on analysis :

Copper	82·33 per cent.
Tin	—
Nickel	0·05 ,, ,,
Arsenic	0·34 ,, ,,
Sulphur	0·11 ,, ,,

Further specimens collected for the Oriental Institute of Chicago, by Dr. Frankfort and by Dr. von der Osten, have been examined, supplementing the list given in the Fifth Report. Their composition is as follows :

	Copper. Per cent.	Tin. Per cent.	Nickel. Per cent.	Arsenic. Per cent.	Lead. Per cent.	
Tell Asmar, Akkadian :						
As. 32.1027 Pin .	85·15	—	1·68	0·39	—	
As. 32.1205 Haft .	63·62	—	0·11	0·24	—	
As. 32.1239 Wire .	92·70	—	0·07	—	—	
Tell Asmar, Early Dynastic :						
As. 32.1138 Chisel .	91·60	0·40	1·70	—	—	Iron 1·2
Khafaje, Early Dynastic :						
Kh. II 75 Arrow butt	74·22	—	0·06	0·47	—	
Kh. II 80 Nail head	79·93	—	0·02	0·38	—	
Kh. II 87 Graver .	67·10	4·34	0·09	0·64	0·86	
Kh. III 44 Dagger .	89·99	2·98	0·30	0·94	—	
Kh. III 215 Pin .	88·98	3·44	0·09	1·06	—	
Kh. III 688 ,, .	94·45	0·32	0·07	0·83	—	
Kh. III 729 ,, .	53·73	3·33	0·03	—	trace	
Kh. III 850 ,, .	87·50	10·64	0·09	0·68	—	
Kh. III 904 Blade .	83·22	9·82	0·16	0·23	—	
Kh. III 1072 Pierced Pin	93·63	0·29	1·42	1·80	—	
K. 319 Pin .	83·37	1·31	0·02	—	—	(Sulphur present)
K. 344 Lump	80·63	—	0·06	trace	—	

	Copper. Per cent.	Tin. Per cent.	Nickel. Per cent.	Arsenic. Per cent.	Lead. Per cent.
Alishar Hüyük :					
e 832	85·29	0·22	trace	0·05	trace
e 860	46·41	7·16	,,	0·11	2·13
e 936	51·78	8·19	0·07	0·06	0·81
e 962	43·09	0·97	trace	—	—
e 1554	55·08	—	—	2·43	— (Sulphur 2·75)
e 1801	59·23	6·05	0·06	0·29	0·25
e 2037	55·75	—	—	—	—

Some of these specimens being almost completely oxidised, the analyses have been reported as found, but it would probably be safe to recalculate to the unoxidised material, as when separate analyses of the outer crust and the metallic core have been made the results have been found to agree satisfactorily. As in the analyses previously reported from these sources, copper and true bronze are found in deposits of the same age, whilst some specimens contain intermediate quantities of tin. The presence of nickel and arsenic in most of them is characteristic, and points to a northern origin.

A cup-shaped vessel of the Luristan bronze series, from Dr. Plenderleith, gave :

Copper	90·59 per cent.
Tin	8·10 ,, ,,
Nickel	0·15 ,, ,,
Arsenic	0·12 ,, ,,
Iron	0·24 ,, ,,

The rest oxygen.

A fragment of a 'bronze' lion from Shibam, Hadramout, Southern Arabia, was received from Dr. Plenderleith. It was only slightly corroded, and gave :

Copper	81·6 per cent.
Tin	5·1 ,, ,,
Nickel	0·3 ,, ,,
Arsenic	trace
Lead	4·0 ,, ,,
Iron	0·5 ,, ,,
Sulphur	0·2 ,, ,,

An important series of objects, in a very perfect state of preservation, was received from the Wellcome Archæological Research Expedition, having been found at Tell Duweir (Lachish) by Mr. J. L. Starkey. These are dated about 2700 B.C., and are mainly copper.

		Copper. Per cent.	Tin. Per cent.	Nickel. Per cent.	Arsenic. Per cent.	Lead. Per cent.	Iron. Per cent.
D. 1500/2272	Lump	94·26	—	0·07	—	2·32	2·28
D. 1513/1831	,,	96·9	—	0·07	trace	0·5	0·5
D. 2009/2303	Dart	95·1	—	—	,,	—	0·5
D. 2032/2349	Javelin	96·0	—	—	,,	—	0·7
D. 2111/2481	Dart	96·8	—	—	,,	—	1·2
D. 2111/2482	Dagger	93·7	—	—	,,	—	2·6
D. 2049/2381	Dart	92·8	—	trace	,,	—	0·3

Two daggers from the same tomb from Tell el Ajjul, about 2000 B.C., were examined for comparison :

		Copper. Per cent.	Tin. Per cent.	Nickel. Per cent.	Arsenic. Per cent.	Lead. Per cent.	Iron. Per cent.
D. 1552/2197	Dagger .	97·4	—	0·1	trace	—	0·3
D. 1552/2199	,, .	97·5	—	0·1	,,	—	1·0

Traces of sulphur were present in the last two.

These copper objects from Palestine are clearly derived from a different source from the Mesopotamian objects. It was therefore of special interest to examine samples of ore and slag obtained by Mr. Starkey from the Arabah region. The ore, from Wadi Menaieieh, 35 km. north of Akaba, proved to be a mixture of malachite and azurite, giving 13·74 per cent. of insoluble matter, almost entirely silica, and 38·68 per cent. of copper. No tin, arsenic, nickel or lead could be detected. The slag, from Umrashrash shore, 5 km. west of Akaba, was a silicate of iron containing some manganese, with 4·30 per cent. of copper. There was no tin, nickel, arsenic or lead, and the slag is of such a composition that it might well have been produced in the smelting of the ore just described.

Two slags, containing 2·02 and 0·44 per cent. of copper respectively, were obtained from sites to the west of Bandar Abbas. Both were silicate slags, rich in iron, with no nickel or tin, but a trace of arsenic was detected in the first.

An Early Minoan triangular dagger, found in a tomb at Platana, in Crete, was submitted by Mr. O. Davies, and proved to be of bronze :

Copper	79·02 per cent.
Tin	9·01 ,, ,,
Nickel	0·11 ,, ,,
Arsenic	0·47 ,, ,,
Lead	0·29 ,, ,,

The presence of both nickel and arsenic, the two key elements in this investigation, is interesting.

Two specimens, found by Mr. Mackay at Mohenjo-daro, marked D.K. 5016, proved to be an ore of copper and a block of metallic lead. The ore gave :

Copper	76·15 per cent.
Tin	—
Nickel	0·23 ,, ,,
Arsenic	0·37 ,, ,,
Lead	trace
Sulphur	1·12 ,, ,,
Insoluble matter	4·80 ,, ,,

This would be an easily smelted ore. The lead, after removing a thin crust of sulphate, was found to contain 99·70 per cent. of the metal, with only 0·05 per cent. of copper and a trace of silver. Such a metal must have been smelted from a very pure ore.

Miss Winifred Lamb submitted a large number of specimens from her excavations at Thermi, Lesbos. These will appear, with those previously reported to the Committee, in her forthcoming report on the site. Almost pure copper and true bronze are found irrespectively of the levels, and both nickel and arsenic are frequently present, the latter occasionally to the extent of 1 or 2 per cent. Further specimens are under examination before attempting a complete classification.

The grant of the Association to the Committee has been supplemented by donations of £10 10s. from Sir Henry Wellcome and of £2 2s. from Miss W. Lamb. Thanks to these generous aids, it is possible to examine sufficient objects to keep pace with the excavations proceeding on Sumerian sites or in regions connected with allied civilisations. A better knowledge of the ores available, especially in the Northern Highland region, is very desirable, but it has been found difficult to obtain specimens. A short paper [2] by the Secretary states the position of the problem of the origin of bronze, and points out the need for more information as to sources of tin. There are at present no facilities, other than those provided by this Committee, for the analysis of copper and bronze objects from these early sites, and the experience gained in this work is increasingly made use of by museums and by excavators, at home and abroad. There are, however, no outside funds available for the purpose, although its importance is recognised. The Committee, therefore, asks for reappointment, with a grant of £25.

BLOOD GROUPING.

Report of Committee appointed to investigate the blood groups among primitive peoples (Prof. H. J. Fleure, *Chairman* ; Prof. R. Ruggles Gates, F.R.S., *Secretary* ; Dr. J. H. Hutton, C.I.E., Mr. R. U. Sayce).

During the past year arrangements have been made for taking the blood groups of primitive peoples in various parts of the world. It is expected that the results of testing the Eskimos in the region West of Hudson Bay will be available when the Canadian Government Expedition returns this summer. Arrangements have been made for testing various tribes in Kenya, including the Masai, Kavirondo and Kikuyu. In India the Haffkine Institute has arranged to supply serum to Dr. E. J. Macfarlane for testing the so-called white Jews and black Jews of British Cochin, and to Mr. A. Aiyappan for testing certain jungle tribes. Connections have also been made with certain anthropologists in Western China, and as soon as conditions are more settled it is hoped that tests of the Lolo, Miao and other tribes in this region will be obtained. Blood tests of the Congo pygmies are now available. During the present summer it is hoped that tests will be obtained of the Micmac Indians in Nova Scotia. Serum for this purpose has been donated by the Wellcome Physiological Research Laboratories.

SYSTEMATIC ANATOMY OF TIMBER-PRODUCING TREES.

Report of Committee for the Investigation of the Systematic Anatomy of Timber-producing Trees (Prof. H. S. Holden, *Chairman* ; Dr. Helen Bancroft, *Secretary* ; Prof. J. H. Priestley, D.S.O.).

During 1934–35 work has been continued on the Monotoideæ (Dipterocarpaceæ) and the genus *Ulmus*. The following papers have been published :

(1) 'New Material of *Monotes Kerstingii* from the Gold Coast' (*Kew Bulletin*, No. 6, p. 233. 1934).

[2] *Newcomen Society Transactions*, 1933–34, **14**, 95.

(2) 'The Taxonomic History and Geographical Distribution of the Monotoideæ' (*American Journal of Botany*, xxii, 505. 1935).
(3) 'Notes on the Status and Nomenclature of the British Elms' (seven articles in the *Gardener's Chronicle*, August to November 1934).
(4) 'The Elm Problem' (*Quarterly Journal of Forestry*, April 1935).

The following will appear shortly:

(1) 'The Wood Anatomy of Representative Members of the Monotoideæ' (*American Journal of Botany*).
(2) 'Material of *Marquesia acuminata* from Northern Rhodesia' (*Kew Bulletin*).
(3) 'The Dipterocarps in Africa' (a note in the *Empire Forestry Journal*).

Continued work on the Monotoideæ supports the view, expressed in last year's report, that the members of the group are closely related to one another, and, as a whole, to the Dipterocarpaceæ rather than to the Tiliaceæ; and that the timbers can be of little value economically outside the areas where they occur naturally.

New material from Nigeria has just come to hand; this, in conjunction with the fossil Dipterocarps from Mount Elgon (described in detail in the *American Journal of Botany*, vol. xxii, p. 164, 1935), indicates very interesting possibilities with regard to the previous history of the Dipterocarps in Africa.

The work on the Elms has indicated that the genus is in a highly variable and plastic condition, and that hybridisation has taken place freely amongst the British species. A considerable amount of field-work outside the British area has also been carried out in this connection.

The timbers of the different species and hybrids vary greatly in their value from the utilisation point of view; and a thorough systematic investigation of those types which produce easily worked timber is desirable.

SECTIONAL TRANSACTIONS.

SECTION A.
MATHEMATICAL AND PHYSICAL SCIENCES.

Thursday, September 5.

DISCUSSION on *Nuclear physics* (10.0).

Rt. Hon. Lord RUTHERFORD OF NELSON, O.M., F.R.S.—*Recent advances in nuclear physics.*

Dr. C. D. ELLIS.—*Some problems in induced radio-activity.*

Dr. J. D. COCKCROFT.—*The production of induced radio-activity on protons and deuterons.*

Mr. M. L. OLIPHANT.—*The masses of the light elements as deduced from transmutation data.*

Mr. M. GOLDHABER.—*The nuclear photo-electric effect.*

The paper deals with the nuclear photo-electric effect, the disintegration of nuclei by γ-rays, which Dr. Chadwick and the author have been studying during the last year. Observations of such an effect were first made with heavy hydrogen, D, the nucleus of which can be split by high energy γ-rays according to the equation

$$D^2 + \gamma \longrightarrow H^1 + n^1.$$

The photo-protons and neutrons have been observed. From the energy of the photo-protons the binding energy of the deuteron can be determined and the mass of the neutron linked up with the masses of H and D. The experimental value for the probability of this photo-electric disintegration of D agrees satisfactorily with quantum theoretical calculations.

Investigations have also been made of the photo-disintegration of beryllium, first reported by Szilard and Chalmers. The energy necessary to remove a neutron from beryllium has been determined and a lower limit for the cross-section of disintegration of Be^9 by γ-rays of radiothorium has been found.

Dr. N. FEATHER.—*Photo-disintegration of the deuteron.*

A mixture of heavy methane and helium was introduced into an expansion chamber and photographs were taken with a source of radiothorium, of about 8 millicuries, placed directly above the chamber. Evidence for the disintegration

$$H^2 + hv \longrightarrow H^1 + n^1$$

was obtained in the form of short tracks of the protons emitted in this process. About 60 of these tracks have been measured and their angular distribution, with respect to the direction of incidence of the quantum, has been investigated. These data are discussed in respect of their bearing upon the mass of the neutron and the nature of the neutron-proton interaction.

Dr. P. B. Moon.—*The influence of temperature on the properties of slow neutrons.*

Fermi and his collaborators in Rome, having discovered the effect of fast neutrons in converting many elements into their radioactive isotopes, and the enhancement of this effect when the neutrons are made slow by collisions in hydrogen-containing materials such as paraffin-wax, suggested that many of the neutrons might lose so much energy as to reach thermal equilibrium with the material through which they diffuse. This suggestion was supported by the work of Bjerge and Westcott, whose investigations of the scattering, absorption and diffusion of slow neutrons showed that a neutron passing through wax or water should make very many collisions with hydrogen nuclei before becoming absorbed.

The existence of ' thermal ' neutrons was finally placed beyond reasonable doubt by the discovery that the amount of artificial radioactivity produced by slow neutrons in elements such as silver and copper depends upon the temperature of the medium through which the neutrons have been passing. For example, the artificial β-activity of silver may be increased by at least 30 per cent. if the neutrons producing it are cooled from room temperature to the temperature of liquid oxygen. No such change could occur with neutrons whose velocities were very much greater than those of thermal agitation.

Friday, September 6.

Presidential Address by Dr. F. W. Aston, F.R.S., on *The story of isotopes* (10.0). (See p. 23.)

Dr. G. Hertz.—*The separation of isotopes by diffusion* (11.0).

The lecturer reported on the experiments he has carried out for separating gaseous isotope-mixtures. By a single diffusion through a porous wall the ratio of the isotope concentrations can, in general, only be varied by a factor which is equal to the square root of the ratio of the molecular weights. There are two possibilities of arriving at a greater variation of the concentration ratio by a single diffusion process. One is : to let the mixture pass through a tube of porous material, with its outer wall adjoining a vacuum and the other : to apply the method of diffusion in flowing gas. In either case it has been possible, with neon-isotopes, to attain a 20 per cent. higher degree of concentration of the heavy isotope by a single diffusion. By combining a large number of separating units an apparatus has been created for the separation of the isotopes. By both methods a practically complete separation of the isotopes of neon and of hydrogen has been achieved. Neon 22 has been prepared containing less than 1 per cent. of neon 20. In experiments with water-vapour and with methane only a low degree of separation of the rare isotopes of oxygen respectively carbon has been reached till now. This may be due to the adsorption of these gases in the porous tubes and at the glass-walls.

Dr. G. W. C. Kaye, O.B.E.—*Noise.* (Experimental lecture followed by discussion) (11.30).

Since its York meeting in 1932 the British Association has been alive to the many indications in the country of awakening general and industrial interest in the very old problem of noise and its abatement. The two major factors to be reckoned with at the present time are doubtless noisy road transport and noise-transparent dwellings. The volume of road traffic continues to expand and large sections of the population are now electing to make their homes in close three-dimensional packing in structures of which the designs and materials are pre-eminently favourable to the transmission of both air-borne and structure-borne noises.

The Ministers of Transport and Health have set up noise committees to deal with motor vehicles and flats respectively, and both bodies have turned to the National Physical Laboratory for assistance. The British Standards Institution has very recently specified standards dealing with noise measurement; and the great railway and aircraft companies are giving much attention to the problem of reducing the background of noise for their travelling patrons.

The cardinal principle of noise abatement is to reduce it at the source, and to this end the co-operation of the engineer is imperative in very many cases. Should noise reduction at the source be impracticable, one must interpose noise barriers, and in this connection much study is being directed to the elucidation of the primary factors which make or mar the soundproofing of floors, walls and windows. The last line of defence against noise is the judicious placing of surface absorbents which may assist in appreciably lowering the noise level in a room, whether of internal or external origin.

Monday, September 9.

Joint Discussion with Section G (Engineering) on *Lubrication* (Section A room) (10.0).

Mr. J. H. Gibson.—*Introduction.*

Adequate lubrication is the life-blood of every slider bearing, and, conversely, all successful bearings, i.e. those which run with the minimum frictional loss, are designed and constructed to make the best use of the lubricating medium. A suitable oil may be regarded as the indispensable link in the mechanism. The elements of bearing design consist in so arranging the several parts that oil, in ample quantity, but not necessarily under pressure, is fed in between the relatively moving surfaces, where it can be automatically entrained by its natural adhesion to the shaft or collar, then rejected and replenished *ad lib.* by the action of the bearing itself.

The tapered clearance space existing in journal bearings facilitates the entry of the lubricant, and an internal pressure is generated in the oil film equal to the bearing load. The oil becomes heated, due to the resistance set up by the shearing action of successive layers. This heat is dissipated by radiation from the outer surface of the bearing or by cooling appliances—water-jackets or coils. In extreme cases the oil used is circulated through an external cooler.

For a long time thrust bearings presented an insoluble problem until Michell conceived the idea of providing tapered films round the thrust annulus, each film generating pressure to support its own share of the load. Single-collar thrusts have thus superseded the old standard multi-collar thrust blocks which, on account of their flat parallel bearing surfaces, were very limited as regards their load-carrying capacity and gave constant trouble due to unequal expansion of shaft and block.

The success attending the universal adoption of the single-collar thrust was followed by the utilisation of the same principle in important journal bearings. The solid top and bottom brasses are replaced by a series of tipping pads all round the journal which produce a ring of tapered oil films carrying a greatly increased unit load on a much shorter length of shaft.

Good clean oil of a viscosity dictated by load and speed is essential for all bearings. When they have been standing for some time and have to be started up under load, the lubricant should possess sufficient inherent 'oiliness' to ensure that however attenuated the film it shall 'persist' between the loaded surfaces and refuse to be squeezed out entirely. This obviates metallic drag and wear at starting, the full pressure film being 'struck' and maintained as soon as the shaft begins to revolve.

Bearings designed, constructed and operated as above described run for years without any sign of metallic wear or renewal of parts. The oil is the only element that wears, and this is easily replenished or renewed as may be required.

Dr. F. P. Bowden; Mr. D. Clayton; Dr. A. E. Dunstan; Mr. H. Higinbotham; Miss M. Nottage; Mr. J. E. Southcombe; Dr. W. J. D. Van Dijck.

Dr. F. J. W. Whipple.—*Recent advances in seismology* (12.0).

Seismology has two principal objects: one is to utilise the records of waves travelling through the earth to determine the structure of the planet; the other is to study the nature of earthquakes, their geographical distribution, the depth of the foci, the conditions under which they occur and their relation to regional geology.

The method of investigation of the waves is to utilise the records from seismographs in all parts of the world. An effective way of doing this is to collect the seismograms of a particular earthquake and compare the details. In general it is simpler to make use of the bulletins which are prepared at the observatories. Such bulletins are collected at Oxford, where the International Seismological Summary is prepared. By this system the epicentres of all but the very small earthquakes can be located and the times of transmission of the seismic waves can be compared. One of the objects of Prof. Turner in starting the I.S.S. was to provide material from which accurate tables of the average transmission times could be deduced. This material has been used with great skill and ingenuity by Dr. Jeffreys, who was assisted in the most laborious part of the work by Mr. Bullen, and Dr. Jeffreys is now able to state that the tables are consistent to a second. This remarkable achievement would not have been possible if it were not for the precision of the readings of the seismograms. This precision is to be attributed not only to the excellence of the seismographs, but also to the facility with which clocks can be regulated by the use of broadcast signals. Seismology owes much to wireless telegraphy.

The number of recognised types of wave is now quite large: Jeffreys and

Bullen include fifteen in their tables. Many of these were first identified by Gutenberg, who realised that waves striking the boundary of the earth's liquid core would be in part reflected and in part transferred from waves of compression to shearing waves or *vice versa*.

The great majority of earthquakes have their foci at depths less than 50 km., but there are others which have very deep foci. Turner insisted that this was the only possible interpretation of some of the observations discussed in the I.S.S. In the last five years much attention has been devoted to deep-focus earthquakes. Scrase and Stoneley demonstrated that such earthquakes can be recognised on our seismograms. Wadati and other workers in Japan find that the deep-focus earthquakes are distributed in a very remarkable way, indicating that there are well-defined flaws in the earth at depths of a few hundred kilometres, far below the basic level of isostatic compensation.

This is the most spectacular of the numerous recent advances in seismology.

DISCUSSION on the above paper.

Dr. A. T. J. DOLLAR; Prof. G. R. GOLDSBROUGH, F.R.S.; Dr. H. JEFFREYS, F.R.S.; Mr. COSMO JOHNS; Mr. E. TILLOTSON.

Tuesday, September 10.

DISCUSSION on *New stars* (10.0).

Dr. H. SPENCER JONES, F.R.S.—*General phenomena of new stars.*

Definition of a nova.

Historical novæ and bright novæ of recent years.

General sequence of events in a nova outburst; the light curve and spectral changes.

The absolute magnitude at maximum brightness.

Evidence for expansion of outer atmosphere of star and for ejection of one or more gaseous shells.

The later stages of a nova outburst.

Novæ in the Andromeda nebula.

Frequency of nova outburst and possibility that every star passes through the nova stage.

The explanation, by Milne's theory, of the nature of a nova outburst.

Mr. J. P. M. PRENTICE.—*The discovery of Nova Herculis*, 1934 (10.20).

Prof. F. J. M. STRATTON, D.S.O., O.B.E.—*The spectral changes of new stars* (10.40).

Before the principal maximum the usual spectrum is of α Cygni (or earlier) type, the absorption lines being markedly displaced to the violet and bordered on the red side by weak undisplaced emission lines. As maximum brightness is approached the displacements diminish and the spectrum becomes of later (or less highly ionised) type. After maximum the reverse takes place: displacements increase to the violet, multiple spectra are formed with different displacements and of different types—earlier types and larger displacements coming together. The absorption spectra give way gradually to emission spectra as the star becomes fainter; the bright bands are usually complex in structure, the radial velocities of some of the components displaced to the violet agreeing with those found earlier from the absorption spectrum. Forbidden lines appear, notably of [*O*I], including the green auroral line, of [*Fe*II] and later of [*O*III), the well-known nebular lines. The final spectrum is that of a Wolf-Rayet star, broad bright bands, suggesting the continued emission of gases. A spectroscopic examination of the growing disc round the nova shows that different parts of the bright bands come from different portions of the envelope. In the case of N Pictoris 1925, the nucleus of the star became multiple and the spectra suggest in general jets or streams of gas rather than spherical shells.

Prof. W. H. McCrea.—*Problems of the atmospheres of novæ* (11.0).

Theoretical work on the motion of the outer layers of a nova and of gases ejected by it; propagation of radiation, and radiation pressure, in the moving gases; 'diffusion drag' of the gases on each other.

Mr. E. G. Williams.—*The photometry of new stars* (11.20).

Photometric measurements give important additional information about novæ. The measurements are of three types, as follows:

(1) *Magnitude observations.*—These indicate that in a typical nova the light flux increases by about a hundred-thousand fold at the outburst. When in addition the colour and distance are known it is possible to estimate the amount of energy liberated.

(2) *Energy distribution data for the continued spectrum.*—When we know this we can find the 'colour temperature' of the star. For R S Ophiuchi 1933 this was found to be 4,000°, a low value which may be explained by selective scattering of the star's light in space. Nova Herculis, however, appears to have had a colour temperature of about 10,000°, which is what might be expected from the type of its spectrum.

(3) *Intensity-distribution measures for absorption lines and emission bands in the spectrum.*—A great deal may be learnt from study of such contours. We may note here that the shape of the several bright bands, due to hydrogen, conforms with the ejection hypothesis; in fact, it is possible, on certain assumptions, to derive from them the velocity distribution of the hydrogen atoms. Also, measures of the intensity of undisplaced absorption lines, due to ionised calcium atoms scattered in interstellar space, provide a very useful indication of the distance of the star. This method, when applied to R S Ophiuchi, gave a distance of over 3,000 light-years, whilst for Nova Herculis we find 1,200 light-years for the distance, so that the star at maximum was 30,000 times as bright as the sun.

Dr. A. B. Wyse and Mr. R. H. Stoy.—*Recent nova observations made at the Lick Observatory, California* (11.40).

(1) The scope of the Lick observations and their relation to a proposed general co-operative scheme for the observation of novæ.

(2) A summary of the more conspicuous changes in the spectrum of Nova Herculis since the beginning of April 1935, the time of its rapid diminution in brightness, with special attention to the behaviour of the forbidden emissions, the permitted oxygen and nitrogen emissions, and to the continuous spectra.

(3) On some recent observations in the spectra of the gaseous nebulæ of some emissions, previously observed in the later stages of certain novæ.

Mr. S. F. Markham.—*The meteorological basis of civilisation* (12.0).

Recent factory experiments on both sides of the Atlantic have proved conclusively that there are certain conditions of temperature, humidity and air movement under which workers are at their most efficient and most energetic. On the other hand, recent investigations into the 'poor white' problem show that even the best racial stocks quickly lose in energy and efficiency, and even in moral fibre, when subjected continuously to temperatures and humidities well above the ideal. Human efficiency and energy therefore have a distinct climatological basis, and the history of civilisation follows extraordinarily closely man's control of indoor temperatures and humidities. Investigations are to a certain extent handicapped by the absence of reliable statistics for radiation and air movement, and by the absence of any instrument which accurately records bodily sensations of comfort or discomfort.

Taking, however, meteorological information from all parts of the world, the paper shows that the civilised portions of the world to-day all enjoy certain conditions of climate and climate control, and that in the past great civilisations have only arisen where there has been an approximation to these conditions.

Dr. E. C. Bullard.—*Gravity determinations in East Africa* (12.30).

A series of gravity measurements has been made in E. Africa by a method which enables a large number of results to be obtained in a short time. The observed value of gravity over the plateau is found to be less than that calculated from the assumption that the surface features are simply resting on the crust. The natural interpretation of this is that the plateau is isostatically compensated, that is, that it is underlain by light matter which projects downwards into the denser substratum and supports the typography in the same way as an iceberg is supported by its roots.

Over the Rift Valleys a further deficiency of gravity is found; they are, therefore, underlain by more light matter than is required for isostatic equilibrium, and if gravity and hydrostatic forces were given free play their floors would rise. This means that they must be held under by the plateau on each side, which can only occur if there is sideways pressure. The Rift floor cannot have 'fallen in,' for if released it would rise, not fall. The gravity results, therefore, give what seems a conclusive decision between the 'tension' theory of Gregory and the 'compression' theory of Wayland.

DEPARTMENT OF MATHEMATICS (A*).

Monday, September 9.

Prof. W. H. McCrea.—*An attempt to examine the relation between physical postulates and mathematical axioms in general mechanical theories* (10.0).

The general problem of the use of geometry in physics. The physical basis for the use of Riemannian geometry in general relativity, and its generalisations in Weyl's geometry and in projective relativity. The construction of a geometry from physical postulates as carried out by A. A. Robb.

Procedure from postulates concerning the relations of matter rather than space time as carried out by E. A. Milne.

The ultimate physical aim, and the relation between physical results obtained by the various methods. Illustrations from a comparison of the results of general relativity and classical theory.

Dr. P. DIENES.—*On spaces with quadratic connection* (10.30).

The experimental verifications of relativity theory refer to quantities of the second order, whereas the underlying geometrical structures, Riemann geometry, metric spaces, are all derived from spaces with *linear* connection. In the Pascal-Vitali theory local (osculating) spaces of higher order have been systematically studied, but the local spaces are still dove-tailed by a linear connection. In this paper, by the example of quadratic connection, I show that such a theory can be completed into a homogeneous construction involving *new* geometrical tensors. Another advantage of our method is that it applies equally well to continuous and to discontinuous distributions.

A vector v^a, $a = 1, 2, \ldots, n$, issued from the point

$$Q(x^1 + dx^1, \ldots, x^n + dx^n)$$

viewed from $P(x^1, \ldots x^n)$ appears as the vector

$$(1) \qquad v^a(Q \parallel P) \equiv v^a + \Gamma^a_{bc}(P)v^b dx^c + \tfrac{1}{2}\Gamma^a_{bcd}(P)v^b dx^c dx^d \quad \text{at } P,$$

where Γ^a_{bc} and Γ^a_{bcd} are two sets of arbitrary functions called *linear* and *quadratic connection parameters*, respectively. If we substitute (1) at P to v^a at Q, we also say that we transport v^a to P by 'parallel' transport. In a change of variables Γ^a_{bcd} are transformed by the formula

$$(2) \quad \Gamma^{a'}_{b'c'd'} = \frac{\delta x^{a'}}{\delta x^a}\left(\frac{\delta^3 x^a}{\delta x^{b'}\delta x^{c'}\delta x^{d'}} + \Gamma^a_{bc}\frac{\delta^2 x^b}{\delta x^{b'}\delta x^{d'}}\frac{\delta x^c}{\delta x^{c'}} + \Gamma^a_{bd}\frac{\delta^2 x^b}{\delta x^{b'}\delta x^{c'}} + \Gamma^a_{bc}\frac{\delta x^b}{\delta x^{b'}}\frac{\delta^2 x^c}{\delta x^{c'}\delta x^{d'}} + \Gamma^a_{bcd}\frac{\delta x^b}{\delta x^{b'}}\frac{\delta x^c}{\delta x^{c'}}\frac{\delta x^d}{\delta x^{d'}}\right).$$

For covariant vectors, and then for tensors of any type and rank, transport and parallelism can similarly be defined by two fresh sets $'\Gamma^a_{bc}$ and $'\Gamma^a_{bcd}$. The necessary and sufficient condition that transport and contraction be interchangeable is that

$$(3) \qquad \Gamma^a_{bc} + {'\Gamma^a_{bc}} = 0, \; \Gamma^a_{bcd} + {'\Gamma^a_{bcd}} + \Gamma^e_{b(c}\,{'\Gamma^a_{|e|d)}} = 0.$$

These definitions lead to the corresponding extensions of the idea of tensor derivatives.

The fundamental fact of the theory is that in a change of variables

$$(4) \qquad S^a_{bcd} = \Gamma^a_{bcd} - \frac{\delta\Gamma^a_{bc}}{\delta x^d} - \Gamma^a_{ed}\,\Gamma^e_{bc}$$

is transformed as a tensor of the type indicated by the position of the suffixes. Since $\Gamma^a_{bdc} = \Gamma^a_{bcd}$, the alternating (skew-symmetric) part of S^a_{bcd} in c, d is the Riemann-Christoffel tensor. Its symmetric part appears in the theory of metric spaces defined by the condition

$$(5) \qquad G_{ab}(Q \parallel P) = G_{ab}(P) \text{ for every } x^a \text{ and } dx^a.$$

In fact, the necessary and sufficient condition for (5) is

$$(6) \qquad S_{(ab)(cd)} = 0.$$

Another geometrical significance of the symmetric part $S^a_{b\,(cd)}$ is given by the formula

$$(7) \qquad v^a\,(P \parallel Q \parallel P) = v^a + v^b S^a_{b(cd)} dx^c dx^d.$$

Thus if we transport v^a from P to Q and back to P, we do not obtain 0 unless $S^a_{b(cd)} = 0$. Therefore this symmetric part expresses a kind of tension between neighbouring points.

Dr. E. T. DAVIES.—*Riemannian geometries of higher order* (11.15).

The ordinary theory of a Riemannian space, as studied by the methods of Ricci, depends largely on the fact that it can always be considered immersed in a Euclidean space E_N of higher dimensionality. A vector is then said to be a vector of V_n if it issues from one of the points of V_n and lies in the tangent Euclidean space to V_n at that point. The transport by parallelism (of Levi Civita) of a vector of V_n to a near point can then be carried out by a translation in E_N followed by orthogonal projection on the tangent plane to V_n at the new point. These notions, of vectors of V_n and parallelism between them, form the basis of the classical Riemannian Geometry.

The recent developments, arising chiefly out of the works of Bornfriani, Pascal and Vitali, are concerned with the study of vectors issuing from points of V_n, and lying in the r^{th} osculating space at these points. Parallelism between such vectors can be defined by an easy generalisation of that of Levi Civita for the ordinary case, and a covariant derivation has been introduced with properties analogous to that used by Ricci.

By using the notation introduced by Vitali, which depends upon the simple artifice of writing a single letter to denote a whole group of indices, the formal part of the work is hardly more complicated than in the classical Ricci theory.

It has very recently been proved that much of the ordinary theory of the immersion of one space in another can be extended without essential modifications to this case.

Dr. A. G. WALKER.—*The plan of geometry in relativistic cosmology* (11.45).

The object of this paper is to construct the most general kinematical model based upon two principles: the cosmological principle and the principle of symmetry. No particular geometry is prescribed, nor is it assumed that the fundamental observers are in uniform relative motion.

It is found that there is a quadratic differential form which is invariant under transformations from one to any other observer, and it is natural to consider the Riemannian space defined by this differential form. The structure is now very similar to the kinematical structure of general relativity, and in particular, the light paths, defined as 'first arrivals,' are found to correspond to null geodesics. There is, however, one important difference: the path of a free particle is not necessarily an ordinary geodesic.

There are three types of models, corresponding to space of positive, zero or negative curvature. The models in the third class are identical with those constructed by Prof. E. A. Milne.

Dr. G. J. WHITROW.—*Linear systems of equivalent observers* (12.15).

In his paper *On the Electrodynamics of Moving Bodies* (1905), Einstein deduced the Lorentz formulæ by appealing to the homogeneity of space and time and the indefinable concept of the rigid body. Owing to the difficulties which are encountered in the applications of these concepts, proofs of the Lorentz formulæ have been sought by many writers on the basis of time observations alone. Most of these have invoked the wave theory of light, but this is not actually necessary.

In *Relativity, Gravitation and World-Structure*, E. A. Milne has shown how equivalent particle observers may correlate the space and time co-ordinates, which they assign to events, on the sole basis of their awareness of a temporal sequence. He obtains general transformation formulæ, which include the Lorentz formulæ as a special case. The analysis is developed in terms of two functions correlating the epochs and distances assigned to each other by two equivalent observers. An auxiliary function p is introduced to facilitate the analysis.

It is here shown that the entire analysis may be developed in an extremely simple fashion by starting with this auxiliary function, which, for physical reasons, is called the signal function.

The operators corresponding to the signal functions correlating the respective members of a linear system of equivalent observers commute with one another. They are, therefore, shown to be expressible in the canonical form $\psi\alpha\psi^{-1}$ where ψ is an operator defining the system and α is a number defining a particular pair of the system. An alternative form is $\Omega[\Omega^{-1}(x) + \lambda]$ where Ω is an operator and λ a constant. These canonical forms may be employed with advantage in considering a wide class of functional equations.

It is shown that it is formally possible for each member to regraduate his clock so that they all appear to be in uniform motion relative to each other. Consequently uniform motion may be described without introducing any indefinable concepts.

The problem of correlating the time scales of two observers who describe themselves as relatively stationary is examined in terms of signal functions. It is shown rigorously that the classical concept of simultaneity has a meaning for such observers and only for such observers.

Signal functions may also be used to construct a one-dimensional universe of discrete particles satisfying the cosmological principle.

Dr. H. S. Ruse.—*The fifteen co-ordinates of a linear congruence* (12.45).

If the skew-symmetric matrices p_{AB}, q_{AB} represent two linear complexes in [3], then the co-ordinates of the linear congruence common to them are defined, after Pasch and Weitzenböck, to be $K_{ABCD} = p_{AB}\,q_{CD} - q_{AB}\,p_{CD}$. They may also be interpreted as the co-ordinates of a flat threefold space in [5]. In terms of them, and by use of the notation of spinor analysis, it is possible to express the geometrical properties of linear congruences simply and concisely ; so, for example, it is easy to obtain a formula for certain quadratic complexes generated by such congruences. The whole theory is treated from the geometrical standpoint, but is not without algebraical interest since the results are not all immediately deducible from the corresponding formulæ for [5].

Tuesday, September 10.

Dr. E. H. Linfoot.—*Schneider's proof of Gelfond's theorem : if ω is an algebraic number $\neq$ 0 or 1, θ an irrational algebraic number, then ω^θ is transcendental* (10.0).

Particular cases : $2^{\sqrt{2}}$, e^{π}, $e^{\pi\sqrt{2}}$, $e^{\pi i\sqrt{2}}$, are transcendental. The logarithm of an algebraic number to base 10 is either rational or transcendental.

Gelfond's theorem gives the complete solution to one of Hilbert's listed problems, *Gött. Nachr.* 1900, p. 253. The proof to be expanded is due to T. Schneider, *Crelle* 172 (1934), 65–69 ; it depends on a direct discussion of the properties of certain specially constructed linear forms of the general type

$$L(x) = P_1(x) + P_2(x)\omega^x + \ldots + P_k(x)\omega^{(k-1)x},$$

where the $P_i(x)$ are polynomials, and involves only the rudiments of algebraic number theory.

Dr. HANS HEILBRONN.—*On Vinogradov's solution of Waring's problem* (11.15).

Waring conjectured in the eighteenth century that every positive integer can be represented as a sum of a bounded number of k^{th} powers (viz. 4 squares, 9 cubes, etc.). This was proved by Hilbert in 1909, but his method of proof cannot be utilised further in this problem.

The problem was attacked again by Hardy and Littlewood with the most powerful weapons of modern analysis.

They showed the existence of a number

$$G(k) = O(2^k k),$$

such that every large integer can be represented as sum of at most $G(k)$ positive k^{th} powers. They also gave an asymptotic formula for the number of representations. The most difficult point of their analysis is the application of Weyl's method of diophantine approximations.

Last year, Vinogradov improved their results to

$$G(k) = O(k^2 \log^2 k)$$

by avoiding diophantine approximations altogether, and quite recently proved even

$$G(k) = O(k \log k),$$

a result which comes very near the truth as it can be easily seen that

$$G(k) \geqq k + 1.$$

Dr. ERIC PHILLIPS.—*On the sequence defined by a quadratic recurrence formula* (11.45).

1. We investigate the behaviour, as $n \to \infty$, of the sequence $\{u_n\}$ defined by the recurrence formula

$$u_{n+1} = au_n^2 + bu_n + c.$$

Without loss of generality this can be written

$$u_{n+1} - u_n = (u_n - \alpha)(u_n - \beta).$$

Putting $\alpha - \beta = 2k - 1$, and writing u_n for $u_n - \beta - k + 1$ we can rewrite this again as

$$u_{n+1} - u_n = (u_n - k)(u_n + k - 1).$$

The behaviour of the sequence depends on the initial value u_0 and on the value of k. The results are as follows :—

A. k complex, u_n diverges to ∞. If k is real we need only consider $k \geqslant \frac{1}{2}$, since if $k < \frac{1}{2}$ the rôles of k and $1 - k$ are interchanged.

B. $u_0 < -k$ or $> k$, u_n diverges to ∞, while if $u_0 = \pm k$, $u_n = k$ for all $n \geqslant 1$ and if $u_0 = \pm(1 - k)$, $u_n = 1 - k$ for all $n \geqslant 1$;

C. $-k < u_0 < k$, $\frac{1}{2} \leqslant k \leqslant \frac{3}{2}$, $u_n \to 1 - k$;

D. $-k < u_0 < k$, $\frac{3}{2} < k \leqslant 2$, u_n oscillates ;

E. $-k < u_0 < k$, $k > 2$, u_n diverges to ∞ except when n_0 lies in a certain set of measure zero. This set contains two distinct enumerable sets of values of u_0 for which the sequence is ultimately stationary and equal to k in the first case and $1 - k$ in the second. It also contains a distinct set corresponding to every prime number p for which the sequence is ultimately periodic with period p.

The first four of these headings were worked out by Mr. Chaundy. The last one, E, is obtained by investigating the roots of the equations

$$u_n = \lambda, \quad -k \leqslant \lambda \leqslant k,$$

as an equation in u_0, and

$$u_{n+p} = u_n,$$

as an equation in u_n.

2. With a view to finding expression for u_n as a function of n, we transform the difference equation

$$u(x+1) - u(x) = \{u(x) - k\}\{u(x) + k - 1\}$$

by putting $x = \dfrac{\log y}{\log q}$, $u(x) = k + qyf(y)$, where $q = 2k > 1$. The equation thereupon becomes

$$(1) \qquad f(qy) - f(y) = yf^2(y).$$

This has a formal solution

$$(2) \quad c\left\{1 + \frac{c_1}{q-1}cy + \ldots + \frac{c_n}{(q-1)(q^2-1)\ldots(q^n-1)}(cy)^n + \ldots\right\}$$

where c is an arbitrary constant and the coefficients c_n are given by reduction formulæ :—

$$c_{n+1} = c_n + \frac{q^n-1}{q-1}c_1c_{n-1} + \frac{(q^n-1)(q^{n-1}-1)}{(q-1)(q^2-1)}c_2c_{n-2} + \ldots + c_n.$$

It is easily seen that c_{n+1} is a polynomial in q. We show that S_n the degree of the polynomial c_n is given by

$$S_n = \tfrac{1}{2}n(n+1) - m(n+1) + (n-2)(s+1),$$

where m and s are such that

$$n = 2^m + s, \quad -1 \leqslant s \leqslant 2^m - 1.$$

Using this and the fact that $c_n = n!$ when $q = 1$, we show that the series (2) is convergent for all values of y when $q \geqslant 2$.

So far the equation (1) can only be completely solved in the two cases when $q = 2$ and $q = 4$. In the first case $f(y) = \dfrac{e^{cy} - 1}{2y}$, and in the second $f(y) = \dfrac{\cos\sqrt{cy} - 1}{2y}$.

Dr. J. H. C. Thompson.—*On the dynamics of the crystal lattice, and its application to some physical properties of crystals* (12.15).

Born's method of describing the dynamics of a crystal lattice by means of a frequency spectrum is briefly described, and its importance in investigating physical properties of crystals is discussed.

The determination of the frequency spectrum for polar crystal lattices is then outlined. The mathematical method for the determination of the contribution of the Coulomb forces to the elements of the frequency equation is dealt with first; and the question of the contribution of the 'repulsive forces' is then considered.

The results of a determination of the frequency spectrum for some of the alkali halides are then described; and the results are compared with those obtained from crystal models. The positions of the subsidiary maxima in the absorption spectra of the alkali halides are deduced according to the theory of Born and Blackman.

A determination of the frequency spectrum for a strained crystal lattice and a consequent investigation of the conditions under which the vibrations of the ions become unstable, lead to a new treatment of the problem of the breaking of crystals under stress.

SECTION B.—CHEMISTRY.

Thursday, September 5.

PRESIDENTIAL ADDRESS by Prof. W. N. HAWORTH, F.R.S., on *The molecular structure of carbohydrates* (10.0). (See p. 31.)

Dr. W. T. J. MORGAN.—*The function of polysaccharides in immunological specificity* (11.0).

The recognition of the important part played by polysaccharide substances in the specific serological reactions that take place between virulent forms of bacteria and the homologous antibacterial immune serum followed the discovery that filtrates from rapidly growing pneumococcus cultures contain a soluble product which gives specific precipitation with the homologous immune serum. Subsequently the serologically reactive material was identified as a complex polysaccharide which had been derived from the bacterial capsule. The capsular substance, which is different for each kind of bacterium, is responsible for the specific serological reactions of the organism with its homologous antibacterial immune-body.

Experiments with synthetic carbohydrate-protein antigens indicate that the ultimate specificity that is characteristic of bacterial polysaccharides depends upon (1) the stereochemical arrangement and the chemical nature of the groups attached to the terminal carbon atom of each hexose molecule, (2) the position of the linkages that join the hexoses together, and (3) the configuration of the hydroxyl groups of the hexoses that exist within the polysaccharide complex.

Evidence has recently been obtained that the specific groupings which are associated with the serological activity of the group specific substance of horse saliva, the blood-group substance A of man and the specific hapten of the heterophile or 'Forssman' antigen are polysaccharide in nature.

Dr. E. L. HIRST, F.R.S.—*Optical activity and structure of sugars* (11.25).

The numerous empirical rules by which attempts have been made to correlate structure with optical rotatory power in the sugar group are valid only within narrow limits. For example, if the lactones of sugar acids and their methylated derivatives followed invariably an extension of

Hudson's lactone rule, both tetramethyl γ-gluconolactone (I) and tetramethyl γ-mannonolactone (II) would be dextro-rotatory. This is true for (I) in all solvents, but the rotation of (II) may be strongly positive or negative, according to the solvent used. The rotatory power of (II) is expressible by the formula $\alpha_\lambda = k_1/(\lambda^2 - 0{\cdot}06) - k_2/(\lambda^2 - 0{\cdot}02)$ and is dependent upon absorption bands at wave lengths given by $\lambda_1^2 = 0{\cdot}06$ and $\lambda_2^2 = 0{\cdot}02$, and associated respectively with the dissymmetric double bond of the carbonyl group and with the single linkages in the molecule. In the far ultra-violet the lactone rule is always obeyed, but wide departures from the rule are encountered in the visible region in those solvents for which $k_2 > k_1$.

The amide rule, which applies to many α-hydroxy- and α-methoxy-aliphatic acid amides, depends on the induced dissymmetry of the CO group and the configuration of the second carbon atom determines the rotation. Failure to follow the rule cannot be explained in terms similar to those used in the case of (II). In 4 : 6-dimethyl mannonamide the sign of the induced term is opposite to that which would be expected. The result is attributable to the vicinal effect of the cis hydroxy groups which are responsible also for the failure of α- and β-mannose to follow the iso-rotation rules.

Dr. S. R. CARTER.—*The determination of molecular weights of carbohydrate derivatives by osmotic pressure measurements* (11.45).

This investigation (with B. R. Record) deals mainly with the methylated and acetylated derivatives of carbohydrates of molecular weight between 1,500 and 50,000 in solutions of organic solvents. According to the theory of van't Hoff a 1 per cent. solution of a substance of molecular weight 20,000 should produce an osmotic pressure of *ca.* 10 cm. water pressure. The liquid may be a colloid dispersion rather than a molecular dispersion, but we have assumed that the osmotic pressure $P = RTn/N$ where $n =$ number of particles in unit volume and $N =$ Avogadro's Constant. The solutions were usually made up in chloroform and the semipermeable membrane was a disc of 'Viscacelle' adjusted for porosity by immersion in alcohol-water mixtures. The osmometer consisted of two glass bells, accurately ground and clamped together, the membrane being enclosed between the ground joints. One bell contained the solution (5 c.c.) and was connected to an air chamber and a water or mercury manometer, whilst the other bell contained pure solvent. The pressure was adjusted by trial until no movement of the solvent occurred as judged by the position of the meniscus in a capillary connected with the solvent bell. The thermostat was kept at $20{\cdot}00° \pm 0{\cdot}01°$ C. The concentration of the solution was determined by weighing the evaporated residue from 1 c.c. on the micro-balance. The observed pressure P is related to the concentration by the equation $P = cRT + kc^n$. The values of P/c are graphed against c and extrapolated to zero concentration, when the last term vanishes and $P = cRT$. The molecular weights so determined agree with the values obtained by the chemical methods.

Mr. E. G. COX.—*Crystallographic evidence on the form of the pyranose ring* (12.5).

Owing to the complexity of the problem, no complete structure determination by X-ray methods has so far been carried out in the case of crystalline carbohydrates. Much preliminary work has been done during the past few years, sufficient in fact to establish certain results not directly accessible by purely chemical methods. The most important of these is concerned with the shape of the pyranose ring; apart from its intrinsic interest this has considerable bearing on the linking of monose residues in polysaccharides. It is generally supposed that the pyranose ring possesses a 'strainless' puckered form; this involves the unwarrantable assumption that the 'strainless' angle between the valencies of an asymmetric carbon atom is $109\frac{1}{2}°$ and ignores the different radius and valency angle of the oxygen atom. Since a hexo-pyranose of given configuration can possess no less than eight 'strainless' forms (excluding mirror image forms), direct experimental evidence is clearly desirable. The X-ray results which have been obtained from about seventy crystalline carbohydrates will be discussed. It appears that the five carbon atoms in the pyranose ring are coplanar or nearly so, the oxygen atom being displaced out of the plane. Various implications of this result will be discussed—e.g. such a ring-form requires the hydroxyl attached to the first carbon atom to be situated differently from the other hydroxyls with respect to the ring; this is in agreement with other evidence. The crystallographic results are found to confirm the configurations assigned to the α and β forms of various sugars.

AFTERNOON.

Visit to Printing Works of Messrs. Richard Clay & Sons, Ltd., Chaucer Lane, Bungay, and to Bungay Castle (2.0).

Friday, September 6.

DISCUSSION on *Surface phenomena, with special reference to substances which occur in nature* (10.0).

Prof. H. FREUNDLICH.—*Displacement of chemical equilibrium at surfaces.*

Chemical equilibrium may be displaced by adsorption on surfaces. This is shown very directly by using indicators. The most convincing experiments are where the colour of an indicator changes, when a surface is produced by emulsifying one liquid in another, and where the original colour of the aqueous solution reappears, when the two phases separate again (Deutsch). If the second liquid is organic, the displacement is always in such a direction that the electrolytic dissociation of the indicator is decreased, compared with its state in the aqueous phase. The reverse takes place if an indicator, for instance a carbinol base, is dissolved in the organic liquid: on shaking with water, the change of colour may indicate the formation of more strongly dissociated substances.

A similar displacement of equilibrium has been observed at surfaces between liquids and gases or solids (quartz, cellulose).

Indicators may change their colour in presence of surfaces of colloidal particles. With colloidal electrolytes the following 'sign rule' holds: colloidal cations only influence the equilibrium of indicators where the colour change is due to a reaction between anions, and *vice versa* (G. S. Hartley). The same rule applies to the influence of proteins on the colour of indicators (Thiel and Schulz).

A displacement of equilibrium has also been found on charcoal with organic substances of low molecular weight, not indicators.

The substances which are stable in adsorption layers may be very different from those stable in the bulk of a liquid.

Prof. E. Waldschmidt-Leitz.—*Some aspects of enzyme action* (10.30).

It has been shown for the first time that, in the case of protein-splitting enzymes, there are specific chemical groups both in substrate and enzyme, through which the specific reactions between enzyme and substrate take place. The various enzymes can be differentiated according to their different modes of reaction with both polypeptides and true proteins. Several examples are given.

The activation of enzymes, and its mechanism, are of particular interest. It may be explained either by the development of a specific active group, through the activator, or by a surface action, e.g. supplying the enzymatically active group with a suitable colloidal bearer. It is suggested that enzyme action in general is a surface reaction between definite chemical groups.

Dr. N. K. Adam, F.R.S.—*Unimolecular films of fatty substances on water* (11.10).

Langmuir showed that insoluble substances such as long chain acids, alcohols, fats, sterols, which have one or two water-attracting groups in the molecule, form films only one molecule thick on a water surface, with the molecules oriented so that the water-soluble groups are next the water. These films are found in states corresponding to the solid, liquid, and gaseous states of matter in three dimensions, the state of the films being determined mainly by the amount of lateral adhesion between the molecules. Different films show different degrees of tilt of the molecules ; if there is only one water-attracting group, situated at the end of the molecules, they usually stand vertically ; two widely separated water-attracting groups usually cause the molecules to lie flat ; in the interesting ' expanded ' state of the films the molecules probably have their hydrocarbon chains in violent whip-like agitation, yet the films are coherent.

These films often give valuable information as to the size, shape, and constitution of the molecules.

Dr. A. H. Hughes.—*Chemical reactions in unimolecular films* (11.35).

Whilst the familiar investigation of unimolecular films by the Langmuir-Adam trough has given much detailed knowledge of the physical properties of this state of matter, the more recently developed technique of ' surface potentials ' has provided a means of measuring a chemical reaction occurring in the unimolecular film. The surface potential of a film is related to the dipole moment of the constituent molecules ; thus chemical change taking place therein is reflected in a change in the observed surface potential. Some simple types of chemical change have been examined in this manner :

(1) Ionisation of a fatty acid, such as myristic or palmitic.
(2) Oxidation of unsaturated molecules (oleic acid and its isomers and various sterols oxidised by acid $KMnO_4$).
(3) Hydrolysis of lactones.
(4) Complex formation, e.g. the reaction of concentrated HCl and a film of an alcohol or an acid to form an oxonium compound, and the effect of heavy metal ions in the solutions.

In certain cases, notably the oxidation of oleic acid and the hydrolysis of γ-stearolactone, the reaction velocity is affected markedly by the orientation of the molecules. By suitable compression the molecules in the film can be so arranged that the reactive group is not accessible to the reagent in the underlying solution. This accessibility factor has been studied in the case of the oleic acid oxidation. With the hydrolysis of γ-stearolactone the absolute reaction velocity has been studied and shown to be amenable to treatment by the kinetic theory of solutions.

Dr. J. H. Schulman.—*Surface reactions in biology* (12.0).

The method of surface potentials has been applied to measure the polar properties of complex biological molecules and to follow the course of a reaction which these substances may undergo with compounds injected into the underlying solution. This has been applied especially to those reactions which are believed to occur at interfaces in physiological systems, such as enzyme, immunity, and hæmolytic reactions. Under the first category comes the study of protein films (which includes denaturation), lipoids such as psychosin, cholesterol and fats and complex compounds as chlorophyll, hæmoglobin, vitamins and hormones.

Under the second category :

(1) *Enzymes.*—This consists in injecting specific proteolytic ferments into the solution underlying protein films or in the case of snake venom under lecithin films. This includes the similarity of the surface activity of lipo-protein complexes to that of ferments.

(2) *Mixed films and complex formation between large molecules.*—Interaction between long-chain alcohols and acid depending on pH of the underlying solution. The combination of surface pressure and surface potentials as a means of measuring complex formation.

(3) *Phenomenon of penetration.*—Injection of soluble substances under monolayers to form insoluble mixed films, such as the action of psychosin, cetyl sulphates and dyes.

(4) Application of the study of complexes in mixed films to such problems as immunity reactions and hæmolysis.

Prof. E. C. C. Baly.

Dr. E. Semmens.

Afternoon.

Visit to Messrs. W. Gaymer & Son, Ltd., Cider Factory, Attleborough (2.7).

Monday, September 9.

Discussion on *Chemotherapy of malaria* (10.0).

Lt.-Col. S. P. James, F.R.S.—*Introduction* (10.0).

The British Empire, with its vast malarious territories in the tropics, is more concerned with the provision of effective anti-malarial drugs than is any other nation in the world.

Until recently the alkaloids of cinchona bark were the one and only effective remedy available. These natural products, however, are not effective for certain therapeutic purposes, particularly for true causal prophylaxis, the prevention of relapses and the prevention of spread. The aim of chemotherapy is to find preparations which will be effective for those purposes.

Two remarkable synthetic anti-malarials, namely plasmochin and atebrin, have been discovered and prepared on a large scale in Germany and their merits and defects for the particular purposes mentioned are now being assessed in the laboratory and in the field. A statement illustrated by lantern slides and microscopic preparations is given of the results obtained. Their discovery has given a great stimulus to chemotherapeutic work.

An outline is given of methods and plans which are being tried or have been suggested for extending anti-malarial chemotherapy research in England, where as yet it has been entirely neglected by the chemical industry and has received almost no financial assistance from Government or other sources.

Prof. Dr. W. Schulemann.—*Methods of chemotherapeutic research as exemplified by anti-malarial drugs* (10.30).

For centuries the physician has had only natural products, e.g. quinine, to support him in his struggle against malarial infection. Concurrent with the increasing elucidation of the chemical constitution of quinine, a very large group of compounds was prepared and tested for effects on malaria, but with practically no results. The first success was at last attained with plasmoquine (prepared in 1924), followed by atebrin (in 1930).

Repeated discussions have taken place on where the secret of success in experimental therapeutic work is to be found. There is the view that success is to be reached only by intuitive work, and the other that only systematic work can attain its object. A combination of both holds out the greatest prospect of success. The discovery of atebrin was due solely to co-operation between chemists and biologists.

Difficulties presenting themselves are: (1) compounds acting on malarial parasites attack different points in the development cycle of the parasites; (2) the action of compounds depends on the type of parasite and of the host. If the biologist limits himself to a single test object the meshes of the sieve through which he must pass the substance to be tested soon become too fine.

Experiments are divided into 'controlled' and 'uncontrolled,' and the relative merits of these are discussed with reference to the workers in each field. The argument that, while quinine favours development of immunity, synthetic compounds prevent the development of or inhibit this immunity, is refuted.

Among important problems remaining to be solved are true causal prophylaxis and the prolongation of the incubation period in benign tertian malaria. These and other problems can be solved only by further pharmacological investigations.

Prof. R. Robinson, F.R.S.—*Synthesis of potential anti-malarials and the relation between constitution and anti-malarial action* (10.55).

The methods employed for the synthesis of potential anti-malarials by the author and his colleagues are described, and some of the results discussed from the point of view of the relation between constitution and anti-malarial action.

Attention is directed to the pressing need for further investigations and some suggestions are advanced as to the organisation of the research on the chemical side.

Prof. D. Keilin, F.R.S., Dr. P. Tate and Dr. M. Vincent.—*Chemotherapy of bird malaria and its importance in relation to the therapeutics of human malaria* (11.20).

Since it was shown that quinine and some other quinoline compounds act in a similar way on human and bird malaria, the latter has been used as a valuable means of testing the anti-malarial action of new synthetic compounds. Synthetic quinoline compounds prepared by Prof. R. Robinson and co-workers have been tested on bird malaria in Cambridge. Twenty-four of the eighty compounds tested have definite anti-malarial action.

Routine tests on birds are made on asexual stages of the parasite transmitted by direct blood-inoculation, but by utilising mosquito infections it is possible to determine the action of a compound on gametocytes and on sporozoites ; and such tests of some of Prof. Robinson's compounds will be considered in detail.

Work on anti-malarial properties of drugs reveals interesting facts about immunity in bird malaria as their action varies according to the relation between the times of inoculation with malaria and of administration of the drugs.

The results of work on bird malaria are not always applicable to human malaria, but so far every synthetic compound of value in human malaria has been discovered by means of preliminary tests on bird malaria.

Dr. T. A. Henry.—*Anti-malarial drugs of natural origin* (11.40).

(*a*) The investigation of natural drugs having a local reputation as remedies for malaria, e.g. the Alstonias of Australia, India, West Africa and the Pacific Islands, from which Messrs. Goodson and Sharp have isolated a group of alkaloids which are of scientific interest, but are devoid of anti-malarial activity.

(*b*) The determination of the relative activities of the various cinchona alkaloids, a matter of practical importance in view of the introduction of crude mixtures of cinchona alkaloids as a means of mass-treatment of indigent malarial populations. For this purpose the eight principal cinchona alkaloids have been prepared in a pure state and tested in bird malaria. The results show that they can be arranged in the following descending order of activity :

(1) Hydroquinine, (2) Quinine, (3) Hydroquinidine, (4) Cinchonidine and Quinidine, (5) Cinchonine, Hydrocinchonine and Hydrocinchonidine.

(*c*) The effects of modification in the molecular structure of cinchona alkaloids on anti-malarial action. In general it may be stated that any change, which diminishes the basic character of such an alkaloid as quinine, reduces its anti-malarial activity, though it may result in the development of pharmacological activity of another kind.

Col. Sir Rickard Christophers, F.R.S.—*Chemotherapeutic effect as a combination through a basic side chain : absorption of acid and base by red cells* (12.0).

A usual conception of chemotherapeutic effect is molecular fit. The chemical nature of such fit is often not very clear, but the necessity of a basic side chain for linkage to protein is sometimes referred to. All anti-malarial drugs natural and synthetic have such side chains. With a view to studying such combination, observations have been made upon absorption by red cells of some simple acids and bases, using critical hæmolysis of a given quantity of red cell substance and electrometric determination of the pH as guides to the reaction. It was found that lysis of the cell was brought about through formation of a critical amount of 'protein salt,' which amount was the same for all acids. With this is associated a fraction due to 'hydrolysis' of the salt, which is greater the weaker the acid. This necessitates a larger dose in the case of some acids than others. This 'hæmolytic dose' can be calculated with considerable approach to experimental findings. 'Hæmolysis' is associated with a critical relation of isoelectric to ionised protein and a characteristic pH. Other critical events, e.g. lethality, if caused by ionisation, can be studied in a similar way. Observations on quinine and malaria parasite substance on these lines have been made.

AFTERNOON.

Visit to the Carrow Works of Messrs. J. & J. Colman, Ltd. (with whom are associated Messrs. Keen, Robinson & Co., Ltd.), manufacturers of condiments, cereals, starch, blue, etc. (2.0).

Tuesday, September 10.

DISCUSSION on *The chemistry of grass crops* (10.0).

Prof. A. C. CHIBNALL.—*The proteins of grasses.*

Introductory: The conventional methods used by agricultural chemists to evaluate the nitrogenous constituents of forage crops.

The preparation and general character of grass proteins—complete amino-acid composition of cocksfoot protein—the essential amino-acids for animal nutrition and the amount present in a comprehensive series of grasses and other green forage crops—chemical composition of the non-protein nitrogen of forage crops.

Criticism of the protein factor ($N \times 6{\cdot}25$) as applied by agricultural chemists to forage crops—relative merits of 'crude' and 'true' protein values.

Mr. H. J. PAGE and Dr. S. J. WATSON.—*The chemical composition of grassland herbage and its relation to fodder conservation and nutritive value* (10.30).

The influence of various factors on the composition of grassland herbage; manurial and climatic factors; stage of growth; botanical composition.

The above are considered in relation to the organic and mineral constituents of the herbage with particular reference to protein and non-protein nitrogen, calcium and phosphorus, and carotinoid pigments.

The influence of methods of fodder conservation on chemical composition of the product; artificial drying and ensilage; protein and carbohydrate breakdown, and carotene content.

The relation of chemical composition of fresh and conserved grassland herbage to its nutritive value.

Prof. A. I. VIRTANEN.—*The chemistry of grass crops* (11.0).

The question of the uptake of nutrients by plants is discussed, particular attention being paid to nitrogenous nutrients and to the ability of plants to utilise organic nitrogenous compounds. In the nitrogen metabolism of the leguminous plants the following questions will be dealt with : (*a*) uptake of nitrogenous nutrients from the nodules, (*b*) excretion of amino-acids from the nodules, and (*c*) nitrogen-fertilising of non-leguminous crops in associated growth with legumes.

The composition of protein undergoes considerable changes during different stages of plant growth, and the vitamin content of plants reaches a maximum before or at the start of blooming. These facts should be considered in cutting forage crops. In the carbohydrate metabolism of plants attention is paid to the easy interconvertibility of different sugars. The inversion of cane sugar takes place chiefly in the stems and leaf-ribs, which possess a high invertase activity. The nature of the sugar compound utilised by the root nodule bacteria of leguminous plants in the fixation of nitrogen is still unsettled.

With regard to growth hormones, water and ether extracts from yeast, indolyl acetic acid and ascorbic acid stimulate the growth of plants in sterile water cultures.

One of the chief problems of practical agriculture, the preservation of immature forage crops at a stage when their nutrient content is highest, was solved by the A.I.V. process, which is discussed.

Dr. H. W. Buston.—*Cell-wall constituents of grasses* (11.45).

Carbohydrate constituents of the cell-wall of grasses ; pectin, hemicelluloses, lignin, etc. Fractionation of hemicelluloses ; constituent sugars and sugar acids.

Origin and development of hemicelluloses in the plant. Comparison of grasses with other plant tissues.

Significance of cell-wall materials in animal fodder.

Dr. R. E. Slade.

SECTION C.—GEOLOGY.

Thursday, September 5.

Prof. P. G. H. Boswell, O.B.E., F.R.S., and Dr. J. D. Solomon.—*The geology of the neighbourhood of Norwich* (10.0).

Joint Discussion with Section H (Anthropology) on *The geological relations of early man in East Anglia* (Section C room) (11.0).

Prof. P. G. H. Boswell, O.B.E., F.R.S.

The recent discoveries of implements of Early Man in East Anglia have, in addition to their archæological interest, an important stratigraphical significance. But the geologist cannot give effective assistance to the solution of the problem of prehistoric chronology unless there is agreement among archæologists on the question as to what is human and what is natural flaking, and as to the industries to which some of the implements belong. In particular, the older records of implements referred to as ‘ Mousterian ’ need to be made more precise. Among the discoveries which have important bearings on East Anglian stratigraphy and the correlation of human industries, the following are selected for discussion : (*a*) Mr. Reid Moir has recently divided the sub-Crag implements into five types. Publication of his results is awaited, but it is already evident that considerable significance appears to be attached to the predominance of certain groups at certain localities. (*b*) Many implements have been found by Messrs. Moir, Sainty and Solomon in stone-beds associated with the Norwich Crag, Weybourn Crag and Cromer Forest-bed ; are these implements to be regarded as pre-Chellian or Chellian ? (*c*) Dr. Solomon's recent investigation of East Anglian sands and gravels and his redefinition of the Westleton Stage at the beginning of the Pleistocene has led to illuminating and important generalisations. The Westleton Beds mark a marine phase contemporaneous with the deposition of the boulder clays known as the Norwich Brickearth and Cromer Till (1st glaciation), containing Scandinavian erratics. The Westleton Beds, thus redefined, include many of the deposits of sand and gravel formerly classed as Mid-Glacial. Some of the Mid-Glacial sands and gravels contain what appear to be rough flake-implements ; also worked pebbles such as the Darmsdenian. To what culture should these Mid-Glacial flints and Darmsden pebble-tools be referred ? (*d*) More information is needed about the so-called Mousterian types from the Great Chalky Boulder Clay (2nd glaciation), from the superincumbent brickearths (2nd interglacial), and from the Chalky Drift. Clactonian flakes have been found by Mr. Sainty in association with Acheulian hand-axes at the Carrow Works, Norwich, in deposits younger than the Great Chalky Boulder Clay ; also at High Lodge, an advanced Clactonian industry occurs in gravels referred by Dr. Solomon to his Little Eastern glaciation (the 3rd glaciation of East Anglia—that of the Upper Chalky Drift). (*e*) The Aurignacian sites occur in deposits which appear to overlie the Upper Chalky Drift, but they are usually at localities where direct stratigraphical evidence is not available. Has the superposition of any glacial horizon on such implement-bearing deposits been clearly demonstrated ? (*f*) If there is general agreement that the implements found by Mr. Reid Moir in the Hunstanton Brown Boulder Clay (4th glaciation) are referable to the Middle Aurignacian industry, a correlation of that boulder clay with the cold phase of the Magdalenian is most probable. (*g*) The few Solutrian flakes found in East Anglia have been obtained from superficial deposits of which the stratigraphical position has not been determined.

Finally, a plea is made for uniformity of spelling (Chellian, Acheulian, etc.), now that these terms and industries have a stratigraphical value.

Mr. D. Baden Powell.

The Quaternary deposits near Cromer present many problems, and it was hoped that an attempt to apply palæontological correlation might help to solve these.

Near Yarmouth a well-defined marine horizon yields about 25 per cent. Pliocene shells, since extinct ; about 10 per cent. now found in Scandinavia and the Arctic ; and about 7 per cent. of warm character. The remainder are of existing British types. The term 'Mid-Glacial Sands,' hitherto used for these deposits, is confusing, and some such term as 'Yarmouth Beds' should be adopted.

The fauna of the March Beds, also marine, occurring in the eastern part of the Fens, is of much younger type, containing only one extinct Pliocene form, also *Nassa reticulata*, unknown in eastern England from any earlier horizon than the March and Kelsey Hill beds. There are no species of Mediterranean type and a correspondingly higher percentage of Scandinavian species.

The stratigraphical position of these marine beds in relation to the boulder clays will be discussed, also the significance of the palæontological differences between the two faunas. It is suggested that the Yarmouth Beds correlate with the only comparable horizon known in the Cromer district—marine sands occurring near West Runton. These sands have been reported to lie between the Contorted Drift Boulder Clay and the gravels belonging to the 'Upper Chalky' glaciation. This correlation, however, leaves no room for the equivalent of the Chalky-Jurassic Boulder Clays in the Cromer sections.

Mr. H. E. Forrest.

The several glaciations of Norfolk, the directions from which the ice came in each case, and their effect upon the habitability of particular areas by Palæolithic man.

Mr. J. E. Sainty.

In view of the difficulties which the problem of distinguishing between the different glacial gravels has presented to the geologist, Dr. Solomon's claim to differentiate between these deposits on purely geological grounds will receive a warm welcome. The implement evidence, so far as it is available, accords well with Solomon's conclusions.

The complex mixture of pre-Crag industries is being studied by Mr. Reid Moir, but the more uniform conditions of staining in the Norfolk Stone Bed appear less helpful than those of Suffolk, and classification depends rather on considerations of technique; it appears on the whole, that the Stone Bed is of rather later date than the Suffolk Bone Bed.

The rich Chellian fauna of the Cromer Forest Beds is unfortunately accompanied by only scanty artefact remains, the most important specimens being those obtained from the overlying Till. The association of hand-axes with elephant suggest that Pleistocene and Early (?) Chellian are preferable to Pliocene and Pre-Chellian.

The 'cold interglacial' intervening between the Till and Norwich Brick Earth and the Chalky Boulder Clay has in Norfolk produced no decisive evidence of human occupation. Developed Acheulian-Clactonian industries appear above the Chalky Boulder Clay, whilst 'Levallois' influence is clearly present; the recent find of a magnificent Combe Capelle specimen in the topmost gravel of Mousehold Heath accords with this. 'Little Eastern' deposits have produced numerous specimens from the Cromer-Holt ridge, Syderstone and Massingham. Upper Palæolithic material found *in situ* is scanty indeed, though some of the surface finds would, on grounds of technique, appear to be Aurignacian, whilst the very rich Mesolithic industries show definite Aurignacian influence.

Dr. J. D. Solomon.

The greatest difficulty confronting the archæologist in East Anglia is the doubtful position of the Chellian industry. The isolated specimen found by Mr. Sainty in the Cromer Till is the only unabraded example of this industry known in East Anglia, and appears to indicate an age not very different from that of the Forest Bed.

On the other hand, the Stone Bed industry from the base of the Crag and Forest Bed is not markedly of Chellian type, but seems rather to indicate crude attempts to produce points and edges in the simplest possible way, using flint nodules as a starting point.

There is a great hiatus between this industry and the next which is found definitely *in situ*, namely a fairly advanced Acheulian; this hiatus appears to be due to the fact that there are no deposits belonging to the

North Sea-Great Eastern Interglacial, which was a period of elevation and erosion.

The approximate contemporaneity of the Clactonian and Acheulian in the Breckland area may be considered as established by the finding of both cultures in an unabraded state in the same gravels.

Mr. S. Hazzledine Warren.

The opinion is expressed that these disputed items in prehistory are not human industries at all, and, if this be so, then the constructive problem of their correlation does not arise. Prehistory has been carried away by the glamour of its superstructure and has never devoted proper attention to its foundation: that is, to the reliable identification of the flint industry.

It is not possible to discuss the evidences in detail, but it is claimed that comparison with the true facts of natural flaking shows that the whole of the supposed Crag and allied industries are the products of natural agencies.

The association of the striation, bruising, and the supposed human flaking that is characteristic of the stone-bed is referred to a common cause —namely to the grounding of floating ice upon the floor of the shallow Crag sea.

Dr. W. B. Wright.

Friday, September 6.

Presidential Address by Prof. G. Hickling on *Some geological aspects of recent research on coal* (10.0). (See p. 47.)

Sectional Discussion with speakers from Section B (Chemistry), on *The development of rank in coal and its geological implications* (11.0).

Prof. W. G. Fearnsides, F.R.S.

The idea of rank in coal as a measure of the stage of its alteration has grown up gradually with the recognition that peat, lignite, bituminous coals and anthracite are members of a continuous series of products derived from vegetable debris by loss of volatile matter. No geologist believes that this alteration has taken place either wholly under surface conditions or at temperatures comparable with those required in the manufacture of coke. Intermediate and progressively rising temperatures were involved.

Hilt's law, ' in a single vertical section the deeper seams are of higher rank than the upper,' limited by application only to similar kinds of vegetable debris, is found true for British coalfields. A rise of one degree Centigrade per 100 ft. of depth is the present ruling geothermic gradient in Midland coalfields ; and the question is put whether such gradient continued through the maximum measured thickness, 10,000 feet, of English Coal Measures, can account for observed variations of rank.

It is stated that there is general correspondence between the pattern of variation of thickness—isohypses—of the upper zones of Coal Measures as they were deposited, and the distribution of coals of coking quality in the Midlands, more particularly in Yorkshire. It is suggested that burial under 5,000 ft. of Red Measures in Warwickshire brought about the conversion of vegetable debris there into low rank bituminous coals. Rank of coals in the concealed coalfield in Yorkshire and Nottinghamshire shows no relation to the thickness of Permian and Triassic strata lying unconformably above them.

Thermal, dynamic, and pneumatolytic metamorphic changes, as recognised by those who work on crystalline rocks and mountain building, are manifestations of variations of stress and temperature conditions through a wider and higher range than those responsible for advance of rank in English coals. It is possible that as water was expressed from consolidating sediments, loosely combined water and carbon dioxide may have been removed from organic constituents of vegetable debris, but chemical changes have not been noted in the mineral constituents of associated rocks.

Prof. W. A. Bone, F.R.S.

Recent researches in my laboratories at the Imperial College of Science and Technology, London, besides proving the benzenoid structure of the main coal substance, have shown that such structure, which originated in lignin (but not in cellulose), has been progressively developed throughout the series lignin→peat→brown coal→lignite→bituminous coal→anthracite, and thus supports the continuity of the series. Also they have shown that the constituents mainly responsible for the coking propensities of bituminous coals have probably originated in, and been developed from, the phenolic constituents of brown coals. Our researches have disclosed no essential or material difference between the chemical constitutions of the 'bright' and 'dull' components, i.e. the 'vitrain' and 'durain,' of bituminous coals; and however apt or convenient such names may be from the morphological standpoint, it is doubtful whether they have any particular chemical significance.

The chemical nature and constitution of coal are questions quite apart from any morphological nomenclature yet suggested, and can be solved only by the persistent application of the experimental methods of organic chemistry; they may ultimately prove to be but little related to the petrology of coal.

Probably 'pressure' has been a more potent factor than 'temperature' in the maturing of the original coal substance after the 'peat-bog stage.' It is hoped to put this matter to an experimental test shortly, as means and apparatus are now available for studying organic reactions under pressures between 10,000 and 20,000 atmospheres.

Mr. F. V. Tideswell and Prof. R. V. Wheeler.

The 'rank' of a coal is a conception expressing the general level of a group of its properties and in its broadest sense is a measure of the extent of chemical alteration of the coal-forming ingredients from their original composition.

This progressive chemical alteration (i.e. change of rank) is a property of the ulmins which form the bulk of all coals, and the changing properties of coals of different ranks can be attributed almost entirely to this progressive change in the ulmin ingredient. Rank can therefore be assessed by measuring properties peculiar to the coal ulmins, for example, oxidisability, or decomposition temperature, although the chemical changes responsible for the alteration in rank of the ulmins are as yet not fully known.

The decomposition temperatures of coal ulmins from secondary or more recent deposits in New Zealand agree well with those of our British Palæozoic coals of corresponding composition, confirming the similarity of the processes involved in alteration of rank despite wide differences in geographical position and geological period.

Dr. J. G. King.

Whatever success may attend microscopic investigations employing the latest advances in photographic technique, it must be realised that they give information only on the physical structure of coal, whereas it is the chemical constitution of the several ingredients which finally determines the nature of the coal. The lack of methods for the complete separation of these various constituents is, however, a formidable obstacle.

Constancy of elementary composition of any constituent is not a criterion of constant constitution.

Professor Hickling has discussed the significance of the variation of rank across a coalfield, and defines ' rank ' as the degree of alteration which has occurred in the original plant débris during its transformation into coal. There is no direct measure of rank ; but in general the youngest (brown) coals are the richest in oxygen, and there is a steady diminution in oxygen as the coal ' matures.' The oxygen content of coal can be varied, as, for instance, by weathering. Thus the plotting of volatile matter, etc., does not provide a complete means of tracing variations in rank across a coalfield. A ' molecular ' weight would be valuable in measuring rank ; but until colloid chemists provide the necessary methods, it would be better to avoid using the term.

Mr. L. Slater.

There is an important relationship between the rank of coal and its microscopic characteristics. In the Coal Research Laboratory at Sheffield thin sections have been made of a Leicester coal of 79·5 per cent. carbon content, many Yorkshire coals with a range of 81 to 88 per cent., Kent coals of 86·7 to 91·4 per cent., and South Wales coals of 87 to 93·5 per cent. There is a steady decrease in translucency as rank increases and it becomes increasingly difficult to differentiate between the types of plant constituents of which the coal was originally composed. In the lowest rank members of the series practically every microscopic constituent can be rendered translucent with comparative ease, and the brilliant yellow of the spores is in sharp contrast with the pale red of the ' vitrinite.' With increasing rank the translucency of the whole diminishes and the colour contrasts become less marked : when a rank of about 91·5 per cent. of carbon is reached the spores have practically the same colour as the ' vitrinite ' and are distinguishable only by their outline against an opaque background. Thin sections of coals of higher rank than this are of little value as organised structure is practically invisible, and etching must be resorted to. Rank then determines the degree to which etching must be carried out in order to reveal structure clearly. Thus a coal of 94 per cent. carbon must be subjected to a given etching fluid for three times as long as a coal of 91 per cent.

The diminution in volume undergone by a coal in increasing in rank from 79·5 to 93·5 in carbon is remarkably slight, probably less than 10 per cent.

Dr. R. Lessing.

The study of the development of rank in coal is the chemist's domain, in which close co-operation with the palæo-botanist and geologist is essential. The principal reactions involved in raising the rank of coal are the elimination of water and CO_2, and later the loss of other volatiles under the influence of the particular geological environment obtaining. The speaker has shown the importance of the presence of inorganic substances either adventitious or contained in the original plants and added to, or subtracted from, their débris during coalification. These substances exert a subtle and profound effect in directing the course and degree of the carbonisation of decaying vegetable matter, the effects being purely chemical or catalytic. Mackenzie Taylor has shown the importance of the pH of the roof material lying above a potential coal seam, and it is important whether this material is calcareous or siliceous.

The speaker holds the opinion that durain is derived from raw material differing in kind and particle size from that which formed vitrain and clarain. In durain the abundant ash is predominantly of the nature of clay; in vitrain and clarain ash amounts to 1 or 2 per cent. only; it represents original plant ash, and is of an alkaline nature. Fusain has absorbed the bulk of its mineral contents after complete degradation, and its original plant ash is liable to have been leached out. The high calcium content of fusain is due to secondary imbibition. Anthracite should have a concentration of inorganic constituents, yet its ash content is low, possibly as a consequence of leaching by water perhaps saturated with CO_2, in the final stages of rank raising.

Dr. Bernard Smith.

From analyses of coals published by H. G. Edmunds in 1933 (*Summ. Prog. for* 1932, *Mem. Geol. Surv.*), it appears that Hilt's law is applicable to the Kent Coalfield. In this case the decrease in volatiles with increase in depth is a general rule, although an occasional seam may give a higher value than one immediately above it. As in South Wales, when the vertical distances between the seams under consideration is less than 100 yds., appreciable differences in volatile contents are small. Taking, however, seven localities in the Kent field, in which the average differences in depth between the highest and lowest seams is about 400 yds., we find that the average decrease in volatiles throughout this range is 8 per cent., giving an average rate of 2 per cent. per 100 yds. This compares well with Prof. Hickling's figure for decrease in volatiles in South Wales in the coals of lower rank.

Mr. C. A. Seyler.

Prof. Hickling in his address had done good service by directing attention to recent progress in the petrological classification of the sedimentary rocks known as coal. In particular the speaker welcomed Prof. Hickling's support of Dr. Stopes in the attempt to distinguish the rock-types from the micro-petrological units or *macerals* and to establish a systematic nomenclature.

All coal petrologists recognise that the simple terms ' bright ' and ' dull ' coal are inadequate. Another service of Prof. Hickling was to emphasise the fact that the effect of the nature of the plant material was reflected in coal mainly by the amount of hydrogen. In 1900 the speaker had classified coals into species and showed that these species could be grouped into genera according to the hydrogen. Modern microscopic research had shown that these genera were not merely logical categories, but consisted of individuals genetically related.

By restricting the comparison to coals of the orthohydrous genus which were chiefly derived from lignified tissue the problem of ' rank ' was greatly simplified. The conception of ' rank ' was primarily a geological one and we had no exact knowledge of the factors which produced the change. Until these were known and correlated with chemical composition no chemical criterion could be a measure of ' rank,' but at most an index. Chemists were not agreed as to the index of ' rank.' The amount of oxygen, carbon, volatile matter, the calorific value and recently the reactivity had been proposed. All these are simply related to each other when the hydrogen is constant. Since the hydrogen of the orthohydrous coals varies only between narrow limits (5 to 6 per cent.), any of the proposed indices will give the same order of rank approximately but not exactly. It appeared that the geologist and chemist were each waiting for the other to produce a true measure of rank. In the speaker's opinion it must come from the geo-physicist. The choice of a chemical index was more or less arbitrary and must remain so until we have a quantitative knowledge of the factors which produce metamorphism.

Dr. A. Raistrick.

In my work on the microspores of coal it has been necessary to subject a very wide range of coals to drastic chemical treatment, and I have had the opportunity of noting the very close correspondence of the responsiveness of a coal and its rank. A recent investigation of the Busty seam of Durham has involved the chemical treatment of samples of that seam from over fifty localities fairly evenly distributed over the whole coalfield and varying in volatile content from 27 per cent. to 39 per cent. The treatment of all samples was standardised, both quantitatively and for time-temperature, and consisted briefly in oxidation of the coal with Schulz's solution, followed by extraction with caustic potash. The types and proportions of types of microspores obtained proved similar in all samples, and enabled direct correlations to be made, but the quantity of spore material varied very markedly with the rank of the coal. The coals of less than 30 per cent. volatiles have yielded less than one-tenth the amount of spore material given by coals above 35 per cent. volatiles. While the extracts from high rank coals need from four to six times as much washing as those from low ranks, there is much to suggest that fewer spores are present in the high rank coals, as prolonged or modified treatment has in no case enabled a greater yield of spores to be obtained. This work suggests that there are two factors connected with rank: (*a*) a very different response to chemical treatment, and (*b*) possibly a much smaller proportion of spore material in coals of high rank.

Mr. C. E. Marshall.

Among the features of structure which can be compared in different coals perhaps the most obvious is the widely varied condition of preservation of the plant tissues. An examination of such tissues from coals of various ages and ranks, therefore, should reveal whether or not there is any diversity in their mode of preservation which could be correlated with the rank of the coals. As a result of such an examination applied to coals of different ranks (ranging from peat to semi-anthracite) and of various ages (from Carboniferous to Glacial) it has been found that the types of preservation of the cell structures in coals of bituminous and higher ranks are entirely similar to those of the earlier stages. In other words, the same types of cell preservations are common to coals of all ranks and ages. Consequently it seems certain that the structure of the coal is determined in the very early stages of its formation, that geological influences cannot have much effect upon the petrography of the coal seam, and that rank is not appreciably influenced by the degree of degradation achieved in the coal swamp.

Saturday, September 7.

Excursions to (*a*) North Norfolk Coast (9.30).
(*b*) Sudbourne and Orford (9.30).

Sunday, September 8.

Excursion to Ipswich, Bramford, Hoxne (10.0).

Monday, September 9.

JOINT SYMPOSIUM AND DISCUSSION with Section E (Geography) on *Denudation chronology* (Section C room) (10.0).

Dr. S. W. WOOLDRIDGE.—*The principles of denudation chronology, with special reference to south-east and south-west England.*

The study of erosion surfaces is a young and undeveloped branch of geology, and one that has many purely geographical aspects. Little notice was taken of such features until early in the present century, but since that time many largely isolated and unrelated observations have been made in this country. In both Continental Europe and America the subject has enjoyed a more favourable position. In this discussion a review of the facts and of the methods of inquiry and interpretation will be attempted.

The major erosion surfaces entering into the constitution of the British landscape are of two kinds : (*a*) uplifted peneplains (or peneplanes) formed under subaerial conditions and never covered save by regolith or thin continental deposits ; and (*b*) stripped planes of unconformity, secondhand peneplains, trimmed by marine abrasion, in most cases. Less extensive surfaces—old valley floors—can also be recognised, and to these also American usage extends the term peneplain, but some alternative term seems desirable.

Whether subaerial or marine, erosion surfaces must be expected to show appreciable gradients, quite apart from later warping, if any. Correlation on a basis of essential flatness along directions measured at right angles to present or former coastlines, leads only to absurd and impossible conclusions, in most cases.

In all the major regions of Britain which have yet been studied, there are the remains of a gigantic physiographic stairway of erosion levels—a succession of uplifted and dissected base-levels—which contains the elements of a scheme of denudation chronology, running parallel with the later stages of stratigraphical history. Interpretation is hindered, however, by the difficulty of distinguishing between Tertiary and older exhumed surfaces. In these circumstances it is essential that interpretation should begin in south-east England, where surfaces can be dated with reference to deposits of known age.

With this principle in mind a summary will be given of the denudation chronology of south-east England, where sub-Eocene, Miocene, sub-Pliocene and various Pleistocene surfaces can be traced, and the form of the sub-Cretaceous surface can also be approximately ascertained. By means of the evidence of river-profiles the later stages of the chronology can be confirmed.

The conclusions drawn from the study of these surfaces in south-east England will be briefly applied to the problems of south-west England.

Prof. A. G. Ogilvie.—*The mapping of erosion surfaces.*

Geologists and geographers are interested in denudation surfaces, though their respective view-points differ. For geographers it is essential that the character, extent and distribution of each surface be determined with reasonable accuracy. Investigation of surfaces in the field should therefore always be supplemented by construction of projected profiles by Barrel's method as developed by D. W. Johnson, and, wherever possible, by erection of the rigid profiles properly spaced in plan. The time has come for serious attempts to map the remnants of separate erosion surfaces in Britain ; for this the reliable O.S. contours are an asset. Special difficulties occur due to the slight separation of surfaces where relief is low and also, as in parts of Scotland, where excessive dissection leaves only small remnants. Nevertheless the aim of all workers should be to produce regional maps of uniform type which may afterwards be correlated. A Commission of the International Geographical Union has suggested a system of mapping and it has already made the correlation necessary to the production of a tentative map of erosion surfaces covering considerable areas of the European continent on the scale 1 : 500,000.

A brief report was given of work, with D. L. Linton, aiming at the recognition and the mapping of surfaces in southern Scotland.

Prof. H. H. Swinnerton.—*The denudation of the East Midlands.*

The loftiest surface in this area is situated on the southern extremity of the Pennines at a level of about 1,000 ft. This was for a long time regarded as a pre-Triassic surface which had been buried under the whole of the Mesozoic series. It has been shown that the members of this series, when traced westwards, tend to become thinner, and may never have reached the Pennines, whose surface may therefore have been always exposed. The existence of such superposed streams as the Dove and the Derwent, however, implies the former presence of at least a thin covering possibly of late Cretaceous rocks. Since that was removed this surface has been lowered continuously by denudation, a fact which raises the question, ' What, after all, are we trying to date ? '

In the adjoining lowlands, on the south and east, there are several erosion levels. The highest of these is at about 650 ft. and is preserved as a fringe around the Pennines and in isolated fragments, such as that of Charnwood. The curves of equilibrium in the upper reaches of those valleys which incise the 1,000 ft. surface conform to this 650 ft. surface. Much of the lowland area is occupied by a very broad shallow valley feature produced in pre-glacial times by the Trent drainage system. The floor of this rises from 300 ft. near Nottingham to 450 ft. south of Ashbourne and in Needwood Forest. The floor of this valley was dissected in mid-glacial times by the Trent and its tributaries, with the production of those flat-bottomed trench-like valleys which are so characteristic of the area.

Mr. A. Austin Miller.—*Erosion surfaces in South Wales and South Ireland.*

The clearly marked erosion surfaces presented by the coastal plateaux of South Wales, from the mouth of the Wye westwards to St. David's Head, occur at a variety of levels. The most frequently occurring altitudes are 200, 400 and 600 ft., but it is suggested that these plateaux constitute the dissected relicts of a once continuous plane of marine erosion and that the apparent breaks are due to cliffing of the emerged shore plane during the progressive retreat of the sea. The platform terminates in a degraded cliff line at 800 ft. against the Prescelly Hills, but farther east, in Carmarthenshire, it is difficult to separate this surface from one rising gradually from 900 ft. to the mid-Wales platform at 1,500 to 2,000 ft.

The 600-ft. platform will be discussed in some detail and the drainage system, developed on the emerged surface, analysed to show at least two erosion cycles graded to progressively lower base-levels.

A somewhat similar sequence of events is apparent in South Ireland; but here the alternation of rock types of markedly differing resistance has brought about an 'Appalachian' drainage pattern. The erosion surface is preserved on most of the interfluve ridges of more resistant rock, and an attempt will be made to reconstruct the original form and extent of the surface.

Mr. J. Hanson-Lowe.—*Morphological data of the Channel Islands and their bearing on the Eustatic Theory.*

The Channel Islands lie well to the south of the southernmost limit of Pleistocene glaciation and are free from volcanic and violent seismic action. Moreover, these Hercynian stumps consist of rocks sufficiently highly resistant to fluvial erosion to warrant the preservation of polycyclic fluvial forms. Furthermore, the three main islands are excellently mapped with small contour intervals and on large scales.

These facts suggest that the islands might well throw light on the vexed question of ancient higher sea-levels; and it is of moment that the three main islands are sufficiently distant one from the other to permit of comparisons being made between them, each island having been examined individually along morphological lines.

The paper deals with the results obtained mainly from the reconstruction of ancient thalwegs, aided by other data afforded by the Clinographic Curve, etc.

Léon (Brittany) is not far distant, and the excellent maps available enabled Baulig to deduce certain characteristic levels in this region; the results of the Channel Island investigation are related in the paper to those obtained in Léon.

The accordant data obtained from the maps have been carefully checked by personal observation in the field, particularly in Jersey and Guernsey.

Dr. H. C. Versey.—*The Tertiary geological history of E. Yorkshire.*

The occurrence and characters of detached masses of sand on the Yorkshire Wolds are described. The peneplane upon which they rest is correlated with the peneplanes of Cleveland.

Excursions to (*a*) Somerleyton, Kessingland, Covehithe (2.0).
(*b*) Corton, Scratby and the Broads (2.30).

(Both excursions repeated on Tuesday.)

Tuesday, September 10.

Prof. Baron G. de Geer.—*Natural annals so far deciphered for* 15,000 *years* (10.0).

Our oldest written records, known from cuneiform inscriptions on clay slabs, do not go much farther back than 4,000 years. Nature has prepared more reliable annals for a longer time, deciphered, so far, for the past 15,000 years. These annals are preserved in slabs of clay which, by their variation in thickness, represent a self-registration of years and of the annual radiation from the sun. This registration is specially discernible where marked seasonal variations during the final stage of the Ice Age every summer gave rise to an accentuated flood of melt-water, depositing an annual *varve* of clay. Such *varves* are now found on the bottom of late Quaternary inland seas or ice-dammed lakes with brackish or fresh water. Here, the more heavy, cold and muddy melt-water currents follow the bottom, registering every seasonal variation in the transporting power of the water by a cyclic lamination. At open coasts with more heavy salt water the clay was carried out along the surface, and no *varve* cycles were formed.

By means of mapping, measurements, photos and lantern slides it is possible to illustrate this process of sedimentation. By comparing long series of annual *varves* a definite connection has been found, and this was so reliable that certain overlooked *varves* could be noted, and afterwards found to exist in their right place and number. As such correspondence was observed between the northern and southern hemispheres as well as under the equator, this proved that all the Quaternary glaciations were synchronous and not alternate, as supposed on several astronomic assumptions. The widespread and rapid annual variations exhibited by the clay *varves* indicate, as a cause, the annually varying amount of heat from the sun. The normal variations may depend on a varying amount of meteoric matter in space, more or less obscuring the radiation from the sun. Biennial variations conclusively established, but independent of each other, may indicate some biennial arrangement of the obscuring dust, as in the case of the cometoids.

Varve connections have been published for all the Fenno-Scandinavian countries, Scotland, Iceland, United States, Canada, the Alps and the Himalayas, British East Africa near the Equator, and, in the southern hemisphere, Patagonia. Teleconnections have been determined, but not yet published, in the southern hemisphere (New Zealand) and in the northern hemisphere (Newfoundland and some parts of Russia and Siberia).

Dr. W. J. Arkell.—*A reinterpretation of the Purbeck and Ridgeway faults in Dorset* (10.30).

The interpretation of the Purbeck and Ridgeway Faults as thrust faults from north to south, accepted for the last 40 years, is untenable. The only thrusting has been on a trivial scale from south to north, as shown at Durdle Cove and Swyre Head. The Purbeck Fault at Ballard Point can be best explained as a normal fault downthrowing north. It does not reach the sea between White Nothe and Bat's Head, near Lulworth, as marked on the Survey map, where only a synclinal bend in the chalk can be found, accompanied by crushing in the axial plane.

The Ridgeway Fault is accompanied by a belt of shattering and upward drag in the chalk to the north of it, and downward drag and contortions with small reversed faults are shown to exist in the Purbeck Beds adjoining it on the south. Hence it is inferred that the Ridgeway Fault is a reversed fault upthrown on the south side. At its western extremity it almost coincides with the Abbotsbury Fault, a normal fault of intra-Cretaceous age downthrowing south about 700 ft. The two faults are believed to run approximately parallel for five miles and to scissor across east of Upwey. The inliers of Oxford Clay and Lower Oolites at Ridgeway and Bincombe are explained as a wedge of rock that has remained on the upthrow side of both faults and been bared locally by erosion. The famous 'dyke' of

Oxford Clay at Ridgeway cutting is a slice severed from the downthrow face of the Ridgeway Fault at the point where the intra-Cretaceous and Tertiary faults nearly coincide. The throws of the faults at Ridgeway and Bincombe need not be nearly so great as has been supposed.

Mr. N. E. Odell.—*The structure of the Franz Josef region of north-east Greenland* (11.0).

Recent work by British and Danish expeditions has shown the existence of Caledonian, Hercynian, and Tertiary orogenies in North-East Greenland.

During the Boyd Expedition of 1933, evidence was found in the western part of the Caledonian belt, north of Petermann Peak, of (*a*) stratigraphical continuity of succession from the lower grade, Petermann Series (Wordie), into the higher grade types of the Central Metamorphic Complex (Parkinson and Whittard); (*b*) the Metamorphic Complex, having mainly acquired its condition dynamically during, and in part prior to, Caledonian orogeny, and not thermally on account of wholesale granite intrusion or syntexis (Backlund); (*c*) the local granites occurring as sheet-intrusions and not batholiths (Whittard *et al.*), and being involved in the Caledonian folding; (*d*) overfolding and not merely tilting of the Petermann Series; (*e*) highly probable equivalence of the Petermann Series and the Eleonore Bay Formation (Koch), or Franz Josef Beds (Wordie).

In western Ymer Island and the neighbourhood block-movements, and some minor local thrustings, appear in part to be post-Caledonian, and probably Hercynian, in age.

The Giesecke Mountains are an inclined Tertiary block composed mainly of Upper Palæozoic and Mesozoic strata, while their northern end is supposedly of Kainozoic rocks. They are extensively intruded by basalts of the latter age, and some acid irruptives of similar, or possibly Hercynian age.

Discussion on *Geology in schools* (11.30).

Prof. A. E. Trueman.

From time to time the suitability of geology as a science subject for schools has been advocated, notably by Prof. W. W. Watts, whose Presidential Address to Section C, in 1903, dealt comprehensively with the functions of geology in education. Those geologist who have opposed its introduction into schools have done so chiefly because they feel that a student should acquire some knowledge of other sciences before commencing geology, and because they prefer that geological teaching should be commenced at the University: so far as the latter reason is concerned it certainly does not affect the case of those who will not proceed to University work in Science.

It seems particularly desirable that such students should gain some acquaintance with geology, which is likely to afford a more lasting interest to many than corresponding periods spent in chemistry and physics.

Recently, the tendency to carry school courses to a further stage, associated with the development of the Higher School Certificate, has created new opportunities for the teaching of science in schools, but it has led to an early specialisation which is greatly to be regretted; the limited choice of science subjects in schools, especially in the smaller ones, has given rise to a particularly difficult problem. The introduction of geology at this stage would be of great value.

Many educationists are profoundly disturbed by the tendencies in science teaching, which is thought to be increasingly dogmatic and specialised. Many experienced teachers hold that a genuinely scientific outlook can be acquired in chemistry and physics during the post-graduate years only; some biologists hold that the same is true for their subjects. Geology is almost unique in that the beginner can feel the excitement of making new discoveries, and it may perhaps be claimed that as a medium for the development of a scientific outlook, few subjects are more suitable than geology.

Partly as a result of dissatisfaction with the present position of school science, there is a tendency for the establishment of courses in General Science up to the First School Certificate stage; the present intention appears to be to include in such courses some physics, chemistry and biology. Geology should also have a place in this scheme, and it is hoped that efforts will be made to secure its inclusion.

The position of geology in schools must also be considered in relation to the growth of geography. In some instances much geology is included in geography syllabuses, and provided that the subject is taught adequately, it may not matter greatly if its name is never mentioned. It is, however, unfortunate that the rise of geography has not led to a greater recognition of the value of geological training.

Prof. P. G. H. Boswell, O.B.E., F.R.S.

In my address to Section C at York in 1932, I emphasised the value of geology as a cultural subject in schools, and expressed the opinion that the breadth of view it unconsciously engenders, the perspective it gives, the enthusiasm it inspires and the training in field-observation it affords, are all arguments for its inclusion in the curriculum of every student. I even quoted the words of the then Prime Minister, Mr. Ramsay MacDonald, to the effect 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 history, the history of its evolution, enforces the true scientific method—geology might be selected as that science.'

But I also expressed the opinion that it might be undesirable further to overload an already heavy school curriculum by adding geology as a full subject in a regular course of study. If, however, our science could be introduced more widely into schools 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. And I know that it is very popular with boys.

Latterly, the Imperial College has contributed to this end by introducing into a new scheme for the award of Entrance Scholarships a general science paper of which sections are devoted to Chemistry, Physics, Botany, Zoology and Geology. The object of the new scheme is to attract to a scientific career candidates who have had a good general education but who have not begun to specialise in science. Papers are set in English, History, Foreign Languages, Mathematics and General Science. While it is still early to judge, the results to date appear to indicate that the experiment is justified.

Dr. A. Kingsley Wells.

There is no doubt that were geology to occupy in schools the position that it should by virtue of its scientific interest, its high cultural value and its fundamental importance to mankind, the University lecturer would have no cause to complain of the size of his classes, and there would be no cause for anxiety concerning the future of geological departments in the Universities. By comparison, geography occupies an important place in the curricula of most modern schools, and is flourishing in most universities. It should be recognised that it is almost impossible to turn out a good geographer unless he has an adequate geological foundation upon which to build. The speaker urges the need for regarding geology as a 'pre-requisite' for all students reading for a degree in geography. Within his experience very few, who have once taken up the study of geology, drop it subsequently; they prefer to offer it as their second subject. Here another serious difficulty arises: those responsible for training many of these students as teachers do not regard this as a good combination of subjects. Much good might be done by urging upon those responsible for making appointments in the teaching profession, that the first essential is that the candidate should be a good teacher, a master of teaching technique. Given this, any University student with a good degree shows by his academic qualification his ability to imbibe information, and should be regarded as reasonably qualified to teach any of the subjects, usually four in number, taken in the Intermediate examination. If this were admitted the charge that geology is not a good teaching subject would not arise, the number of geologically-minded teachers would steadily increase, and the problem might well solve itself.

Miss M. E. Tomlinson.

For several years the speaker has had charge of the Geography in a large mixed school in Birmingham and has had experience of the great interest which pupils have taken in Geology, both in field excursions and in talks organised by the school Scientific Society, and also in the Geology which is, of necessity, introduced into Geography lessons. Great enthusiasm has been aroused, and it has always been a matter of regret that lack of time in and out of school has limited these activities. Judging from this interest the speaker is convinced that the study of Geology should be available for school pupils, particularly those who do not proceed to a university, since it creates an interest in phenomena out of doors, which may well develop into a lasting life interest. It may not lead to important geological results, but will undoubtedly contribute to the happiness of the individual by helping him to a satisfying means of enjoying his leisure, now too often spent indoors with cinema and jazz.

Co-operation in the teaching of Geology and Geography is essential in each school to show the pupils the relationship between the two subjects and to prevent overlap.

Mr. A. N. Thomas.

To meet possible objections to the teaching of Geology in schools on the grounds of impracticability, the speaker recounted his own experiences as a pupil in a large secondary school in South Wales, where Geology is taught to the Higher School Certificate standard with remarkable success. The school is situated in one of the 'natural laboratories' referred to by Prof. Trueman, where curiosity in geological phenomena is naturally aroused. The interest of the pupils has been fostered by the formation of a Geological and Geographical Society which organises excursions, promotes discussions and solicits lectures. These activities have stimulated the interest of many people in the district outside the general sphere of school influence. A representative collection of British rocks and fossils is being formed, having as a nucleus the personal collection of the Geology master, supplemented by purchased specimens and by contributions collected by past and present students.

Among those who have qualified in Geology from this school some have proceeded to the University, others to Training Colleges, mining schools, while others have entered business life. The examination results have been excellent: for example, this year 13 pupils obtained their Higher Certificate; of these, 7 took Geology, 5 passing with distinction and 2 with credit.

There is some prejudice, however, against the teaching of Geology, and it is hoped that one of the results of this discussion will be to remove this and give Geology a fair chance of surviving on its own merits.

Prof. A. H. Cox, Prof. A. E. Gilligan, Prof. W. W. Watts, F.R.S., and others.

AFTERNOON.

Excursion to Corton, Scratby and the Broads (2.15).

Wednesday, September 11.

Mr. J. H. Taylor.—*The use of heavy minerals in correlating igneous rocks* (10.0).

The communication gives a summary of the results achieved in an examination of the validity of the correlation of intrusive igneous rocks by means of their accessory minerals as elaborated in a series of papers by Dr. A. W. Groves, who dealt in particular with the Armorican intrusives of South-West England, the Channel Islands and the Cotentin. American interest in the subject is evidenced by the appointment of a committee of the National Research Council to deal with the subject, but as yet the opinion of the members seems to be divided.

The author has thoroughly tested the hypothesis by examining the Tertiary granites of northern Ireland and elsewhere, applying quantitative methods involving counting all the heavy non-magnetic accessories and the several types of zircon and apatite. In the large composite intrusion of the Mourne Mountains the following results have been reached:

(*a*) Rocks of the four members of the complex are individually distinctive as regards their major constituents and texture; but cases are recorded in which rocks of the same petrographic type yield dissimilar accessory suites, while rocks dissimilar in type and belonging to different members of the complex yield similar accessory suites.

(*b*) Samples from different parts of any one member of the complex vary considerably in regard to the mineral species present, their varietal characters and relative proportions.

(*c*) The vertical distribution of zircon and fluorite has been carefully examined and it is evident that the depth of erosion has an appreciable effect upon the proportions and varieties of these minerals.

Finally, by comparison of the granites of the Mourne Mountains with others, both Tertiary and older, it is concluded that the Tertiary granites cannot be separated by their accessory minerals alone from those of other ages.

Dr. A. T. J. Dollar.—*The geology of Ailsa Craig* (10.30).

Ailsa Craig, at the south end of the Firth of Clyde, is a heterogeneous mass of riebeckite microgranite (the *ailsyte* of Prof. N. F. Heddle), cut by a swarm of basic dykes. Special interest attaches to the sedimentary xenoliths, drusy facies and columnar joints in the ailsyte; to the distribution and petrography of the dolerite and basalt sheets, and to a raised beach at fifteen feet above present mean high-water mark.

The Craig has the form of a blunt sugar-loaf, rising to a height of 1,114 ft. above the sea at a point nine and a half miles due west of Girvan, Ayrshire. In plan it is sub-rectangular, with its greatest length (over three-quarters of a mile) north-south, and its greatest breadth (over half a mile) east-west. On the south and west are vertical, columnar cliffs, while on the north-east and east are more stable joint-controlled slopes; from the east coast a cusp-shaped spit of shingle projects for nearly three hundred yards, and storm beaches encircle the isle.

The ailsyte occurs in coarse and fine varieties, known, locally, as the *common rock* and the *red* and *blue hones* respectively. The coarse rock, which includes drusy types, has been used in the past for road metal and monuments; the fine varieties are still sold for curling stones. A few small but well-preserved sedimentary xenoliths have been found by the author in both varieties.

The basic dykes, which number about twenty, are sub-vertical sheets of coarse and medium dolerite or basalt, as much as thirty-nine feet thick, with a dominant north-south trend but a local zigzag course round groups of ailsyte columns. Weathering in these rocks has given rise to parallel 'steps' and *clais* (Gaelic for a 'trench') structures on the slopes of the Craig, and to caves of flask-like profile at present sea-level as well as at the height of the fifteen-foot raised beach. The latter is marked by pebble deposits bearing erratics, and an impersistent coastal notch.

Dr. S. W. Wooldridge.—*The glaciation of the London basin and the evolution of the Tertiary escarpment in Hertfordshire* (11.0).

This communication directs attention to certain problems connected with the belt of drift deposits containing Triassic debris and extending from Goring Gap to Hertford, along the northern margin of the London Basin. Dr. R. L. Sherlock contends that the pre-Glacial Thames followed this course. Other workers have examined parts of the belt and reached partial conclusions. A thorough re-examination of the evidence has been undertaken to see whether Dr. Sherlock's hypothesis can be substantiated or amplified, and what alternative possibilities should be considered.

The morphological features of the region considered alone point to conclusions difficult to reconcile with those derived from the drift deposits. In western Herts, two wind-gaps in the Tertiary escarpment appear to indicate drainage *across* the line of the Vale of St. Albans at a relatively late date in the evolution of the region. The eastern end of the escarpment is unbreached by wind gaps and any cross drainage must have antedated the present cycle of erosion. This line of argument, however, leads to a complete dilemma when the drift deposits of the Vale are considered. At least two sets of glacial or fluvioglacial deposits occur separated by 100 ft. or more in level. The lower series represents ice advancing from the east after the abandonment of the wind-gaps. The upper series, largely fluvioglacial, is apparently of westerly provenance, but the relation of the drift to the wind gaps is very difficult to interpret—and the reading of the physiography of the whole region must turn on this point.

The problems at issue were discussed in the field during the Centenary Meeting in London, and this paper offers a further contribution to an unsolved problem.

Reports of Research Committees (11.30).

SECTION D.—ZOOLOGY.

Thursday, September 5.

PRESIDENTIAL ADDRESS by Prof. F. BALFOUR-BROWNE, on *The species problem* (10.0). (See p. 63).

Mr. F. LENEY.—*The zoological collections of the Norwich Museum* (11.0).

Prof. C. M. YONGE.—*Mode of life and symbiosis in the Tridacnidæ* (11.20).

The family Tridacnidæ is composed of the two genera *Tridacna* and *Hippopus*. The former includes a variety of species some of which, including the Giant Clam, *T. derasa*, the largest of all bivalves, are unattached in adult life, resting, hinge undermost, on the surface of reefs. Other species of *Tridacna* bore into rock, but in a different manner from any other bivalve; in these the byssus is retained throughout life. *Hippopus hippopus* lives unattached on the surface of reefs.

The mantle edges are greatly enlarged, especially in all species of *Tridacna*. In this are immense numbers of zooxanthellæ of about the same size as those occurring in corals but differing from these in important details. They invariably occur enclosed in blood cells within blood sinuses. The mantle edges are curled back over the edge of the shell, affording the maximum of light for the algæ within. The so-called ' eyes ' in the mantle increase the effective light-receptive surface. The digestive diverticula are much reduced in number, and around those that remain are immense numbers of blood cells containing zooxanthellæ in all stages of digestion.

The Tridacnidæ have been profoundly modified owing to their association with zooxanthellæ, which they literally ' farm ' in the mantle edges and later consume. The twisting of the mantle in relation to the body mass, which has given rise to extensive controversy in the past, is the direct result of this association.

Mr. H. RAMAGE.—*The spectrographic analysis of animal tissues* (12.0).

Considerable use has been made of spectrographic analysis in the past ten years for the detection and estimation of the mineral constituents of tissues. Much new knowledge has been gained, and a new field of work has been opened up. Arc and spark spectra provide very sensitive tests for most of the elements, but the oxy-coal gas flame method is sufficiently sensitive for the detection of almost all the metals usually found in tissues and it gives, in less time and in one operation, more accurate quantitative results. By its means the specific composition of tissues and organs has been determined, and changes in composition during life have been followed in ways hitherto scarcely possible by the laborious processes of chemical analysis which only were available.

Dr. G. S. CARTER and Mr. J. A. H. MANDER.—*The flight of the flying-fish, Exocœtus* (12.30).

A description of the flight is given, and its function as an escape reaction in which the fish makes use of refraction at the surface of the water to escape a pursuer below the surface is discussed.

At the beginning of the flight the fins vibrate passively as a result of the movements of the tail, which at this time is being actively vibrated below the surface of the water. During the remainder of the flight no evidence can be obtained of any flapping of the fins by the fish. That no such flapping occurs is confirmed by the results of dissections of the fin muscles. These dissections show that no muscles are present which could result in flapping movements by their contraction. It must be concluded that the flight is a glide, and that after the preliminary stage, when the tail is vibrated below the surface of the water, the fish obtains no energy from the contraction of its muscles.

From measurements of cinematograph photographs of the fish in flight, taken by Mr. E. N. Willmer during a voyage across the Atlantic, it has been calculated that the normal flying speed of the fish is never greater than 25-30 miles an hour. This is too low a speed to enable a fish of the size and weight of *Exocœtus* to glide in still air for the distances and times which are often observed. It is suggested that disturbance of the air above the uneven surface of the water may be the source from which the fish is able to obtain energy for a longer glide than would be possible in still air.

Afternoon.

Prof. F. A. E. Crew.—*Colour inheritance in the Budgerigar* (2.15).

Attention is drawn to the value of the budgerigar as a material for the experimental study of evolution. All the existing colour varieties have arisen out of one wild type within the memory of living man, and it is known that the wild type form itself has not been crossed with any other species.

A mutant gene (*b*) is responsible for the blue plumage colouration; (*y*) for the yellow; (D) in the simplex state turns light green into dark green, and in the duplex state into olive; sky-blue into cobalt and mauve; yellow into dark yellow and yellow-olive. Greywing (*gr*) is an allele of yellow which lightens all pigmentation, especially that of the wing undulations. Cinnamon (*cn*) is a sex-linked recessive replacing the black by brown. It is not yet known whether the buttercup colour (yellow without the green suffusion) is another allele of yellow or is due to modifiers. White is the homozygous blue-yellow compound. Fallow, lutino and albino are new characters, the genetics of which is not yet known.

The budgerigar is of interest also because autosomal colour mosaics are common. A series of some two dozen of these ‘ halfsiders ’ is discussed and explained by an appeal to the chromosome elimination hypothesis.

Prof. W. Garstang.—*The marine biological station at Bermuda* (2.45).

Dr. H. B. Cott.—*The nature and function of disruptive colouration in animals* (3.15).

Concealment by means of adaptive colouration is an important factor in the lives of different animals. The problem of concealing colouration must be approached as a field study: the significance of colour and pattern can only be appreciated in reference to the habits of animals in nature, and to the habits of potential enemies and prey. The function of concealing colouration is deception—the rendering of an animal unrecognisable. Theoretically the concealment of an exposed object depends for its success upon the creation of certain optical illusions, underlying which there are three fundamental principles: (1) the resemblance in colour between an object and its background ; (2) the obliteration of light and shade by counter lighting and shading ; and (3) the breaking up of form by means of a superimposed disruptive pattern. These principles are those actually found to operate widely in nature.

Disruptive patterns are considered in relation to the habits, posture and habitat of the animals exhibiting them ; a special aspect of disruptive colouration, described as coincident disruptive colouration, has for its essential feature the extension of the pattern across separate but adjacent parts of the body. This greatly strengthens the disruptive effect by uniting parts morphologically separate, by concealing otherwise conspicuous organs, and by replacing the real form by a superimposed apparent configuration. The effect may further be intensified by actual modification of form and by diffusion of outline. The above principles have important applications in relation to camouflage in modern warfare.

Dr. R. H. Thouless.—*Protective colouration as a problem in the psychology of perception* (3.45).

The *Gestalt* theory of perception makes possible a psychological statement of the principles of the concealing colouration of animals in terms of the organisational properties of a perceptual field. The perceptual field is organised in such a way that parts of it are more or less segregated as separate configurations (Gestalten) seen as figures against a background. The tendency of such separate parts of the perceptual field to appear as mental units may be strong or weak. Strong (or insistent) configuration is determined by such factors as the possession of a definite, continuous and smooth boundary, difference in brightness (tone value) from the background, movement of the configuration as a whole relative to the background, etc. Cryptic colouration makes the configuration proper to the animal adopting it (the body configuration) as weak as possible. Disruptive colouration makes an alternative configuration much stronger than the body configuration. Flash colours may be a special device for dealing with the insistency of a configuration moving relative to the background. An attempt will be made to illustrate some of the relevant properties of visual configurations by epidiascope projection.

Friday, September 6.

Dr. J. A. Kitching.—*The osmotic function of contractile vacuoles* (10.0).

Contractile vacuoles occur in all fresh-water Protozoa, and in some marine ones. In Peritricha the rate of output of fluid is increased by a decrease, and decreased by an increase in the osmotic pressure of the external medium. A contractile vacuole probably prevents excessive swelling of the body by ejecting water as fast as this comes in through the body surface by osmosis, and is probably more important for this purpose in fresh-water forms. However, when marine Peritricha are transferred to dilute sea-water the contractile vacuole, by its increased output, probably controls the body volume. Suppression of vacuolar activity with cyanide leads to an immediate increase in the body volume ; and removal of the cyanide results in a rapid recovery of the contractile vacuole followed by a shrinkage of the body. Vacuolar action must involve the separation of water from salts, and therefore the expenditure of energy, which is probably obtained directly by an oxidative process. The inhibitory effect of cyanide is immediate, as in the case of the selective process of the kidney tubules, and not delayed as in the case of muscular contraction and other mechanisms where the immediate process is an anærobic one.

Mr. L. C. Beadle.—*Osmotic regulation in some brackish water invertebrates* (10.30).

Experiments with several brackish water animals (*Gunda ulvæ*, *Nereis diversicolor*, *Nereis virens* and *Arenicola marina*) have shown that the weight changes undergone on transference from normal to dilute sea-water are essentially similar in all these forms. A rapid rise in weight due to uptake of water is checked at a maximum considerably lower than would be expected if osmotic equilibrium were established. There follows a fall to an equilibrium value above the original weight. The general activity may fall during this process, but is ultimately regained. A typical marine invertebrate such as *Nereis cultrifera*, when subjected to these conditions, will take up water continuously until osmotic equilibrium is reached. The nature of the water control in the above brackish water forms is under investigation. Experiments indicate (1) that different species and individuals of the same species at different seasons differ in their powers of control; (2) that the water enters the body through the skin; (3) that the rate of entrance and consequently the power of control is influenced by temperature and by the calcium content of the sea-water; (4) that the water content of the body is not primarily controlled by the excretory organs, but that the animal is able to regulate the rate of inflow through the skin.

Symposium on *The herring problem* (11.0):—

Mr. E. Ford.—*The nature, extent and significance of vertebral variation in the herring with reference to the 'race' problem* (11.0).

Dr. W. C. Hodgson.—*Recent additions to the knowledge of the herrings of the southern North Sea* (11.30).

Since it became possible to forecast the general characteristics of the main fishery of the southern North Sea, attention has been directed to the study of factors which have an influence on the swimming of the herrings.

Besides phytoplankton concentrations, it appears that wind, either before or during the fishery, has a considerable effect on the catches of the drifters, and a detailed study of the variation in the amount of fish landed in relation to the direction of the wind is at present being carried out.

Further, lunar influence on the catches of herrings, especially in the southern part of the North Sea, is considerable, and the characteristics of the fishery vary according to the date of the October full moon.

It is also evident that there is a connection between the relative strength of year-classes and the temperature of the water in January in the Channel, which is the main spawning ground of the herrings of the southern area.

Prof. A. C. Hardy.—*The herring in relation to the plankton* (12.0).

Earlier work on the planktonic food of the herring is reviewed and reference made to the work of Pearcey, Savage and Hardy on the influence of phytoplankton on the herring. Recent work carried out with Dr. G. T. D. Henderson, Mr. C. E. Lucas and Mr. J. H. Fraser from the University College of Hull is described. The distribution of the herring in relation to that of the plankton is studied by experiments with an instrument, the plankton indicator, used on herring drifters during 1930–1934. Positive correlations between the number of herring caught and their food *Calanus* and negative correlations with phytoplankton have been demonstrated. Other correlations are suggested. The instrument is now used commercially. The progress made with a wide survey of the plankton by means of continuous plankton recorders towed by steamships crossing the North Sea is briefly described, and a general review made of the distribution of the herring fisheries in relation to the plankton. The continuous recorder survey is being conducted in close association with the Fisheries Department of the Ministry of Agriculture and Fisheries, who are making a more detailed study of the plankton in relation to the herring in certain areas of the North Sea.

Mr. R. S. Wimpenny.—*The plankton communities of the North Sea and their relation to the herring fishery.* (A résumé of work done by Lowestoft Planktologists) (12.30).

It has already been shown that the phytoplankton forms at times such dense patches that the movements and shoaling of the herring are interfered with. In this contribution the development and movements of these patches are considered for the past twelve years, but with especial reference to 1933 and 1934.

1933 produced the most luxuriant and dense growth of *Rhizosolenia styliformis* yet observed and also an unusually high salinity in the area of its occurrence. This was difficult to account for, and the possibility of its having been caused by the photosynthetic activity of the diatom itself is discussed.

In both 1933 and 1934 there was a tendency for the autumn herring shoals (as revealed by the charted catches) to mass against the edge of a diatom patch. A similar orientation was observed when some of the zooplankton organisms caught by the Hensen net were charted. Zooplankton are not absent even in dense phytoplankton patches, but in these areas the community consists of a greater proportion of young forms. It is possible that the phytoplankton patches may be nursery grounds and there may be a physiological gradient for the zooplankton between the edge and centre of a patch. Similarly herring that shoal prior to spawning may be taking up a position in relation to the phytoplankton patch that has a connection with the physiology of reproduction.

Afternoon.

Centenary of the Landing of Darwin on the Galapagos Islands, and of the Birth of the Hypothesis of the 'Origin of Species.'

Prof. Sir E. B. Poulton, F.R.S.—*Introduction* (2.15).

Prof. J. H. Ashworth, F.R.S.—*Charles Darwin in Edinburgh, October 1825 to April 1827* (2.45).

Information obtained chiefly from a notebook of observations made by Darwin and from the minute book of the Plinian Society of the University of Edinburgh, a biological society of which Darwin was a member from November 28, 1826, until he left Edinburgh in April 1827.

Prof. G. D. Hale Carpenter.—*Charles Darwin and entomology* (3.10).

Galapagos insects. Similar habits of ant-lions in Australia and Europe suggest unity of creation in 1836 : by 1845 view-point changed. Colouration of insects formerly ascribed to need for concealment : bright colours resembled flowers. Unpleasant odours repelled enemies: no one correlated this with conspicuousness and peculiar habits. Bates in 1862 described resemblances of butterflies to others, not nearly related, conspicuous and avoided by enemies, as ' Mimetic Analogies ' produced by Natural Selection. Reason for conspicuousness explained in 1867 by Wallace for brightly coloured caterpillars on appeal by Darwin. Natural selection explains (1) association of conspicuous colouration with habits displaying it, toughness, and repugnant qualities ; (2) acquisition of conspicuousness by a form lacking the other qualities ; (3) why mimicry deceives the artist and not the anatomist, and (4) production of mimetic effect by different means. Coincidence, affinity, or similarity of environment cannot explain niceties of geographical distribution of model and mimic.

Observations and experiments on insectivorous vertebrates show preferential feeding according to demands of theory.

Darwin stressed insects as exemplifying sexual selection, but elaborate scent-producing apparatus in males, acrobatic performances, and presentation of gifts to females provide little evidence of preferential choice by female of one particular male.

Modification of whole groups of insects and flowers for mutual benefit strong argument for natural selection.

Prof. E. W. MacBride, F.R.S.—*Darwin and the problem of the population of the Galapagos Islands* (3.30).

Darwin's reputation as a naturalist and a great observer would be secure if it rested on his description of the Galapagos Islands alone. In a masterly chapter in *The Voyage of the Beagle* he makes these islands live before our eyes. We see their arid burnt surfaces of lava studded with innumerable cones ; the great tortoises and the hard beaten paths which they pursue in their search for water ; the two peculiar lizards obviously nearly related and unlike the Iguanas, but one clearly adapted for life in water and the other for life on land ; we recognise the curious fact that the main islands, so closely similar in their physical features, are inhabited by species of birds and insects closely allied but nevertheless differing in the different islands.

In *The Voyage of the Beagle* he speculates on the mystery of these remote islands having been centres of so much creative activity, but in *The Origin of Species* he puts forward as an explanation ' Natural Selection.' At another meeting of this section I have maintained that this explanation really resolves itself into falling back on ' chance ' as a cause, and such a course I regard as unscientific. But the only alternative course is to suggest reaction to the environment as the cause of specific characters, and it might be asked how environment differs in such similar islands. Darwin suggests the existence of different proportions of enemies, but this is in the highest degree unlikely. A precisely similar phenomenon was described by Kammerer in his description of the varieties of lizards inhabiting the rocky islets of the Adriatic. He shows that in one islet the male has a rosy flush on the breast in the breeding season, and in another during the whole of the year, and yet there are no natural enemies as far as Kammerer could discover. One islet is more washed by spray than the other, that is all the difference that could be discovered between them.

An animal is not a piece of clockwork, but as Macdougal has pointed out, a centre of active striving. It rises up to meet the environment, and its effort alters its growth in every character.

Mr. H. W. Parker.—*The herpetological fauna of the Galapagos Archipelago* (3.50).

A century ago it was the reptiles which gave ' the most striking character to the zoology of these islands.' It was not the multiplicity of species, but the enormous numbers of individuals and the fact that ' the different islands . . . are inhabited by a different set of beings ' (Darwin, *Journal of Researches*) which most impressed Darwin, and the combination of these two features, the one implying competition and the other change, first suggested the idea of cause and effect—selection and the origin of species.

This fauna has, in the last hundred years, been decimated ; many of the larger species have been completely exterminated, and others have been so reduced in numbers that to-day not a dozen specimens exist on islands which formerly supported thousands. These larger forms, Giant-Tortoises and Iguanid Lizards, have a commercial value, and their destruction is due to direct human action. But the smaller lizards and snakes which are of no economic importance have also been seriously affected by the commensal animals accidentally or deliberately introduced by man.

The future of this fauna, so full of historical interest and possibilities for research, is bleak indeed ; irreparable damage has already been done and only immediate and drastic action can hope to save any fragment of it for posterity.

Dr. P. R. Lowe.—*The finches of the Galapagos Islands in relation to Darwin's conception of species* (4.10).

No attempt is made to give a general description of the birds of the Galapagos. The very peculiar and interesting condition which exists in connection with one group, viz. the *Geospizids*, or finches. They are the dominant group, and the diversity presented by their colouration, colour-pattern and external structure far surpasses anything found elsewhere in the world either on islands or the mainland masses.

When Darwin came to work out his collection of birds from the Galapagos he was struck with the diversity existing among the finches from the various islands and thought that each island had its own peculiar variant. These finches are therefore historical in that they inspired Darwin with his ideas on the subject of the effects of environment, natural selection, etc., in the origin of species.

But a very different condition exists. There are some twenty islands in the Galapagos group, on all of which these finches are found, and on the different forms of which no less than sixty-seven specific, or subspecific, names have been bestowed by systematists. The most conservative admit forty, and their distribution is very remarkable, for some of the islands, as for example, James, Charles, and Indefatigable, have as many as ten or eleven different forms comprised within their limits ; while the little Wenman, seventy-eight miles from the nearest point of Albemarle, has six (referred by systematists to three genera). Duncan Island, again, with an area of only ten square miles, has no less than ten different forms (comprised in five genera) herded together.

Compared with other insular groups such a condition of things is phenomenal. It seems clear too, from descriptions published of the various islands, that the environmental conditions existing cannot be regarded as satisfactory factors which have caused this extraordinary diversity.

To what then can it be ascribed ?

(1) Is it due to hybridisation ?

(2) Were the segregates of a cross between ancestral forms distributed over a large insulated area which was subsequently broken up by subsidences or upthrusts leading to the present disposition of the islands ?

(3) Is it due to the fact that the natural tendency to vary resident in all organisms has been uncontrolled by any selective action ?

No attempt is made to answer these and other questions. The Galapagos problem can only be solved by establishing a biological station on the spot where experiments in genetics can be conducted.

Monday, September 9.

Discussion on '*The species problem*' *based on the Presidential Address* (10.0).

Prof. E. W. MacBride, F.R.S.

Even if he could not agree with everything the President said, the speaker recognised that the President had the true zoological point of view. For the species problem was *the* zoological problem ; as Lankester said at the meeting of the Association in York in 1906, there was this in common between the Church and zoological science, that both had set their hearts not on the present but on the distant future. The course of evolution was the problem which distinguished zoology from its allied sciences of comparative physiology and histology. Prof. MacBride agreed with the President that the theory of natural selection did not account for the evolution of all species. In his opinion it accounted for the evolution of no species. It was simply a dishonest truism and signified merely that 'the survivors survived.' It covertly assumed that small heritable variations in all directions were constantly occurring 'by chance' and the chance correspondence of one of these 'random variations' with the needs of the environment determined the survival of the individual. This, so far as modern research went, was simply not true. He thought that the President was right in stressing the unbroken passage from biological races to sub-species and eventually species. But the President should not be distressed by the fact that we could not see within our lifetime the inheritance of environmentally produced differences of structure. The 'engraining' of environmental effects was a very slow process. Woltereck examining lakes in South Bavaria found no peculiar species of Daphnid Crustacea in them, but only peculiar sub-species. These lakes were morainic lakes left behind by the recession of the great Alpine glacier of the Ice Age, and could not be less than 10,000 years old.

The President was also worried because he could not see the utility of certain 'characters.' Let him remind the President that characters were abstraction. What lived and survived was not the character but the animal. A character was a peculiarity of growth, and the growth of the animal in all its parts was a response to the demands of the environment. Certain zoologists finding colour variations in parts of gastropod shells which were covered by the mantle and therefore invisible, must be due to chance. One of our brilliant younger naturalists had shown that in one gastropod at least these colour varieties were correlated with different kinds of food.

Lastly, many naturalists had emphasised the difficulty of seeing how one structure presumably derived from another could have been evolved, except by chance mutations. He would remind them where, as in lineage series, the actual course of evolution was known, the functional nature of the slow gradual changes was evident. Let what we know not be shaken by what we do not know.

Dr. R. Gurney.

The distribution of fresh-water Entomostraca shows, in many cases, precise association of species with particular environments which can only be accounted for by almost unlimited means of dispersal and selective destruction. The trivial structural differences between pairs of species cannot have survival value, but must be accompanied by physiological differences which cannot be estimated. Evidence can be given of structural changes directly caused by change of environment, but these changes are so small that the direct influence of environment cannot be one of the main factors in evolution.

Prof. H. L. Hawkins.

Palæontology shows the history of the relation between organisms and environment. Most fossil evidence that is reasonably consecutive is found in marine organisms; and even there no genetic relationships can be proved.

Given a constant environment, the tendency of the struggle for existence is to prevent the origin of species; but the histories of the Micrasters and Gryphæas show that progressive change proceeds in defiance of this tendency. Such evolutional changes affect characters that are only incidentally connected with physiological efficiency, although they may prove fatal when carried too far. Such cases imply the existence of a directional momentum of change that is wholly intrinsic.

Changing environment may cause migration or extinction; but it cannot be proved to produce direct adaptive change. The correlation between organisms and their environments is most easily explained by the influence of habitat on structure; but in many cases this leaves the 'choice' of environment as a problem. Any effect caused by environment is limited by the potentials of the organism, and is subordinate to the course of intrinsic change.

Dr. W. K. Spencer, F.R.S.

The species clusters are those arranged around evolving lines of starfish found in the chalk of Western Europe. Here there was fairly uniform physical conditions existing over a wide area for a very considerable time. Evolution was gradual and in definite directions. The changes involved are increase in diameter, in depth of body, and in modifications of shape and of ornament of marginalia. These modifications are parallel in several independent lines. The ornament characters could have had little functional importance. They are definitely related to the age of the lines and may be indices of physiological changes in the race. Branches from lines, giving new genera and species, seem to owe their new character in part because of acceleration in their racial history giving earlier maturity and premature senility.

There is no evidence of suppression of lines by competition. Lines which have become rare and then disappear are those which have had a long history behind them. The lines which are most productive in new species seem to be comparative newcomers which burst into activity under conditions which may have been exceptionally favourable. It is also noteworthy that the species appear to be most abundant when they, as judged by the above prolific characters, seem to be at the height of their vigour.

Dr. C. C. Hurst.

Genetic experiments lead to the conclusion that four prime factors are concerned in the origin of species: (1) Mutations of genes. (2) Transmutations of chromosomes. (3) Sex. (4) Natural Selection.

It is now definitely established that the living molecules known as genes, which are linked together in the chromosomes in the nucleus of every growing cell, are the organisers and determiners of all structural and functional characters and the transmitters of these from one generation to another.

Random changes in the genes and chromosomes, brought about by high-frequency radiations and irregular divisions, are the source of almost all heritable variations and the gene and chromosome complex constitutes the mechanism of heredity, variation, individuality and evolution.

The importance of sex cannot be overestimated as a means of segregation, recombination and distribution of new characters. So long as these are not lethal to the species they will persist under natural selection, giving a great range of variation.

Natural selection is not a primary cause of evolution, but it is the final arbiter and determiner of the survival of species in nature. Man, by the exercise of his intellect, can replace natural selection by human selection, not only with plant and animal species, but also with his own species.

Dr. W. M. Wheeler and Dr. N. A. Weber.—*Unusual prevalence of sex-mosaics (Gynandromorphs) in a colony of a Trinidad Ant* (12.0).

During the spring of 1935 Dr. Weber found nesting in the trunk of a large saman tree in Trinidad, B.W.I., a large colony of *Cephalotes atratus* L. containing more than 2,600 sex-mosaics, or 27·9 per cent. of the population. All these anomalies exhibit combinations of worker (sterile female) and male characters. In most of the individuals the sexual mosaic pattern is confined to the head, and the thorax, legs and abdomen are of the normal worker type, but several also exhibit admixture of male abdominal characters. The occurrence of so many sex-mosaics in a single colony and as the offspring of a single mother is remarkable, because very few ants exhibit such striking structural differences as Cephalotes between the normal male and worker, and because since 1854 less than 75 gynandromorphs have been observed among the hundreds of thousands of ants that have been studied by myrmecologists. Nor is the proportion of sex-mosaics to normal individuals greater among other insects in nature. Under artificial conditions the proportion, especially in hybrid cultures, is greater, but still very far from comprising a fourth of the population.

The queen mother of the Cephalotes colony is perfectly normal, with large ovary containing many eggs in all stages of growth. In sections none of these eggs shows any indication of binuclearity or of having arisen by fusion of two oocytes. This case, therefore, fails to support the hypotheses of the origin of gynandromorphism advanced by Dönhoff, Wheeler, Doncaster and von Lengerken. The colony lived under conditions which seem to preclude the effects of hybridism, parasitism, low temperatures, X-rays, ultra-violet rays or mechanical shock, which, according to several authors, are capable of producing sex-mosaics in insects. The study of the large number and great variety of the Cephalotes mosaics has not as yet proceeded far enough to enable us to estimate their bearing on the hypotheses of Boveri, Morgan, Goldschmidt and Whiting.

Dr. D. M. Wrinch.—*The structure of chromosomes* (12.30).

A molecular structure for the chromosome is proposed as a working hypothesis. This structure is designed to interpret the findings of the cytologists as to the capacity of the chromosome to swell, to contract, to grow and to divide ; and to explain in molecular terms the postulates of genetics and the nature of the gene.

Afternoon.

Lt.-Col. R. B. Seymour Sewell, F.R.S., C.I.E.—Semi-popular lecture on *The John Murray Expedition to the Arabian Sea* (2.0).

(1) The origin of the expedition.
(2) An account of the ship, H.E.M.S. *Mabahiss*.
(3) The scientific staff.
(4) The itinerary.
(5) The character of the coasts in (*a*) The Red Sea.
(*b*) The S.E. coast of Arabia.
(*c*) Muscat and the Gulf of Oman.
(*d*) Zanzibar.
(*e*) The Seychelles.
(*f*) The Maldives.
(6) The bottom topography and the different characters of the North-east and South-west basins.
(7) The main trend of the deep circulation.
(8) The distribution of the fauna, with special reference to certain areas in which there seems to be but little or no animal life.

Exhibition of Prof. J. S. Huxley's film '*The private life of the gannets*' (by kind permission of London Films Production Ltd.) (3.0).

Excursion to the Marine Biological Station at Lowestoft, by kind invitation of Dr. E. S. Russell, Ministry of Agriculture and Fisheries (3.30).

Exhibition of the following films, by courtesy of British Gaumont Instructional Films (9.0) :

Amœba ; earthworm ; worms ; the life of the frog ; the life history of the blow-fly ; the early development of the sea-urchin ; the life history of the tortoise-shell butterfly.

Tuesday, September 10.

Symposium on *Animal migration* (10.0) :—

Prof. J. Ritchie.—*The migrations of terrestrial and aerial mammals.*

Wanderings of limited extent, restricted to short periods, are a common expression of the rhythm of mammalian life, and some specialised mammalian structures are accommodations to this habit. Whether these movements be reversible or irreversible, their objectives suggest some of the factors which have determined the great seasonal and reversible movements properly called migrations. In their limited way the seasonal migrations may be likened to the migrations of birds, for some are only local affairs, while others cover a wide range ; but birds pass without record, while many mammals create regular migration tracks or roads which they follow year after year. The migrations of bats, which ought to form the closest parallel with bird movements, do not appear to be essentially different from those of other mammals. In a different category from migration proper must be placed those occasional eruptions of such as the lemming in Scandinavia, the brown rat of Asia, or the grey squirrel and marten of North America, which are one-way pressure movements due to abnormal increase of numbers.

Dr. N. A. Mackintosh.—*The migration of whales* (10.25).

It is generally assumed that the whalebone whales of the southern hemisphere spend the summer on the feeding grounds of the Antarctic, and migrate in winter into warmer waters where breeding takes place. Evidence of these migrations is partly derived from direct observations on the movements of the Humpback off the African coasts, and partly from indirect sources such as fluctuations in the abundance of Blue and Fin whales in cold and temperate waters, variations in the fatness of whales, and the existence of certain scars contracted in warmer regions but distinguishable on whales found in the Antarctic. Direct evidence is also forthcoming from the Discovery Committee's marking experiments.

It is difficult to distinguish between the long seasonal migrations and the various movements connected with changing ice conditions and local wanderings in search of food. Whales travel long distances, for instance, on the retreat of the pack ice in summer.

The means by which whales orientate themselves during migration is not known. They are evidently sensitive to small changes of temperature, but this seems inadequate to guide them on a long migration.

Dr. A. Landsborough Thomson, C.B.—*The migration of birds* (10.40).

Annual migrations are common among birds, from wanderings in which the breeding place is the only fixed point to extensive journeys between widely separated seasonal habitats : there are also some less regular movements. In its more highly developed form, bird-migration shows a combination of complexity and regularity : *inter alia*, some remarkable examples of migration in purely tropical species are now known. Much evidence is available to show that migration is not performed merely under the compulsion of external forces, but commonly anticipates—and often apparently exceeds—the requirements arising from seasonal change in the environment.

The inevitable assumption that migration is the expression of an instinct raises questions of causation. Migration must serve useful ends, and recent investigations have helped towards a closer definition of these. Its origin and development necessarily remain matters of speculation. The nature of the recurring stimuli which annually evoke the behaviour has, however, been the subject of interesting experimental work in the last few years. The final problem is that of orientation, including the manner in which the path to be followed is determined.

Dr. E. S. Russell, O.B.E.—*The migration of fishes* (11.5).

Dr. C. B. Williams.—*The migration of insects* (11.30).

Mr. G. A. Steven.—*The growth and migrations of the Thornback Ray* (12.0).

During recent years ray-marking experiments have been carried out in the English Channel—in the vicinity of Plymouth—particularly on the Thornback Ray (*R. clavata*). Returns of marked fish have shown that, during the whole period of growth, from hatching to adolescence, the Thornback Rays, in the area investigated, are entirely non-migratory. So remarkably sedentary are these fishes during their immature years that in numerous instances the same fish has been captured again and again on exactly the same spot of ground in the open sea after intervals varying from two weeks up to almost two years. One fish, for example, has been captured and recaptured in the same place no fewer than six times at varying intervals over a period of fifteen months.

Such repeat captures of the same fish at intervals over an extended period are unique in the history of fish-marking experiments and afford a valuable check on growth-rate data obtained in the ordinary way from the larger number of fish which are marked, liberated, and recaptured once only.

From the data so far obtained, growth in *R. clavata* appears to be relatively slow, averaging about 5 cm. per annum increase in width of disc during the period of immaturity.

Miss L. E. Cheesman.—*The zoo-geographical evidence of the former extension of land masses in the Western Pacific* (12.30).

The Austro-Oriental sub-region can be separated zoo-geographically into two divisions : a northern containing the Celebes and adjacent islands, and a southern (herein called Papuasia) which consists of New Guinea, definite areas in North Queensland, Aru and Key Islands, and islands east of New Guinea, including the Solomons and part of the New Hebrides Archipelago. Geological evidence of the land movements. Evidence deduced from the insect fauna. Deductions based on the Hymenoptera Parasitica. Distribution of Aculeate Hymenoptera influenced by man's activities. Genera and species confined to Papuasia compared with those belonging to the entire sub-region.

Afternoon.

Mr. F. S. J. Hollick.—*The flight of insects* (2.15).

If a dipterous fly, such as *Muscina stabulans* Fallén, is suitably held stationary relative to the ground, it will perform regular wing movements, and it is considered that an investigation of what occurs is of value in elucidating the process of normal free flight.

The wing of a fly is capable of a certain degree of bending, and this, combined with the nature of the articulation, results in its attitude changing during each complete beat. It is possible to reconstruct the successive attitudes that make up the complete beat by studying the paths traced out, while the wing is vibrating, by the beams of light reflected from small mirrors attached to different parts of the wing surface.

The velocity and direction of flow of air produced may be analysed by recording photographically the paths travelled by small particles carried along in the air-flow.

A consideration of these data shows something of the manner in which the insect is maintained in the air and propelled forwards ; first, by virtue of the effect due to the independent action of each wing, and secondly, due to that produced by mutual action of the two wings while at the top of their beat.

Mr. J. M. Reynolds.—*The nature of aptery in the Apterygota* (2.45).

A discussion of the secondary or primary nature of wings in Insecta, beginning with a review of proposed solutions of the problem.

Lankester's comparison with the Ratites is a mere analogy. Sŭlc's theory, based on the thoracic flaps of *Lepisma*, is not sufficiently supported by evidence. The fossil 'insects' from the Rhynie Chert are probably true Collembola, but there is no evidence as to whether or not they possessed wings. Tothill's idea of balancing primitive and specialised features found in the Apterygota is unsatisfactory, because it excludes the possibility that the nature of the aptery in all three orders may not be the same.

A detailed review of the characters of *Machilis* ('typical' of Thysanura) leaves little doubt that they are more primitive than the Pterygota in all respects, presumably including their aptery. The same is probably true of the Protura, but not of the more specialised Collembola. These, however, may ultimately be shown to be primitively apterous by the discovery of an intact thorax of Devonian forms.

The conclusions reached are supported on general principles by the relatively late appearance of wings in Pterygote development, suggesting that their evolutionary acquisition is relatively recent.

Mr. E. A. Parkin.—*Recent work on the food relations of the Lyctus powder-post beetles* (3.15).

Morphological and histological examination of larvæ shows that there are no accessory glands appended to the gut, and that micro-organisms, present in a pair of mycetomes in the body cavity, can play no direct rôle in digestion. Chemical analysis of the food and frass, determination of the enzymes present in the larval gut, the effect upon larval development of extracting wood with various solvents, and the results of some preliminary experiments upon feeding larvæ on powdered substrates such as wood of various species and wood flour mixed with different carbohydrates, etc., all show that *Lyctus* larvæ feed upon the cell contents and not upon the cell wall constituents of wood. Starch and a water-soluble factor, probably sugars, have been shown to be necessary for normal larval growth. Ovipositing beetles are able to detect wood suitable for larval development by chemotactic means. Wood rendered free from starch and sugars would be immune to *Lyctus* damage, and several methods to achieve this are now being investigated.

Demonstrations on view during the meeting :—

A series of living budgerigars in illustration of Prof. F. A. E. Crew's paper to the Section.

A series of specimens and slides illustrating 'The pattern of the *medulla oblongata* in the Teleostean Fishes,' by Dr. H. Muir Evans.

A collection of fresh-water Polyzoa by Mr. H. E. Hurrell.

A collection of Mycetozoa by Mr. H. J. Howard.

SECTION E.—GEOGRAPHY.

Thursday, September 5.

PRESIDENTIAL ADDRESS by Prof. F. DEBENHAM, on *Some aspects of the Polar Regions* (10.0). (See p. 79.)

Mr. R. H. MOTTRAM.—*The site and present lay-out of Norwich* (11.15).

(1) The site of Norwich probably represents the best landing place on the shores of the East Norfolk estuary during racial migrations. Here the river Wensum passes between the sharpest contours of its course, and receives its main tributary, the Yare, which gives its name to the combined stream.

(2) The first settlers. Negligible Roman influence. 'Gerguntius.' Saxon Conisford, now King Street, Thorpe and Trowse. First documentary evidence, mention of Norwyk in Anglo-Saxon Chronicles.

(3) The open hundred of Norwich in Domesday and its Danish named trackways. What the Normans altered, Castle, Cathedral and Mancroft Ward.

(4) Building of bridges and use of streams by cloth and leather workers affects internal development, but main roads retained.

(5) Thirteenth century fortification further fixes main thoroughfares. Exempt jurisdictions and effect of Black Death and Reformation.

(6) Altered physical conditions revealed by Kett's Rebellion in 1549. Effect of eighteenth century Industrial Era. Nineteenth century changes due to making of Cattle Market (1780), Railway (1844) and Trams (1900).

(7) The twentieth century and the return to the road. The establishment of an air port (1933) and regular air services (1935).

Miss ELLEN M. HOLE.—*The industries of Norwich* (11.45).

Norwich, once the third city of the realm, presents a curiously attractive mixture of ancient cathedral city and modern industrial town.

Until the beginning of the nineteenth century her citizens wove home-spuns from local wool, while Flemish immigrants had taught them to make silk and satin materials. Revolutions and wars in the early nineteenth century ruined the weaving industry and spread poverty throughout the city. This misery was stemmed by the growth of a second staple industry, the making of shoes.

The present industries of Norwich are determined by the fact that, whereas it has neither mineral wealth nor coal, Norfolk is a rich agricultural and pastoral county. There are two main types of industries, those which obtain their raw materials from farmers, and those which, importing their raw materials, manufacture wooden and steel buildings and implements for farmers. In both groups are firms which have increased their output far beyond local requirements and have gained international repute.

Norfolk, formerly cut off by Fen and Breck from other populated areas, had to develop its own industrial centre. Geographical factors indicated Norwich as that centre. Bridge town, river port, focus for roads and railways, it offers to industry transport facilities and convenient factory sites.

Mr. W. J. Taylor.—*Norwich of the future* (12.15).

Area of Scheme No. 1 . .	6,096 acres, approx.
Area of proposed Scheme No. 2 in built-up area . . .	1,827 „ „

Proposals for future development of built-up portion of city to preserve as far as possible the historic, archæological and architectural buildings, and to open up vistas of such buildings.

Detailed plans prepared by agreement for the preservation and future development of the Cathedral Close, clearance of buildings surrounding the old city wall, gates and towers.

Proposed new roads reduced to a minimum, but at least two inner circular roads required—gradient difficulties on south-east side of city. Reference also to flood prevention, provision of car parks and to ultimate treatment of civic centre.

Road and traffic problem difficulties illustrated by a similarity of Norwich to a hand and wrist—the wrist being the one main outlet to the coast, the thumb and fingers the main roads north, south and west.

The co-ordination of business, residential, industrial and shopping centres, illustrated by a user map, also a map indicating streets of architectural interest.

'The City of Parks,' to preserve its reputation.

Preservation of amenities, shop limits, heights of garden fences, preservation of trees, incongruous roofs, and building materials, redevelopment of slum areas.

Afternoon.

Norwich Old and New. A walk round the City. Conducted by Messrs. R. H. Mottram, J. E. G. Mosby, W. J. Taylor and Miss E. M. Hole (2.15).

Friday, September 6.

Dr. Vaughan Cornish.—*The cliff scenery of England and the preservation of its amenities* (10.0).

The coast scenery of England is partly urban, partly rural, and of the latter the cliff lands are the most important section. Their outlook on the sea is comparable in its natural majesty to the Alpine heights which are the culmination of Continental scenery.

It is important that Local Authorities, under the powers conferred by the Town and Country Planning Act, should (1) secure a permanent right of way along all cliff fronts not yet comprised in private gardens ; (2) procure as a public open space a strip of at least 100 yds. broad reckoning from the cliff edge. The setting of the building line at this distance is not by itself an adequate provision, the garden fence should not be allowed a nearer approach.

The preservation of our cliff scenery for the public should not, however, be saddled entirely on the Local Authorities, for it happens that many of the parts which are of most importance to the nation as a whole are situated in localities where rateable value is relatively small and where scenic preservation is of much less financial benefit to the residents than in the neighbourhood of the large watering places. Certain stretches of coast should, therefore, come under the proposed scheme for National Parks, reservations of wild scenery, of which the cost is to be defrayed wholly or in part from the national exchequer. In relation to national reservations of cliff lands Cornwall has a pre-eminent claim, not only on account of the rugged grandeur of the rocks but of its blue oceanic waters and mild oceanic climate. The peninsula of the Land's End, with its granite rampart, is the most important part, but there are other stretches of the Cornish coast which should be included, notably the cliffs of dark blue slate from Tintagel to Boscastle and parts of the Lizard peninsula. In this connection it is important to free the mind from the idea that each nationally administered portion of cliff land is to be reckoned as an individual National Park; rather should we conceive all the portions of cliff land placed under the National Park Authority as constituting together a reservation equivalent to one of the proposed inland National Parks, as that of the Lake District or the Welsh National Park of Snowdonia.

Mr. J. E. G. Mosby.—*Some aspects of land utilisation in Norfolk* (10.45).

Organisation of the survey in Norfolk, number of volunteers taking part, and methods employed in carrying out the work from 1931 to 1935. Ways and means used by the editors to produce the five 1-inch maps relating to this area, viz. Cromer, Norwich, Swaffham, Fakenham and Thetford. These maps cover the greater part of Norfolk and some adjoining parts of Suffolk.

The conclusions of the paper are based on (1) the patterns suggested by the 1-inch sheets; (2) a personal knowledge of the area, and (3) a study of such factors as physical features, soils, economic conditions, land ownership, etc.

Conclusions.—1. On the good loams of north-east Norfolk arable farming still continues despite changes in the prices of farm produce, government policy and change of ownership.

2. The introduction of sugar beet has enabled a large number of farmers to keep their lands in cultivation.

3. Change of ownership is often accompanied by a change in the utilisation of the land, especially in the boulder-clay areas.

4. On the sandy lands and Breck soils the amount of land going out of cultivation is assuming alarming proportions. Such land is reverting to stony wastes, and it is in these districts that the activities of the Forestry Commission are most pronounced.

5. In the marginal areas between the chalk uplands and the rich loams the presence or absence of suitable roads sometimes decides the land utilisation policy of the farmer.

The paper includes illustrations from Great Hockham and the neighbouring parishes.

Mr. N. V. Scarfe.—*The agricultural geography of Essex* (11.30).

From a study of the correlations between soil, land utilisation and settlement in Essex it will be obvious that a zoning of agricultural patterns, relative to the conurbation of the south-west, has evolved. Soil differences add considerable complexity to the cultural landscape in each zone.

Within twelve miles of London is a very densely settled region, on the fringes of which has developed a very intensive form of market gardening. Beyond this, and concentric with it, is a zone, five miles in width, with much sparser settlement where dairy farming is the chief occupation. From this zone as far as thirty miles from London extends an area of recent residential settlement where marked concentrations of people are found along the main roads. It is a hilly dairy farming and market gardening region.

The remainder of Essex is divided more obviously on a soil basis into :

(i) A north-western boulder clay plateau where a declining population still carries on cereal cultivation ;
(ii) An eastern estuarine lowland which is a grass-covered London clay region where population is also decreasing ; and
(iii) An area of increasing population extending along the main roads from Chelmsford to Ipswich, Harwich and Clacton, which is essentially a region of fruit, truck and mixed farming developed on a variety of light or medium soils.

Mr. E. C. Willatts.—*The land use regions of the London Basin* (12.15).

This paper gives a summary of the land utilisation in the centre of the London Basin, the area covered by the four 1-inch sheets surrounding London. An analysis of the major categories is shown in the form of abstracts from the land utilisation maps.

It has been found possible to distinguish the following ' rural ' land use regions : Chilterns, Thames Valley, Cookham Loam Plateau, Burnham Wooded Plateau, Colne Valley, Vale of St. Albans, South Herts Hay Belt, Middlesex Clay Plain, Lea Valley, Epping Forest, Essex Mixed Farming Area, Brentwood Forest and Hay Belt, Romford Market-gardening Plain, Bulphan Clay Plain, Thames Market-gardening Plain, Windsor Forest and Grass Belt, Bagshot Heath and Pine Forest Plateau, Blackwater Valley, North Surrey Clay Plain, Hayes-Chiselhurst Heath-Wood Belt, Kent Market-gardening Plain, Thames Marshes, North Downs, Rough Scarp Belt, Fertile Chalk Slope.

The urban growth is treated as a feature which is superimposed on these natural regions : it is a growth which has almost completely masked certain areas.

The character of each region is separately considered and is illustrated by specimens of the 6-inch Land Utilisation Field Sheets.

Afternoon.

Prof. E. G. R. Taylor.—' *England's blame if not her shame* ' ; *or the seventeenth-century pamphleteer on country, town and nation planning* (2.0).

The creation of a green belt about London, the location of industries on selected rural sites, the preservation and creation of urban amenities, re-afforestation, the reclamation of waste lands, national waterways, a planned agriculture, the husbanding and balanced utilisation of the nation's heritage in the shape of natural resources : all these were urged 250 years ago. What would the geography of England be to-day had planning achieved the victory over *laissez-faire* ?

Mr. E. W. Gilbert.—*The human geography of Menorca* (2.45).

Menorca, the second largest of the Balearic Islands, is 263 square miles in extent, and contained about 41,500 inhabitants according to the census of 1930. The island can be divided into two regions. The northern region contains low hills of which Toro (1,150 ft.) is the highest. The southern region is a limestone plateau and is deeply dissected by ravines. In spite of the fact that Menorca is only twenty-five miles distant from Mallorca, the character of its climate is very different. The smaller size of Menorca gives it a more maritime climate than its larger neighbour, and the absence of any protecting range of mountains leaves it more exposed to the winds. The cold dry north wind called *Tramontana*, which blows with great frequency in the winter half-year, limits the agricultural activities of the inhabitants. Life is much harder in Menorca than in Mallorca, and the density of population is considerably lower.

Menorca was occupied by the British for three distinct periods in the eighteenth century. During the seventy years of the occupation roads were built and many other reforms were introduced, especially by Sir Richard Kane, who was Governor between 1712 and 1736. The seat of the capital was moved by the British in 1722 from Ciudadela to Mahôn, which became an important naval base. Mahôn soon surpassed Ciudadela in size and now contains about twice as many inhabitants as the old capital. The long period of foreign rule left behind some permanent marks. English sash windows and over a hundred English words, some in corrupt forms, are still in use.

Prof. E. P. Stebbing.—*The encroaching Sahara : increasing aridity in West Africa* (3.30).

During a tour made last year through parts of several British and French Colonies in West Africa it became possible to carry out some investigations into the increasing aridity of parts of the country and to study the influence which the southward encroachment of the Sahara exerted upon this problem. It is possible to attribute the present position to several well-known factors :

(*a*) The method of agriculture practised throughout the Colonies by the population is ' shifting cultivation.' A piece of forest is felled, the material burnt, when dry enough, and the seed of one or more crops sown on the area. The site is occupied for two to three years ; the cultivator then moves to another piece of forest. Forest thus utilised gradually becomes degraded : this accounts for the large areas of ' bush ' or so-called savannah throughout the country.

(*b*) To this agricultural practice must be added the habit of annually firing the forests so common in all the Colonies, and

(*c*) The growing pressure of the large herds of cattle, sheep and goats which are pastured on the lands in the more northern areas. With the increase of the population and the herds under the settled administration now in force these practices are resulting in a growing desiccation of the soil and decreasing water supplies in parts of the country.

(*d*) The question of the encroaching Sahara is discussed and it is shown that the great desert sands have advanced southwards 300 kilometres during the last three centuries.

Saturday, September 7.

Excursion to Norfolk Broads. Conducted by members of Norfolk Geographical Association (9.25).

Sunday, September 8.

Excursion to Scolt Head Island. Conducted by Mr. J. A. Steers (9.20).

Monday, September 9.

JOINT SYMPOSIUM AND DISCUSSION with Section C (Geology), on *Denudation chronology* (Section C Room, 10.0). (See under Section C, p. 374.)

AFTERNOON.

Excursion to site of Hockham Mere, Breckland and Peddlar's Way. Conducted by Mr. J. E. G. Mosby (2.0).

Tuesday, September 10.

Capt. A. W. HEAP.—*Aeronautical maps* (10.0).

1. *Introductory.*

Maps were originally produced for the use of soldiers, later the general public began to use them and to demand special types of maps for special purposes. The airman now requires special maps for his use.

2. *The Problem.*

(a) *Scale.*

Deciding factors: Speed of flight. Map-carrying capacity of the aeroplane. Amount of detail of use to the airman.

These factors conflict with one another. The present trend of opinion favours a scale of 1/500,000 for general navigational purposes.

(b) *Projection.*

Requirements are: Accurate bearings. True shape of topography. True scale.

These ideals are not attainable on any one map. Choice of projection must depend on the shape and latitude of the country mapped and on neighbouring countries.

(c) *Detail.*

In all cases hill features and heights are of importance and usually water. Relative importance of other detail must vary with the country being mapped and with the purpose and scale of the map.

3. *Conclusion.*

The ideal method of designing any aeronautical map is to survey the ground from the air. This is usually impracticable. Aeronautical maps are still very much in their infancy; the preceding remarks therefore show the present trend of thought and do not pretend to be a statement of final conclusions.

Specimen aeronautical maps passed round during the discussion.

Lieut. M. O. COLLINS.—*The revision of large scale Ordnance Survey maps* (10.45).

The large scale revision surveys are of peculiar interest to this country, as it is the only one where such surveys have been in existence for upwards of fifty years. The system of carrying out these surveys is in itself a development of the methods employed in the original work. The history of the various revisions is of interest, showing as it does both the present position and the possibilities of the future. The future possibilities may be considered under two heads: the technical question, which has of recent years been affected by the introduction of and advances in air survey technique. The second question is that of general policy, which has been accentuated by the rapid development of the country, together with much legislation dependent to a large extent on an adequate survey. Revisions may be of two types, either cyclic or continuous. The former has been in practice in the past. No survey can ever be up to date owing to the time required for publication and issue of the actual work to the public. Continuous revision will, however, ensure an up-to-date field document which can be reproduced and published according to the particular needs of the area concerned.

Dr. Hilda Ormsby.—*The definition of Mitteleuropa and its relation to the conception of Deutschland in the teaching of modern German geographers* (11.30).

The political idea of a Central Europe, constituting a geographical and cultural unity and having Germany as its heart and core, has, from the first, received the support of eminent German geographers, whose elaborate, albeit varying definitions, supported by geographical arguments are of considerable interest. Since the break-up of the Austro-Hungarian Empire, and the re-alignment of the boundaries of Germany, a remodelling of the formula has been necessary, and the modified conception of Central Europe receives a fresh significance in association with a newer conception: that of a 'Deutschland' which is limited only by the extent of continuous German influences, whether expressed in racial characteristics, in language, in cultural habit or in economic method, or in any combination of these expressions. The 'cultural landscape' as a basis for geographical study fits in aptly in the development of this conception, though the classical method of building from the structural and geomorphological basis is also adopted where it can be usefully applied. The German student of geography to-day is taught to visualise not the German State, whose boundaries may be only ephemeral, but the larger conception of an area coinciding closely with that of Central Europe, itself usually envisaged as a conscious entity, with interests and cares apart from those of peninsular and continental Europe, and he is shown 'Deutschtum,' extending in a wider radius beyond the areas of *continuous* German influences, embracing, as outliers of Deutsch*land*, all settlements of German origin or affinities which have become at one time or another established in foreign lands.

Mr. D. T. Williams.—*Linguistic divides in Wales* (12.15).

The maps show that the Welsh language remains the medium of ordinary conversation over two-thirds of Wales. Bilingualism is general, but in the remote western parts and in the highland parishes monoglot Welsh prevails amongst the older people and the younger generation below school age. Monoglot English areas are found in the eastern marcher shires and on the coastal plain of both South and North Wales. The present linguistic distribution is partly the result of historical evolution, especially of the Norman and English conquest period, producing anglicised areas in South Wales and the Eastern Marches. In North Wales, the castle towns of the Edwardian period did not result in anglicisation to any marked degree. There has been in recent centuries a movement of Welsh-speaking farmers from the hills into the lowlands, but this does not necessarily mean a language change in those areas. During the nineteenth and twentieth centuries extensive linguistic zonal changes occurred, resulting from the migration of population into the mining and industrial areas. Bilingualism has advanced rapidly with the introduction of universal education, the need of specialised scientific knowledge in the industrial areas, contacts with external culture, the growth of modern transport and the economic demands of organised industry. The problem to-day is whether Welsh culture can be expressed satisfactorily through the medium of the English language without the loss of its essential characteristics.

Afternoon.

Baroness Ebba Hult de Geer.—*Biochronology* (2.0).

Biochronology is defined as time measuring from evidence afforded by any rhythmically stratified organic matter. Annual deposition whether in clay or wood, i.e. varve deposition, appears to derive its mechanism ultimately from the sun and should be a durable register both of time and solar effect.

De Geer's measurements of the melt-water clay varves give a chronology which covers a period of 15,000 years, but the record is more complete for the glacial than the post-glacial period, and the latter is perhaps more important in human studies. By his record of the clay varves of the Ångerman Valley in North Sweden, Lidén fixed the length of the post-glacial period at about 8,700 years, and Prof. L. von Post's study of the pollen record of peat bogs and of the evolution of our forests affords a rich and valuable content in the chronological frame.

Prof. Douglass by his studies of the rings of the sequoia tree has established a time-scale of 3,200 years, and it is now possible to date historic dwellings such as those of the pueblos in Arizona by studying the rings of the yellow pine used in their construction, tying them on to rings of recent pines from the same region, and also comparing them with those of the sequoia. Far-distance comparisons with the sequoia record sent over by Douglass for the purpose are now being carried on at the Geo-chronologic Institute in Stockholm under the name Biochronology.

Lidén's graphs of clay varves match those of the sequoia rings. The striking coincidence of the curves leads us to accept the date of A.D. 1017 for the formation of the most recent clay varves and to reduce the length of the post-glacial period to 8,640 years. Graphs of the rings of logs used in an old bulwark or water-fort in Lake Tingstäde, Gotland, have been found also to match those of the sequoia in the fourth, fifth and sixth centuries A.D., and by using Douglass's time-scale it is estimated that the logs of the main fort were cut in the year A.D. 450, and those of the palisades at various times from A.D. 450 to A.D. 585. There is a coincidence which cannot be ignored.

Some object to the application to conditions in Sweden of a time-scale worked out on American data, especially when the scale is based on the examination of trees whose growth depends on so many factors which are all liable to differ locally. De Geer has shown that whatever seasonable or monthly variations may occur, there is a general close correspondence of the graphs of annual mean temperature in widely separated regions. The points of similarity and difference match those of the clay varves and tree rings of the same localities. We may therefore regard clay varves and tree rings as a kind of materialised climatic annual mean, and the sun as the ultimate source of climate. Variations in isolation from year to year are regarded as due to variations, often biennial, in the meteoritic dust occurring between the planets within our solar system.

Wednesday, September 11.

Dr. R. E. Dickinson.—*The development and distribution of the medieval urban grid plan* (9.30).

In the Middle Ages the urban grid plan developed simultaneously and independently in two principal areas, South France and Germany. It emerged gradually and reached perfected form in the middle of the thirteenth century. Its development is reflected in a morphological sequence of plans.

1. *Radio-concentric plans,* built round a nucleus.
2. *Route plans* (main route axis of plan).
   (*a*) Rib and ladder patterns (*N.B.* South Germany).
   (*b*) Parallel street patterns.
   (*c*) Spindle and meridian patterns (*N.B.* spindle pattern and long market place of Silesia).
3. *Grid plans.*
   (*a*) Carrefour patterns—spontaneous growth on two co-ordinates.
   (*b*) Block grouping without architectonic unity.
   (*c*) Block patterns based on right-angle co-ordinates.
   (*d*) Unified block patterns grouped around central market block.

South France.

The rectangular lot found in ' sauvetats ' of eleventh and twelfth centuries (1 and 2*a*). Foundation of ' bastides ' as means of defence and political allegiance (1150–1350). Region extends to Pyrenees, Dordogne R., and Central Massif. Mixed plans, but dominance of rectangular block composition. All types, 2*c* rare.

Germany.

The grid developed with evolution of market place (main street, widened street, adjacent long rectangular market, central market square of ' Zentralanlage '). Regular patterns (Neustädte) established adjacent to irregular town patterns (Altstädte) in West Germany. Expansion beyond Elbe-Saale (1150–1400) where regular plans (Kolonialstädte) dominate. Spread east of 3*d* with German commercial settlement, e.g. Breslau, Cracow, Lemberg, Posen.

Mr. T. W. Freeman.—*The early settlement of Glamorgan* (10.15).

The study of early settlement in Glamorgan reveals the significance of the space relations and the physical environment of the time. The region was reached by people of varied cultures from Palæolithic times, but not intensively occupied. Sporadic infiltrations of people from the English Lowland and from the sea routes occurred and, though the colonisation was both late and scanty, favoured areas received many immigrants during the Bronze Age.

The chief regional division is between the Highland (the ' Blaenau Morganwg ') and the areas of ' lowland,' which include the ' Bro ' of Glamorgan, the Gower peninsula, stretches of unstable sand-dunes in Merthyr mawr Warren and Kenfig Burrows, and the coastal fringe of marshes guarded by sand-dunes between the Kenfig and Tawe rivers.

The earliest traces of settlement occur in Gower ; other coastal areas, such as Merthyr mawr Warren, were occupied from Neolithic times and with the entry of the Dolmen builders and the Beaker peoples favoured areas in the Bro and Gower were settled. The Blaenau was penetrated from early Bronze Age times and the later penetration, to which sections of existing trackways, with earthworks, presumably date, may be assigned to the period of vegetational changes in sub-Atlantic time (first millennium B.C.). The higher, bleaker parts of the moorland were used only for seasonal migrations, or else, with the forested valleys, avoided.

Miss ALICE B. LENNIE.—*Agriculture in Mesopotamia in ancient and modern times* (11.0).

Ancient records give much information that throws light on the antiquity of many modern practices, and suggests that the climate has varied little. Modern barrages, and pumps run by oil-engines are innovations, but the summer level of some canals is still raised by temporary earth dams, and old methods of watering the fields still persist.

Date Gardens.—'Iraq with some 30 million palms is still the foremost country for dates, and the archaic methods of culture are almost unchanged, e.g. propagation by offshoots, artificial pollination which requires one male palm to fifty or sixty females. The walled gardens, intersected by canals, occupied the more valuable sites near the cities and bordering the rivers or main canals.

Fruit trees were planted between the palms. Fig, vine, pomegranate, citron and mulberry were, and are, the commonest. Orange groves at Baghdad to-day require the palms for shade and protection from hot winds. Under all were fodder crops like lucerne, vast quantities of garlic and onions, and beds of other vegetables of which Babylonia had a notable variety. Gherkins were abundant, also flowers and aromatic plants.

Arable Farms.—The fenced fields, of a few acres, were cultivated by ox-plough and irrigated. To-day wild pigs often devastate the ripening rice, and locusts are still a plague. In early spring before the grain was shot, the rank growth was cut and domestic animals pastured on it for a time. At harvest (end of April to mid-May) the ears were reaped by sickle, then the straw cut and stubble burnt. Fields were often rented for a third of the crop, or for fixed rents paid in kind, but not necessarily from the produce of the field. In the Neo-Babylonian Empire fixed money rents were in vogue. Barley, much the most important cereal, formed a standard of value. Emmer was used for bread for feast-days ; wheat, at twice the price of barley, used only by the rich. Other winter crops were pulses and flax. Sesame was the chief summer crop, with durra. Tree-cotton was introduced under the Persians, rice under the Seleucids. The recent success with seed-cotton has been ruined by the fall in price.

SECTION F.—ECONOMIC SCIENCE AND STATISTICS.

Thursday, September 5.

Mr. COLIN CLARK.—*The world's food supply* (10.0).

We are celebrating this year the centenary of Malthus. Nevertheless it is our duty to state in no uncertain terms that under present circumstances Malthus is wrong. The pressure of population on food supply has been replaced by the pressure of a glut of foodstuffs on a stationary population.

Malthusian views have become not only stale but pernicious. Nearly everyone has got it firmly fixed in his head (*a*) that the population ought to be reduced, (*b*) that each country ought to grow more food. The first is a matter of taste, but the second opinion is demonstrably wrong. It is one of the items of the fashionable economic-nationalist point of view, and has resulted in far more labour than is necessary being spent on producing the world's food supply. Except in certain specialities, European agriculture cannot at present, without artificial aid, compete against American or Australasian agriculture. It is a sign of agricultural progress that labour should be released from agriculture, as indeed has been the case in the advanced agricultural countries, and not that more labour should be taken on.

An excuse, but not a justification, for the artificial aid given to agriculture in many countries, is the world-wide inequality of the ratio of exchange between agriculture and industry, i.e. the relative dearness of manufactured goods and the relative cheapness of agricultural produce. This also has serious indirect effects, the most serious being that peasant producers over many parts of the world cannot yet afford the implements and fertilisers even to bring their agriculture up to a nineteenth century level of efficiency and have to use an agricultural technique which has been obsolete in England for centuries.

Mr. J. C. Gilbert.—*Some monetary problems of international trade* (11.0).

A comparison of domestic and international trade. The theory of international trade as part of the theory of equilibrium. The advantage of this approach rather than that of comparative cost theory. International trade distinguished from domestic trade by the special monetary problems arising from separate monetary systems. The monetary mechanism under gold standard arrangements in the cases of international trade variations and changes in one-sided international payments. The relationship between changes in the terms of trade and changes in relative price levels. A consideration of the difference between international income adjustments and those which take place between different parts of the same country. The monetary mechanism under independent paper currency arrangements. A discussion of appropriate monetary policy in the light of the theory of neutral money and the preceding analysis of variations in international economic relations. Monetary policies under gold standard and independent paper currency arrangements considered.

Mr. R. A. Hodgson.—*Occupational changes and population movement in S.E. England* (12.0).

Friday, September 6.

Presidential Address by Prof. J. G. Smith on *Economic nationalism and foreign trade* (10.0). (See p. 89.)

Prof. L. M. Fraser.—*Present-day economic problems in Germany* (12.0).

Monday, September 9.

Presentation of Report of Research Committee and Discussion.—*Chronology of the World Crisis* (10.0).

Miss L. S. Sutherland.—*The use of business records in the study of history* (12.0).

The use of business records in the study of history is comparable to the use of archæological records for the same purpose. In a concrete, finite way they show 'how the wheels go round.' The wheels are, moreover, those of economic processes in which the many varieties of economic determinism now common have given us an especial interest.

In a discussion of business records one is bound to refer some time to the term 'business history.' This may be defined as the historical study of the unit of production and exchange of wealth; with the corollary that its sources are chiefly to be found in business archives, the working records of these units.

The importance of business records in the study of history is that they may make it possible for us to see the actual workings of these units, knowledge valuable for its own sake and also in helping us to comprehend wider movements. The difficulties in the way of using them are partly those of interpretation, but much more their own deficiency and inaccessibility, due to their purely utilitarian nature and the comparative impermanence of business units whose activities they record. Much valuable work can be done in preserving and classifying such records for the use of the historian.

Tuesday, September 10.

Joint Discussion with Section I (Physiology) on *Economic aspects of diet* (Section F room) (10.0).

Prof. E. P. Cathcart, C.B.E., F.R.S.

Provision of an adequately balanced diet in proper amount is essential for health and nutrition. Neither health nor proper nutrition can, however, be attained by such provision alone. States of health and nutrition are dependent on other important factors besides food. Admittedly when it comes to the finance aspect the provision of such an adequate diet demands, in the case of those with small incomes, the expenditure of a high proportion of the income. Percentage of total income spent on food rises with falling income. Even in the case of those with reasonably adequate incomes the proportion spent on food is fairly high. Two outstanding factors—there are more—intervene to-day, factors which may, however, not operate together, to make the provision of the necessary diet more difficult of attainment. Admittedly the provision of accommodation is admirable in itself and of direct assistance in many ways towards improved health and nutrition, yet such provision may be made, in part at least, at the expense of the income previously available for the purchase of food. Thus great majority of new housing placed at periphery of the large cities, i.e. inhabitants of necessity further from work places, hence increased transportation charges. Also rentals are in many instances higher. Frequently, too, more costly provision of fuel (electricity or gas) for cooking and heating.

Provision of adequate balanced diet does not necessarily mean provision of costly diet. Probably the main economic difficulty, the second of the two outstanding factors, is lack of education on part of those who need it most. Ignorance of most economical methods of spending and cooking.

It is simply futile to draw up dietary tables with costs for general use, as prices, not only in different parts of the country but also in different sections of the same city, may vary as much as 150 per cent.

Prof. K. NEVILLE MOSS.—*The energy output and input of the coal miner* (10.30).

The coal miner can be relied upon, if wages are adequate, to consume food of sufficient calorie value to enable him to expend the necessary energy during work and non-working hours. When wages are very low one of two things happen: either the miner has to do with less food and in consequence reduce his work-output, or he maintains his work-output and dietary standard at the expense of his family. In 1923 I published a paper showing that the average daily calorie value of the food actually consumed by 60 colliers was just over 4,700. Two years later the Medical Research Council issued a report entitled 'The Nutrition of Miners and their Families,' in which is stated, 'We shall therefore assume that the daily net energy requirement of a coal miner certainly does not exceed and probably falls a good deal short of 3,500 Calories.' This figure was arrived at on the assumption that the average work-output of the coal miner is 10,000 kilogram-metres per hour, which is equivalent to walking on the level at the rate of just under 2 miles per hour.

Actual determinations prove that the energy-output is $3\frac{1}{2}$ times greater than that assumed by those responsible for this report. Thus it is seen how seriously the experts misjudged a collier's energy output and how gravely wrong, in consequence, was their estimate of his food requirements.

Sir JOHN ORR (11.0).

Prof. P. SARGANT FLORENCE.—*The actual cost of food requirements to working-class families* (11.30).

I. *Economic and psychological factors increasing the cost of any given food values for working-class families.*

(1) Ignorance of the housewife what to purchase and how to cook it. Knowledge *versus* custom, prejudice and advertisements.

(2) Poverty. Inability to purchase except hand to mouth in small quantities and often 'on tick.' The wife's housekeeping allowance often much below the husband's earnings. Families not always models of thrift.

(3) Poor judgment and household management. Mental wear and tear of straitened circumstances and large households. Lack of houseroom, storage and refrigeration.

II. *Relation of cost of food to working-class incomes.*

A survey of recent social surveys. The family budget. Various sources of income, and contributions of various members of the family. Necessary expenditure on housing, clothing, fuel and household requirements. Proportion of families in destitution, with incomes below the bare minimum cost of living. Is destitution diminishing? The effect of low wages, unemployment and large families. Correlation of poverty with death-rates.

III. *Calculation of changes in the cost of food from time to time.*

The official index number of the Ministry of Labour. Items included: methods of weighing and averaging of prices; comparison with base period; recent trends; outlook for the future.

GENERAL DISCUSSION (12.0).

Wednesday, September 11.

Dr. A. Plummer.—*British air transport* (10.0).

(*a*) Early experiments and pioneer air services. The formation of Imperial Airways, Ltd., in 1924. Its policy and progress. The principal other British air lines. (*b*) The essentials of successful air transport. Types of freight most likely to be attracted. Speed and carrying capacity. Organisation. Costs. Fixed and variable costs compared. (*c*) State subsidies in aid of air transport. Questions of size and form. The present degree of dependence upon State subsidies. British and European air lines compared. (*d*) Air Mails, Imperial and Foreign. Charges and speeds. Proposals for greater speed on Empire air mail routes. The chief obstacles. (*e*) Measurement of the progress of British commercial aviation. Comparison with European air lines. Is safety increasing ? (*f*) The future. Development of a national system of air transport for Britain. Britain's rôle in the development of international air transport.

Mr. P. A. Forrester.—*Economic causes of the localisation of industry in Norwich* (11.0).

The problem presents itself that Norwich, although situated quite away from the industrial areas of Great Britain, yet has a population of 129,000 and important industries. The existence of these cannot be explained, to any great extent, by their dependence on local supplies of raw material or fuel. Other areas seem equally well situated as regards these things. This suggests that other factors are of more importance in determining the localisation of the Norwich boot and shoe, engineering, textile, mustard and starch industries.

In its theoretical aspect the subject of localisation is in its infancy, but, in practice, certain specific factors may be seen at work in determining the situation of an industry. The significance of these in regard to Norwich may be considered, and attention, in turn, be directed to the historical factor, to the influence of raw materials, of markets and transport, of supplies of labour and capital, and of the organisation of industry in the City. Further, Norwich may be compared with areas of similar industrial development.

A study along these lines leads to the conclusion that, in Norwich, less substantial factors have been of more importance than the theory of localisation would lead us to expect. In particular, it would seem that the existence of a plentiful supply of skilled labour, and the effects of a long manufacturing and commercial tradition, are, to a large extent, the key to the position of Norwich. And it would also seem that the condition of the continued existence of her industries is their skilled organisation on specialist lines. Finally, Norwich, in a small way, shows the extreme difficulty of attempting to generalise on the problem of localisation.

DEPARTMENT OF INDUSTRIAL CO-OPERATION (F*).

Thursday, September 5.

AFTERNOON.

DISCUSSION on *The Universities and business* (2.45).

Dr. J. A. BOWIE.—*The case for more intimate co-operation.*

This paper assumes that the case for university education for business has been accepted, and proceeds to discuss the types of organised contacts that might be established. This raises the question of the occupational opportunities in business for university men, and the merits of general, as contrasted with specialised, training. The question is discussed as to the relative importance of scholastic tests and personal traits in the light of the qualifications necessary for successful business careers. The great variety of careers is emphasised and the necessity for 'job analyses.'

Questions relating to curricula are raised with reference to the place of Economics and kindred subjects. In view of the purpose of business education, the problem of teaching methods is discussed, the working relations that should exist between the school and the world of business, and the qualifications that are desirable in the teaching staff.

The paper concludes with a consideration of the methods at present in use for selecting, training, and promoting managerial staff, and some recommendations are made for regularising procedure.

Prof. P. SARGANT FLORENCE.

Industrial-educational films (5.0).

Friday, September 6.

AFTERNOON.

DISCUSSION on *Probable future trends of scientific management in Great Britain* (2.45).

Mr. HARGREAVES PARKINSON.—*Industrial management and the investor.*

Modern investment machinery—capital market, Stock Exchange, issuing houses, financial press, etc.—presupposes complete differentiation of function between investor and management. In practice, 'sleeping partnership' conception undesirable and unworkable. Rôle of industrial management in investment sphere. Where should its boundaries be drawn? Rôle of investors in management. Every public company a 'constitutional oligarchy.' Directors, as fountain-head of management, removable by majority vote of shareholders. How are latter's 'constitutional' powers exercisable? How far are results satisfactory in practice? Defects of present position. Consequences, from viewpoint of management and investors respectively, of modern trend towards (*a*) large industrial units, and (*b*) widely diffused shareholdings. Suggested reforms, as regards (*a*) disclosure of essential facts of management to shareholders ; (*b*) organisation and extension of responsible opinion among investors, as ultimate 'democratic' check on management. Conclusions.

Dr. E. S. Pearson.—*The rôle of probability theory in the control of quality in production.*

The term 'statistics' is understood in many senses. An essential characteristic of the particular aspect of the subject discussed in this paper is the use of probability theory as a guide to practical action. In the last few years it has been increasingly realised that an approach long ago followed in the theory of errors in astronomy and more recently in problems of human heredity, biology and agricultural experimentation can be usefully employed in connection with the control of quality of industrial products.

The introduction of these ideas into a new field of application is necessarily a gradual process, partly because the trained statistician must adjust himself to new conditions and new problems, partly because the engineer is at first baffled by terminology and conceptions with which he is unfamiliar. In this paper a situation arising in the manufacture of electric lamps is used to suggest why it may be of value to relate the ordinary conceptions of confidence and risk with more precise numerical measures of probability.

The bearing of these ideas on the choice of sampling clauses in specifications is discussed, and finally it is pointed out how, by means of statistical controls applied to the results of routine testing by the manufacturer, a considerable extension of the efficiency of specification should be possible.

Mrs. Ethel M. Wood, C.B.E.—*Domestic management of to-morrow.*

Until recently the approach to problems of management and labour in the domestic field has been largely sentimental. Now the methods of study are beginning to resemble those applied to other industrial problems—that is, scientific methods are being introduced.

The only logical way is to regard the parts of the house primarily intended for work as workshops ; to observe flow of work, frequency of operation, etc., in connection with the placing of equipment ; and such matters as the health and convenience of the worker by means of time and motion studies, study of posture, surface heights, etc., as in other factories and work places.

These matters are of more than academic interest in view of their influence on the health of the women concerned who are the mothers of the future generations.

Various bodies are now directly concerned with the elimination of waste and fatigue in domestic work, but the need for education not only of women workers but of public bodies, equipment manufacturers, builders, etc., is emphatic.

The attitude of employers of domestic labour is a relic of the feudal system, but the improvements of conditions, wages, and even of status are discernible.

The efficient performance of domestic duties constitutes highly skilled work involving budgeting, planning, skilled craftsmanship, costing, etc.

Afternoon.

Industrial management films (5.15).

Office management : illustrating reorganisation of the Post Office Savings Department.

Monday, September 9.

AFTERNOON.

DISCUSSION on *Problems of amalgamation and decentralisation* (2.45).

Mr. L. URWICK, O.B.E.—*Executive decentralisation with functional co-ordination.*

Organisation may be regarded technically or politically. Necessity for a technical approach. The nature of responsibility : its relation to (*a*) power, and (*b*) authority. Practical reasons for decentralisation : (*a*) the time factor ; (*b*) the space factor ; (*c*) psychological factors. Distinction between executive and policy-making (administrative) responsibility. Growth of functional specialisation : its inevitability. Need for co-ordination of functional methods. Reconciliation of these two tendencies the central problem in modern business organisation. Failure to recognise the nature of the difficulty : failure of combinations for this reason. Tentative attempts to meet the situation. Committees, standard practices, staff and line, etc., etc. Where a new duty arises the only ultimate solution is to define that duty and to assign it to individuals, properly selected and suitably trained. Inevitable that business organisation will evolve towards a true system of ' staff ' positions and relationships as distinct from either ' line ' or ' functional ' positions. Organised ' staff ' training an essential corollary of this development.

Mr. T. G. ROSE.—*Some cases from the experience of a management consultant : Decentralisation in Small Undertakings.*

(*a*) *Head-office in London—Works in provinces.*—Necessity frequently arises for head of business to work from London whilst manufacturing is carried out in provinces to instructions received from head office. London is primary centre of sales activities ; place of manufacture usually unimportant, except in certain cases where raw material supplies decide location. Management difficulties arising from this form of divided operation.

(*b*) *Financial control from London—management and manufacturing activities carried on in provinces.*—Difficulties here arise from those controlling finance being out of touch with current working conditions. Loss of local good-will and *esprit de corps.*

(*c*) *Decentralisation of management in group of rationalised small firms.*—Difficulty of retaining individual good-will of member firms and at the same time loyalty to wider policy of combine. Methods of retaining management control from headquarters of combine.

Dr. K. G. FENELON.

Commercial management films : illustrating training in retail selling. Commentary by Mr. CLIFFORD J. HARRISON (5.0).

Wednesday, September 11.

DISCUSSION on *The place of the individual business in a planned economy* (10.0).

Mr. A. P. YOUNG, O.B.E.—*Industrial freedom within a system of planned economy.*

This paper deals with the broad human problem of building an ordered and balanced economy within an ordered self-governing society, without obscuring individual liberty or retarding the dynamic impulse to progress of individual initiative. It examines closely the following aspects of the problem :—

(1) The labours and sacrifices of generations of scientific thinkers and workers have given the human race, with amazing swiftness, a new age of MACHINES, full of immense potentiality as the productivity of man soars upwards. We are now in process of adjusting ourselves economically and spiritually to the new world of untold material plenty which lies ahead. Unless we solve the problem aright, man will become enslaved to the machine, and civilisation will crumple.

(2) The era of 'laissez-faire' is swiftly closing. Free and ruthless competition was the guiding principle of this phase of industrial evolution. Many still feel that industrial liberty is inseparable from competitive industry. A new mentality and a new spirit must be projected on to this intangible thing called individual liberty and freedom. The issue between democracy and dictatorship is raising its head high. The basic principle of service, 'We are all members one of another,' must receive widespread recognition if we are to find world salvation.

(3) The planned economy of the future must be erected on the foundation 'Plan to Serve.' Management must operate through an enlightened system of planned budgetary control. There must be planned co-ordination of production and distribution, and our monetary policy must be adapted to serve the needs of the planned industrial policy. The objective of the industrial policy must be to improve its service function—service to all those within industry ; service to the owners of capital ; and service to the community.

(4) The human factor—that intangible and supreme factor in any economic system—cannot be planned. The final test of any such system must be the degree to which it permits human personality to unfold its divine destiny. The planned economy of the future, to be successful, must be founded on the principle of planned co-operation. Its self-governing mechanism must afford every human unit the chance to contribute, to the working of the system, the maximum service which can be drawn from his distinctive personality and ability. The 'Industrial Highway Code' of the future must be dedicated to the divine law of love.

Mr. O. W. ROSKILL.—*Freedom and planning : some problems of industrial structure.*

(*a*) The post-war growth in large scale industrial enterprises. The anticipated and achieved benefits of rationalisation and amalgamation. Central purchase and central sales. The movement towards administrative decentralisation. Staff and their recruitment in relation to increasing size of units. (*b*) Trade Associations : their functions, objects, and limitations. Co-operative sales development and research organisations. Price fixing and price cutting. Standardised costing systems. Independent chairmen. Compulsion of minority by majority. (*c*) Redundancy problem and relation of capacity to output. Inoperativeness of the check of bankruptcy with growth in size of units owing to social implications. Relation of financial strength to technical efficiency. Effect on amalgamations. Family investment trusts. (*d*) Marketing at home and abroad. Different types of retail outlets. The growth of the chain store and its effect in reducing retail prices. Opposition from small shopkeepers and the possibility of grouping the latter either under the ægis of a wholesale house or in financially linked chains of independently managed shops with central purchasing services. Growth of the manufacturer's desire to be in touch with his export markets and of direct selling overseas. Consequent divorce of export from import trade and need for closer co-ordination. The functions and objects of overseas marketing corporations. (*e*) The location of industry and factors governing it. Problems of regional development in relation to depressed areas. (*f*) Dividends, prices and wages : the trend towards uniform return on industrial capital. Co-partnership and labour policy. Effect of unemployment insurance on flexibility of costs. Equities and risk ; the stimulation of new enterprise. (*g*) Co-ordination of competing services : road and rail : gas and electricity.

Throughout the Meeting an Exhibition, in Dept. F* meeting room, of 'Scientific Aids to Management' (charts, diagrams, apparatus models, documentation).

SECTION G.—ENGINEERING.

Thursday, September 5.

PRESIDENTIAL ADDRESS by Mr. J. S. WILSON on *Stability of structures* (10.0). (See p. 113.)

Prof. R. V. SOUTHWELL, F.R.S.—*A new method of solving redundant structures* (11.0).

Prof. B. P. HAIGH and Dr. J. C. DOCHERTY.—*Stresses in overstrained materials* (Research Committee Report) (12.0).

AFTERNOON.

Visit to Carrow Works (Messrs. J. & J. Colman, Ltd.) (2.15).

Friday, September 6.

Major R. G. CLARK.—*Problems in fen drainage* (10.0).

Captain A. G. D. WEST.—*The present position of television* (11.0).

Monday, September 9.

Prof. E. W. MARCHANT and Mr. B. J. O'KANE.—*Dielectric properties of insulating materials at very high frequencies* (10.0).

JOINT DISCUSSION with Section A (Mathematical and Physical Sciences) on *Lubrication* (Section A room) (10.0). See under Section A, p. 348.

Mr. J. L. MILLER.—*Surges in transmission lines and transformers* (11.0).

It is pointed out that on the higher voltage transmission systems overvoltages arising from switching operations and arcing grounds are unimportant and that the only dangerous ones are produced by lightning, and further that only direct lightning strokes closing on the line conductors, tower or ground wires need be considered, induced surges only assuming importance on low voltage lines.

The dependence of the occurrence of a flashover across an insulator string from a stricken tower or ground wire to the line conductors on the stroke current and the tower foot resistance is then discussed, and from the equations included it is shown how flashovers may be prevented by the use of low values of the earth resistances or by the use of counterpoises. As yet the actual value of the rate of rise of lightning voltage at a stricken point is not known, but it is reasoned that particularly on medium voltage lines many flashovers may be initiated by breakdown across an insulator string before the return of the reflected wave from the tower foot by reason of a rapid rate of increase of lightning voltage of the order of several thousand kilovolts per micro-second.

The influence of direct strokes and flashovers on line behaviour both from the point of view of power frequency follow up current and the propagation of travelling waves is then considered. The effects of the latter, together with those of direct strokes to shielded and unshielded sub-stations, is discussed in relation to internal stresses in transformer windings, and it is pointed out that the most severe are axial stresses due to rapid voltage collapse or rise, oscillograms and voltage distribution curves being given which support this view-point. Some remarks are then made on non-resonating transformers and also the impracticability due to the different characteristics of air and solid insulation of satisfactorily employing rod gaps for insulation co-ordinating purposes.

Finally, some aspects of the operation of various wave front flattening devices are dealt with, these including the consideration of short cables, where it is shown that a flashover at a junction of the line and cable gives rise to H.F. oscillations.

Dr. L. G. A. Sims.—*Specification of magnetic qualities with particular reference to incremental magnetisation. The need for agreement* (12.0).

The established magnetic testing specifications of Britain, France, Germany and America are first examined and discussed. It is noted that they are all directed towards the testing of iron which is to operate either under steady-state conditions, as in D.C. work, or under alternating magnetisation, as in A.C. work. The case of magnetisation by combined A.C. and D.C., which has nowadays considerable commercial importance, is not included. The paper shows that this case offers difficulties. In particular, correlation of A.C. and ballistic test methods of measuring incremental permeability is not generally possible owing to unsymmetrical waveform distortion introduced by even harmonics. Certain aspects of this problem are demonstrated and suggestions for a common method of testing are put forward. But the views of other experimenters are sought. An agreement is already very desirable in the interests of present research work, the value of which should be enhanced by established methods of measurement.

The view-point adopted throughout the paper is that the simple ballistic method of measuring permeability is only justified if the results are a guide to the behaviour of the iron when excited by A.C. It is further assumed that the alternating flux conditions, which are typical of most practical applications of the iron, should be those specified for the measurement of iron losses.

Although the paper is chiefly concerned with the effect of waveform upon measurements, a reference is also made to the 'time-decrease of permeability,' studied by Webb and Ford at the National Physical Laboratory, which will probably affect any specification relating to incremental measurements at low induction densities.

AFTERNOON.

Visit to the works of Messrs. Boulton and Paul, Ltd., Aircraft Engineers (3.0).

Tuesday, September 10.

JOINT DISCUSSION with Section J (Psychology) on *The applications of science to the control of road traffic* (Section G room) (10.0).

Mr. A. T. V. ROBINSON, C.B.E.—*Introduction.*

Road traffic control; a common topic of uninformed dogmatism. The need for scientific investigation. The problem is far wider than the mere prevention of accidents: what must be considered is how to move with a minimum of delay, discomfort and damage a vast aggregation of utterly heterogeneous units of passengers and goods.

Accident figures emphasise the importance of the personal equation. Of 7,000 fatal accidents in 1934 only 2 per cent. were attributable solely or mainly to defects of the road, and 2 per cent. to defects of the vehicle. The remaining 96 per cent. must be attributed to the personal factor.

The need of co-operation between the road engineer, the vehicle engineer, and the psychologist.

Various practical measures affecting the problem:

A. *The Road.*—(i) The site and dimensions of the road and of its junctions with other roads: its gradients, lateral and longitudinal. (ii) The construction of the road: materials, carpeting, colouration. (iii) The equipment of the road: traffic signals (effective only if obeyed), street lighting.

B. *The Vehicle.*—Improved stability, higher degree of mechanical reliability, simplified gears, power-assisted brakes, silent seconds and direction indicators all tend to facilitate the free movement of traffic on the roads.

C. *The Driver.*—Extension of the list of physical and mental defects constituting a bar on the grant of a licence, and introduction of driving tests. Of 77,000 candidates during the past six months nearly 12 per cent. rejected. Psycho-physical tests. Accident proneness.

The limitations of the applications of science.

Mr. H. ALKER TRIPP, C.B.E., J.P.

The majority of road accidents are the direct result of human failure, and the degree of danger is in direct ratio to the speed of moving objects. The speed of motor traffic has been loosed on towns and villages without the preparation essential to render it innocuous. An example of proper control should be sought from the railways, where suitably prepared tracks led to increase of speed. On the roads, increased speeds led to the need for proper tracks. The inversion is the root of the whole trouble: to rectify it is the central problem.

The objects of the administrator in dealing with the traffic problem are: (*a*) to separate the opposing streams of traffic; (*b*) to control traffic movements at cross roads and junctions; (*c*) to control the speed of vehicles in crowded areas; (*d*) to segregate pedestrians from vehicular traffic. Mechanical safeguards are superior to restrictive legislation.

Automatic traffic signals are of great value, but they should be more widely installed and the systems better co-ordinated. A progressive system would solve many difficulties.

Fenced tracks for road traffic should be provided. In the towns, planning schemes should allow adequate and uniform road and pavement space and convenient reservoir space for standing vehicles.

Among the problems facing the inventor are dazzle by motor lamps, brake mechanisms, road surfaces which will look white instead of black at night, but will not be too glaring in sunshine, and non-skid surfaces cheaply and easily renewable.

The facts have now been put before the scientist, and most useful results can be produced if the scientist will apply his ingenuity not to invention only but to discovery of the particular directions in which invention is required.

Mr. King.—*Tyre factors in vehicle control.*

Statistical Evidence.—From an analysis of published figures with regard to road accidents, the conclusion is drawn that tyre behaviour is a minor factor. This is confirmed by accident figures from the records of the Dunlop test fleet. (Over a given period a total of nearly three million car miles was run with no fatal accidents and only five other accidents involving personal injury.)

Factors affecting Vehicle Safety.—These are divided under five main headings, three of which are purely 'personal factors.' 'Controllability' and freedom from failure of the vehicle or its component parts are, however, important considerations involving tyres.

Tyre Reactions affecting 'Controllability.'—These are considered under three headings: braking, acceleration and cornering.

Braking.—Considerable attention is devoted to methods of measurement of tyre efficiency in braking. The method finally adopted by the Dunlop Technical Department involves the use of an accelerometer carried on the vehicle, and results obtained in this way are quoted comparing the behaviour of new and smooth tyres on various types of road surface (dry and wet).

It is found that factors of major importance governing the behaviour of a vehicle when brakes are applied are speed and 'balance' of brakes.

Acceleration.—The forces involved are much smaller than in braking. Wheel-spin, resulting in side-slip, is the only thing likely to cause any difficulty.

Cornering.—Theoretical considerations are discussed and results of actual tests are quoted comparing the effects of new and worn tyres on the cornering ability of a car. In general, cornering tests place different tyres in the same order of merit as braking tests, but the differences between tyres are much smaller in the former case.

General Consideration of Tyre Design and Use.—The necessary qualities of the 'ideal tyre' are outlined, and it is emphasised that a high level of tyre efficiency is wasted unless brakes are efficient.

The various effects of pattern, inflation pressure and state of wear are referred to, and it is pointed out that the most undesirable feature of worn tyres is the difference in their behaviour on smooth wet and dry surfaces. In the case of new tyres this difference is very much smaller.

Tyre Safety.—Finally, reference is made to the safety of a smooth tyre from the point of view of structural failure, and some erroneous views regarding the function of the tread in this respect are corrected.

Practical Demonstration.—Several of the points referred to in the paper were illustrated by skidding tests carried out on two cars.

These were designed to show :

(*a*) The difference between new and worn tyres in their effect on braking a car on a wet surface (brakes correctly adjusted).
(*b*) The difference between stopping distances on two different types of wet road surface (on worn tyres).
(*c*) The effect of a small variation in speed on cornering ability.
(*d*) The effect of badly adjusted brakes on the behaviour of a car in an emergency stop.

Dr. C. S. Myers, C.B.E., F.R.S.—*The psychological approach to the problems of road accidents.*

The psychologist's approach to the problems of road accidents is broader than that of most other experts—statisticians and engineers, for example—who are concerned with the same problems, since he must study *all* the factors which react upon road users and may therefore have some influence on accidents. He is not content, for example, with mechanical perfection in car controls ; but he would institute an enquiry into which forms and positions of controls best satisfy the human requirements of the driver. A similar study is required of traffic signals and of road lighting systems. The psychologist holds that there is need for a thorough investigation of the combined total effect of traffic regulations, for he realises that there is a danger of their becoming so numerous that an excessive strain is imposed on a driver's attention—a strain that may easily enhance his liability to accident.

A further line of enquiry is into the values of incentives and deterrents in promoting good road behaviour. The industrial psychologist's experience with these problems in other spheres will be valuable to him here. The technique which he has evolved for market researches, and especially for those researches which relate to the use of advertisements, would be particularly useful in exploring methods of propaganda for road safety.

In studying accidents, the psychologist will take into account the remote as well as the direct causes—the effects of predisposing previous strain, fatigue, worry and irritation. He must further be in a position to recognise the mental and physical abilities and the qualities required for a safe driver, to assess them, and to discover whether a driver possesses them in adequate measure for him with fair safety to follow his unquestionably dangerous occupation or amusement. Experiments on tests which will enable him to do this have been conducted by the Industrial Health Research Board, which has sought for a means of detecting the 'accident-prone,' whether engaged in industrial occupations or in driving. A battery of tests has been prepared by the National Institute of Industrial Psychology specifically for motor-drivers, and results obtained with them show that while they cannot, of course, pretend that a driver who passes them satisfactorily will never be prone to reckless conduct, yet they can claim to select those drivers who possess the necessary abilities to extricate themselves from a dangerous situation when it confronts them. The use of similar tests in the Paris omnibus service reduced the number of accidents to these vehicles by 66 per cent. during the period 1929–33, although the number of omnibuses increased by 77 per cent., and their speed limit by 44.5 per cent. During the same period the number of accidents to *all* motor vehicles in Paris increased by 5 per cent.

It may be argued that the use of these tests may result occasionally in the exclusion of good drivers, and thus in some individual hardship. But surely it is better to do this than to admit those whose unsuitability will result in injury or killing their fellow-citizens. Even if this be not conceded, the tests might usefully be given to those whose conduct has resulted in threatened or actual accidents, especially as the tests reveal, from time to time, deficiencies in drivers which can be remedied by special training.

Finally, the psychologist insists on the importance of systematic training for *all* road users.

Mr. E. Farmer.—*Accident proneness among motor drivers.*

Statistical methods are available for determining from the recorded accidents of a group of individuals exposed to similar risks to what extent their accidents are mainly due to specially prone individuals. It has been found from all the accident records so far examined by this method that the accidents of any group of individuals are mainly due to a very small number of specially prone persons. If these few specially prone persons are eliminated, the subsequent accident rate of the group is considerably reduced. It has also been shown of these specially accident prone individuals :

(1) That they sustain an undue number of accidents in different periods of exposure.
(2) That they sustain an undue number of accidents of different kinds, both blameless and blameworthy.
(3) That they sustain an undue number of both minor and major accidents.

This means that accident proneness is a relatively stable individual quality that will manifest itself whenever the opportunity is given.

Accident prone individuals can be detected by (1) psychological or other tests, (2) by examining their previous accident records. The former method is not yet sufficiently reliable for general use. The second method is reliable if means can be found for making it effective.

The motor accidents recorded by the insurance companies could be examined to see how far it is possible from previous records to prognosticate an individual's accident proneness. This has already been done for a few thousand drivers and positive results obtained. Before any definite conclusion can be drawn it is necessary to examine the validity of the hypothesis over a wider field, embracing every possible class of driver. Government co-operation would be necessary to do this. It is suggested that before licences were renewed a certificate from the applicant's insurers should be produced giving his accident record for the previous period. If this plan were put into operation for a few years it would be possible to see what practical measures could be taken to lessen the number of accident prone drivers.

Afternoon.

Demonstration of skidding (2.0).

Wednesday, September 11.

Committee Reports and Discussions (10.0).

Wing-Commander T. R. Cave Browne Cave, C.B.E.—*Noise* (10.0).

Mr. J. S. Wilson.—*Earth pressures* (10.30).

Sir J B. Henderson.—*Electrical terms* (11.15).

Capt. W. N. McClean.—*Inland water survey.*

SECTION H.—ANTHROPOLOGY.

Thursday, September 5.

Mr. J. Reid Moir.—*The antiquity of man in East Anglia* (10.0).

The earliest artifacts of East Anglia are found in the Bone Bed of Pliocene age, beneath the Red Crag, and can be divided, possibly, into five groups of different ages. Each earlier than the Crag, the most ancient examples of the succeeding Palæolithic epoch are found in the Cromer Forest Bed. Lower Acheulian implements are rare in East Anglia, and the exact geological horizon to which they should be referred remains uncertain. Possibly it may be placed in the Middle Glacial deposits : such as occur between the Norwich Brickearth, and the Kimmeridgic Chalky Boulder Clay, at Corton, near Lowestoft. The Upper Acheulian and Early Mousterian horizons in East Anglia are well known, and are found between the Kimmeridgic and the Upper Chalky Boulder Clays, the late Mousterian and Aurignacian cultures occur between the latter Boulder Clay and the Brown Boulder Clay of Norfolk. The Solutrian and Magdalenian phases *in East Anglia* seem to be associated with post-glacial times. Neolithic implements are found either upon the surface, or in the deeper deposits of the Fenland.

Joint Discussion with Section C (Geology) on *The geological relations of early man in East Anglia* (Section C room) (11.0). See under Section C, p. 366.

Afternoon.

Prof. D. Atkinson.—*Saxon site at Caistor, near Norwich* (2.0).

Miss D. A. E. Garrod.—*The Mousterian people of Palestine ; their culture* (3.0).

In the caves of the Wady Mughara, Mount Carmel, skeletal remains of a number of individuals were found associated with flint implements of Levalloisian type, and with animal bones pointing to warm, moist climatic conditions—in contrast with the temperate woodland fauna of the overlying Mousterian levels in the same site. It is suggested that the Carmel skeletons date from the end of the Riss-Wurm interglacial, and are therefore approximately of the same age as those of Ehringsdorf and Taubach, and older than the Neandertal remains of La Chapelle-aux-Saints, Spy, Gibraltar, etc.

Mr. Theodore D. McCown and Sir Arthur Keith, F.R.S.—*The Mousterian people of Palestine : their anatomy* (3.30).

The human remains from the Wady Mughara caves near Atlit, Palestine, comprise three relatively complete skeletons and the more fragmentary remnants of six other individuals from the Mugharet es-Skhūl, a complete skeleton from et-Tabūn and a nearly perfect isolated mandible as well as the very fragmentary remains (teeth, carpal bones, a radius) of several other human beings from the same cave. This provides, we believe, the most abundant and complete representation of a population yet discovered in a cemetery of such antiquity. The present report is intended as a preliminary statement introducing both the interesting character of the remains themselves and the no less important problems raised by them. The study of this material is a joint enterprise of the Royal College of Surgeons of England and the American School of Prehistoric Research.

The anatomy of these fossils reveals a series of characters which, both in combination and singly, leave no doubt that we have to do with a variant form of Neanderthal man, but a type which in certain respects exhibits features that are comparable to those of the more primitive races of modern man. We have also the opportunity of examining changes due to age, differences attributable to sex and the ever-present variability inherent in any human group from the same locality and period. These considerations are to be emphasised at the present time because they bear directly on the racial affiliations of Mount Carmel Man. At the same time they serve as a means of presenting a brief survey of the nature of the specimens now being studied.

Dr. C. P. Martin.—*Irish skulls* (4.15).

Recent discoveries have shown that the racial history of Ireland was very similar to that of Great Britain, at least up to the time of the Roman invasion of the latter country. The Bronze Age round-headed people, which were thought not to have entered Ireland except as stragglers, are now known to have invaded the country in considerable numbers.

The earlier Neolithic inhabitants appear to fall into two groups. The first, found in the kitchen middens, belonged to a race similar to Huxley's river-bed type. The second, found in the chambered cairns, belong to the Iberian type. The former had long, narrow and high skulls with apparently broad faces and noses ; the latter had broader and lower skulls and the face and nose were narrow. The Iberians, however, often had good sub-nasal fossæ and in this were more primitive than the river-bed type.

Many skulls with very broad bases are found among the present inhabitants of the Western Isles. Skulls with similar broad bases are also found among the remains from the Crannogs and the Norsemen. All these people were constant sowers and this perhaps develops the neck muscles and leads to a broadening of the skull base.

Friday, September 6.

Discussion on *Mr. J. Reid Moir's theories concerning the patination of eoliths* (10.0).

Mr. A. T. Marston.—*Exhibition of a human occipital bone from Pleistocene deposits at Swanscombe, Kent* (10.45).

Dr. Grahame Clark.—*A bone find from the North Sea bed* (11.0).

Mr. A. LESLIE ARMSTRONG.—*Evolution of flint mining at Grime's Graves, Norfolk* (12.0).

Aided by a grant from the trustees of the Percy Sladen Memorial Trust, a scheme of systematic research was instituted at Grime's Graves in 1921, and has been carried on progressively since that date.

Trenching and trial excavations have defined the area within which flint mining was carried on and also revealed the circumstances which caused the mining to be confined within these limits. The flint mines have been fully excavated and a further mine shaft is now in progress. These excavations demonstrate a gradual evolution both in mining methods, in the tools used, and in the form of the mine shafts. Three well-defined phases are recognisable, viz.:

(1) *Primitive phase.*—Shafts, devoid of galleries, in which picks made from the long bones of animals are used exclusively.

(2) *Intermediate phase.*—Shafts in the form of open workings, but devoid of galleries, in which deer antler picks first appear. In the earlier examples bone picks predominate. In those of the later phase deer antler picks exceed the bone picks in number.

(3) *Late phase.*—Deep shafts with mined galleries; celts with pointed butts. Deer antler picks.

The probable period of commencement and cessation of mining is discussed and evidence advanced of occupation in Bronze-Iron Age times, prior to which all mining had ceased.

AFTERNOON.

Excursion to Caistor Camp, Woodhenge, Armingham, Whitlingham (2.30).

Saturday, September 7.

Excursion to Grime's Graves, Brandon, Thetford (9.30).

Sunday, September 8.

AFTERNOON.

Excursion to Monastic Buildings of Norfolk and North Norfolk Coast Sections (2.0).

Monday, September 9.

PRESIDENTIAL ADDRESS by Sir A. SMITH WOODWARD, F.R.S., on *Recent progress in the study of early man* (10.0). (See p. 129.)

Mr. O. DAVIES and Mr. E. E. EVANS.—*Horned cairns in Ulster* (11.0).

This paper deals with some results of a series of excavations conducted under the auspices of the Belfast Municipal Museum, the Belfast Natural History and Philosophical Society and the Queen's University of Belfast, during the last four years. They have revealed a vigorous horned-cairn culture of the megalithic period in Northern Ireland. Some forty megaliths of this type have now been recognised in the six counties and five have been excavated: they show many variations in detail of construction, but most of them consist of long cairns containing segmented chambers (normally three in number) opening on to a semicircular façade of standing stones which embrace a paved forecourt. Some cairns are built on a prepared floor of clean soil or clay. Burials are after cremation or inhumation (apparently partial). Finds include leaf-shaped arrowheads, hollow-scrapers, chipped flint axes, polished axes, stone and bone beads, and a polished javelin-head. The pottery is nearly all round-bottomed (with the exception of some Early Iron Age intrusions) and has strong affinities with the Scottish horned-cairn pottery. Although it possesses certain Windmill Hill features, the use of cord and whipped-cord ornament is not uncommon and some high-shouldered pots find their nearest parallels in the Isle of Man. On the other hand some features can only be matched farther afield, either in the Baltic area or in Brittany. One of the most interesting discoveries is a proto-food-vessel from Ballyalton, County Down.

Mr. J. Foster Forbes.—*Megalithic circles and monolithic monuments of north-east Scotland* (11.45).

It is the purpose of this paper to endeavour to extract, from known data out of the remote past, evidence that will go far to solve the mystery not only of the megalithic circles, but to show that the incised monolithic symbols were carried out by the same people and that they formed an integral part in the megalithic construction. It is vain to search for evidence of the origin of these stones amongst races and peoples coming in from other countries and settling in Scotland, where no trace of megalithic circle formation has been known to exist in their own lands. In this category one can well exclude those who migrated from Northern and Central Europe and penetrated as far as the eastern and north-eastern seaboards of Scotland.

Although it has long been known that the Phœnicians penetrated as far as these islands and traded with the inhabitants, there is no evidence to show the existence of the megalithic circles in the country of their origin. On reputable authority it has been stated that the race of people more correctly known as the Caledonians (and afterwards given the name of the 'Picts') originated from Spain and the Basque country; that, at one time, numbers of their race migrated from Spain and formed colonies on the shores of Brittany, Cornwall, South Wales and Cumberland. Others proceeded to Ireland, from which country they were ejected, taking with them a number of their Irish women-folk as wives and finally landing in Scotland. These people constituted the earliest race of settlers at a period known as the New Stone Age, which followed that of the Second Ice Age.

Dr. Margaret Murray.—*Dating of folk-lore* (12.30).

Much work has already been done on the geographical distribution of folk-lore, especially of folk-tales. The ethnographical side of the subject has also received some attention, but the dating of folk-customs and beliefs has been neglected. Some of these customs and beliefs can be dated to a definite time, others are more vaguely dated to the Middle Ages or to post-Christian and pre-Christian, and a few can only be referred back to the Bronze Age and the Palæolithic Age. The chronological method applied to the study of folk-lore still requires a great amount of careful and scientific research.

AFTERNOON.

Mr. C. S. ORWIN.—*The origin of lynchets* (2.0).

The name ' lynchet ' is applied to the banks and terraces which occur plentifully in some parts of England, and occasionally in most parts of the country.

It has been accepted for a long time that they are the results of early ploughing—in fact, that they represent ordinary ridge-and-furrow work controlled by the exigencies of operating on gradients.

There is no question that some of the banks which are called ' lynchets ' have resulted from the way in which land has been laid out for ploughing across a slope. The suggestion in this paper, however, is that this explanation is not applicable to the terrace lynchets, the formation of which has been attributed by archæologists for the past hundred years to the use of the plough to turn furrows across the hillsides on which they occur in the downward direction only, thus cutting out the soil on the higher side of the ploughing and piling it up on the lower side, to produce the well-known terraces.

The author of this paper seeks to upset this explanation by reference to farming practice and to the limitations which the sites, the soil and the performance of primitive implements would exert. He suggests that although some terrace lynchets have obviously been ploughed in modern times, and that here and there a few may be under cultivation to-day, they were made in the first place neither by ploughing nor for ploughing.

Mr. R. U. SAYCE.—*Principles of folk-lore* (2.45).

Mr. K. JACKSON.—*What was the language of Roman Britain?* (3.30).

It was believed at one time that one consequence of Romanisation in Roman Britain was that the native British speech was entirely abandoned and Latin adopted in its place. The theory has recently been revived. It was modified by Haverfield, who concluded on the evidence of the graffiti that British survived only among the lower classes in the country districts. But this evidence can be interpreted differently ; and it can be shown from the Latin words borrowed into British, from place-names, and from other sources, that though Latin was certainly the speech of the administrative and upper classes in Roman Britain, the mass of the people spoke British. The Anglo-Saxon invaders came into contact with a population whose language was British, not Latin, in the ' Lowland Area ' of Britain as well as in the ' Highland Area.'

Rev. Canon J. A. MACCULLOCH.—*The household brownie as an ancestral spirit* (4.15).

Belief in the brownie, kobold, or household fairy or spirit, was widespread in Europe and has analogies elsewhere. It can be traced back to early medieval times, but is probably much older. The brownie attached himself to a household, giving willing service in his own way, and bringing prosperity when treated with respect. He was touchy, however, and departed if insulted or for other reasons. Some of the folk-lore of the brownie is shared with other beings.

The brownie is more closely allied to spirits of the dead than fairies in general. Especially is he connected with the hearth, as were many ancestral guardian spirits. This ancestral connection is most clearly seen in Russian belief regarding the *Domovoy*, at once a brownie and an ancestral spirit, and in similar beings in Eastern Europe. This belief is connected again with the household snake, real or imaginary, embodiment of an ancestral spirit. Belief in such a household spirit was aided by burial in the dwelling, probably a survival from the Stone Age.

Though connected with the ancestral spirit, the personality of the brownie is one round which imagination and mythopœic fancy have played freely, showing man's desire to give corporeality to the phantoms projected on the stage of his existence.

Tuesday, September 10.

Miss B. Blackwood.—*Physical types of the N.W. Solomon Islands* (10.0).

This paper is based on material collected by the writer in three villages on the north coast of Bougainville and two small islands off the west coast of Buka, the most north-westerly of the Solomon Islands. The principal physical measurements and observations on series of both sexes are analysed and discussed with reference to the available comparative data. The main points of interest are illustrated by lantern slides, including examples of racial crossing.

Dr. M. A. MacConaill and Dr. F. L. Ralphs.—*Development of pigmentation in a Nordic group* (10.30).

The population of Sheffield has been shown to deserve the status of a Nordic group (MacConaill, Clegg and Ralphs, *Proc. 1st Int. Congr. Anthrop. and Ethnol.*, London, 1934). The percentage of eyes falling into different classes in a total of 2,600 male children from 5 to 20 years old was observed and the same kind of analyses was carried out for hair colour in the same individuals. Eyes were classified as dark blue, light blue, gray, hazel, light brown, dark brown, black. Hair was classified as light blond, dark blond, red, light brown, dark brown, black.

A statistical consideration of the tables strongly suggests that all forms of pigmentation in the adult are derived from an infantile combination of light blond hair with dark blue eyes. From the thirteenth year onwards this combination is stabilised as a constant fraction (seventeen per thousand) of the population. These facts are briefly discussed in connection with the idea of the evolution of the full Nordic type by a process of neoteny.

Prof. A. M. Blackman.—*The value of Egyptology in the modern world* (11.0).

Owing, among other factors, to the extreme conservatism of the Egyptian peasants the importance of Egypt for anthropology can hardly be exaggerated.

Egypt offers the philologist an unique opportunity for linguistic studies, and must occupy a prominent position in any history of astronomy, mathematics, or medicine.

That country can also supply the economist and historian with much interesting material.

Modern architects and sculptors might study with considerable profit the works of their ancient predecessors in the lower Nile Valley.

European literature and religious thought are much indebted to ancient Egyptian writers and sages.

Mr. Trevor Thomas.—*Approach to primitive art* (11.45).

If art is conceived as manipulation of material in such ways as to express varieties of experience and vision, appreciation of expression as embodied in primitive art is likely to prove difficult for sophisticated people. Approach to the primitive will be conditioned by previously determined concepts, but resultant evaluations will not be without worth as criticism. Disadvantages of a limited field of perception are well exemplified in ethnographical studies which, regarding primitive works as artefacts rather than art, are concerned with them mostly as adjuncts to religious, social and tribal organisation.

Human geographical and environmental view-points provide interesting but limited angles of interpretation through correlated factors of climate, vegetation and habitat. Tending to stand in opposition to these two schools of intellectual approach, the emotionally conditioned advance guard of modern art recognises, in the plastic tensions of native work, abstract expressions of universal awareness similar to its own.

The dangers and extravagance of such approaches can be balanced by more tangible standards of criticism indicated in the study and analysis of primitive art in relation to technique and materials employed. This approach, whilst logically linked with the methods previously indicated, deals directly with the specimens, thus avoiding some of the weaknesses implicit in the introduction of external factors.

Mr. J. E. Sainty.—*Whitlingham* (12.30).

Whitlingham lies two miles east of Norwich, on the right bank of the Yare-Wensum. The derelict chalk pit shows a section of chalk, stone bed, shelly crag and glacial beds, and produced the ' Norwich Test Specimen ' rostro-carinate and the huge worked flake (6 lb. 6 oz.), both in the British Museum, as well as the boldly flaked hand-axe in Norwich Castle Museum.

On the sewage farm shallow diggings for gravel disclosed hand-axes, and subsequent excavations produced 550 artefacts, ranging from derived sub-Crag and Chellian specimens, rolled and striated, to evolved Acheulian hand-axes in mint condition. These occurred in a terrace gravel 40 ft. above present river level. Clactonian flakes were common, whilst a small number of finely worked racloirs and flakes with faceted butts and heavily resolved flaking were obtained. The overlying stony clay supplied a few gray or white hand-axes of late type and a fine scraper similar to High Lodge specimens. An orange stained rostro-carinate showed the survival to late Acheulian times of this form.

No late Palæolithic material has been recognised, but the presence of Cissbury artefacts confirms Arderon's account of the finding in ancient workings in the chalk of red deer antler picks (now in Norwich Castle Museum) and of a human skeleton.

In the adjoining garden at Crown Point was found a hoard of five superbly flaked axes showing no sign of usage.

Afternoon.

Mr. M. C. Burkitt.—*Technique as a criterion of culture* (2.0).

Prehistoric implements have been classified hitherto according to a system of typology, certain arbitrary characteristics being selected as representative of different types of tool. These tool-types are themselves sub-divisible. Thus a collection of implements can be separated into tool families, each family being in turn subdivided and re-subdivided. Always the *type* of tool is the criterion. Recently studies of the processes of making the tools have been undertaken, and a new basis for the classification of industries introduced. Not all tools—even when belonging to the same tool family—were manufactured in the same manner. Thus it is possible to apply more definite criteria for classification purposes than the somewhat arbitrary type characteristics alone. Typology will still be essential, of course. Broadly speaking, industries can be classed as 'core,' 'flake,' or 'blade-and-burin.' In each category various methods of making the tools occur.

In early Palæolithic times two distinct sets of industries belonging to two different sets of cultures, i.e. to two distinct civilisations, exist—the one Asiatic, the other African. The Asiatic group includes the Cromerian, Clactonian, Levalloisian and Mousterian cultures; the African the great *coup-de-poing* culture. In Aurignacian times a distribution map of the fluting technique shows that this is of Asiatic not African origin and is associated with bone tools and home art. As certain other elements in our western European Aurignacian were introduced from Africa the dual origin of this culture is thus demonstrated.

Miss E. Dora Earthy.—*Kisi tribe of Liberia* (2.45).

The Kisi tribe of Liberia inhabits villages dotted about the north-western corner of Liberia, and adjacent territory in French Guinea and the Sierra Leone Protectorate.

The paramount Chief of the Liberian section belongs to the Kandakai family. His kingdom is divided into three districts, Wam, Rankolle, and Tengia. The clan chiefs under the paramount chief have each a number of subject sub-clans. Each sub-clan chief rules a number of villages called 'towns.'

The language belongs to the West Atlantic group, and is apparently semi-Bantu in character. Arabic seems to have had some influence on the structure.

The physical type of the ruling class is tall. The prevailing type is short of stature, almost pygmy.

The Kisi acknowledge a totemic origin. The tribal totems are the baboon (called grandfather), crocodile, alligator and kola nut. Clan totems are numerous. A certain river and secret mountain are worshipped, with impressive rites.

Marriages are exogamous and often arranged when the bride is an infant. The bride-wealth is paid in iron-bar currency, called *kilindi*.

Burial places are marked by a mound of stones. The 'towns' may be said to be built round the family vault.

Rt. Hon. Lord Raglan.—*Was early man a scientist?* (3.30).

The belief that 'among primitive races similar needs and materials are apt to produce objects of similar appearance' is ill-founded. There is no evidence that needs lead to artefacts at all; the prevalence of skeuomorphs shows that material is a factor of minor importance, and e.g. wooden weapons differ widely in type.

Current theories about early man are based on a belief in the inventiveness of the savage which is derived, not from fact, but from myth and from assumptions such as that ability to use implies ability to invent, and that local sequence implies local evolution.

Inventions such as bows and boats are probably beyond the reach of primitives, and of the calendar beyond the reach of illiterates, for whom it has no practical use. All inventions the history of which is known are the products of wealth and leisure.

What is needed in anthropology is a clearer distinction between fact and theory.

Dr. M. A. MacConaill and Dr. F. L. Ralphs.—*The post-natal development of the brain in a Nordic group* (4.15).

The population of Sheffield has been shown to deserve the status of a Nordic group (MacConaill, Clegg and Ralphs, *Proc. 1st Int. Congr. Anthrop. and Ethnol.*, London, 1934).

From measurements made upon 2,600 male children from five to twenty years of age the growth of the cranial capacity has been estimated over the period indicated. It is assumed that the Lee Pearson mean formula for cranial capacity in relation to length, breadth and auricular height, conjointly, holds good over the period considered.

During this time the final fifth of adult cranial capacity is attained at a rate which steadily increases. The ratio of brain growth to that of other parts shows a definite return to the infantile proportion during the period of adolescence. It is concluded that the 'corporeal concomitant' (of Keith) is supplemented by an increment connected with the onset of sexual maturity.

Wednesday, September 11.

Mlle. Simone Corbiau.—*Archæological surprises* (10.0).

Dr. Gordon Ward.—*The Roman colonia in Britain* (10.45).

The study of Roman veteran colonies in Britain has scarcely yet advanced beyond the recording of the names of those few towns which are known to have had the civil status appropriate to colonies. It is possible to make further progress by seeking for the remains of that peculiar rectangular road system which characterised the true colony. This road system is not to be sought for in the towns but in the open country in the neighbourhood of Roman cities. It demarcated the holdings of veteran soldiers, and is still easy to identify near Brancaster in Norfolk and both north and south of Lincoln. Gillingham in Kent affords a further example, but only these three have as yet been studied at all closely. There are certain road plans which resemble those of the colonies but are of different origin, and there are certain particulars in which the three colonies studied appear to depart from the classical model, for example, the individual small holdings appear to have been oblong rectangles and not squares. It is possible to suggest some rules for the identification of colonies, but this paper is not intended to be more than an introduction to a fascinating study likely to advance our knowledge of Roman and later Britain in ways as yet hardly suspected.

SECTION I.—PHYSIOLOGY.

Thursday, September 5.

JOINT DISCUSSION with Section J (Psychology) on *Hearing and aids to hearing* (Section I room) (11.0).

Dr. P. M. T. KERRIDGE.—*The hearing of children in London schools for the deaf.*

About 0·1 per cent. of the school population of London are deaf enough to require special educational provision. The deaf children vary from those with minor defects in hearing who only need to be taught lip-reading, to those who have been so severely deaf from birth that they did not acquire speech in the ordinary manner. The hearing of 456 children, of ages 6–17, in 13 schools, was tested with a pure tone audiometer. Twenty per cent. were retested after an interval of several months, as a guide to the reliability of the results.

The audiograms have been classified and compared with the clinical history. Cases deaf from birth had most commonly maximum hearing loss for high tones, or patchy hearing. Cases of deafness following infection of the ears had high tone maximum loss, or middle tone maximum loss, with about equal frequency. Meningitis usually left patchy hearing of small amount, or none at all. Deafness due to congenital syphilis was associated with audiograms similar to those of cases deaf from birth, but the age of onset was later.

Speech defects have been considered in relation to the age of onset of the deafness, the intelligence of the child, and the amount and nature of the deafness. Sixty-four per cent. were deaf before the age of 2, and in these cases there was a definite correlation between the amount of residual hearing and their proficiency in speech.

Dr. A. F. RAWDON-SMITH (11.20).

The effect of loud pure-tone stimuli upon the acuity of hearing is discussed. An apparatus for producing such stimuli, and for testing the auditory threshold before and after their application is briefly described. It is shown that the absolute threshold of the ear rises as a result of pure tone stimulation, and that this result is not confined to the ear stimulated. A smaller, though often considerable, acuity loss is found in the other ear. This fact is thought to indicate that the losses are of cortical mediation, a supposition confirmed by the discovery that the losses may, on occasions, be restored by the application of certain unexpected stimuli. This phenomenon, it is thought, places the effect in the category of inhibition, the unexpected stimulus producing disinhibition. These latter terms are used in somewhat the same sense as that employed by Pavlov, when discussing the inhibition of conditioned reflexes.

The fact that a slightly greater acuity loss is found in the stimulated than in the unstimulated ear indicates that, in the latter, an additional peripheral acuity loss may be found. Such a loss has been found in the ear of the cat, using Davis and Saul's method of recording the electrical activity of the auditory mid-brain.

Dr. A. W. G. Ewing and Dr. T. S. Littler.—*The response of partially deaf patients to amplified speech at controlled intensities* (11.30).

In the investigation described speech was transmitted to a group of partially deaf and normal subjects through a specially designed high quality amplifier system set up in a sound-proof room. The intensity level at which speech could be made most intelligible to each subject was determined by adjustment of an attenuator network. It was found possible to obtain approximately 100 per cent. intelligibility for both vowels and consonants with some of the partially deaf patients.

In certain instances speech proved to be most intelligible at high levels of intensity involving very considerable amplification.

With the partially deaf subjects there was found to be no apparent decrease in acuity after use of the apparatus for some time. Although the peak intensity in the speech sounds approached the intensity that would normally produce fatigue in the case of a maintained pure tone, the duration of the peak intensities in speech sounds is small.

The auditory acuity of each subject was measured under experimental conditions with pure tone stimuli produced by a beat-tone oscillator (*a*) in free air, (*b*) with a bone conduction receiver, and (*c*) when listening through the amplifier system.

Mr. L. E. Heath.—*Amplifiers in schools for the deaf* (11.50).

Amplification for children with residual hearing must be studied from three angles. The teacher's aspect involves psychology and specialised teaching ; the physiological aspect involves the extent and type of hearing defect ; the mechanical side endeavours to satisfy the requirements of the other two.

The children may be classified as follows :

(1) Those hearing all amplified speech, and understanding, or capable of being taught to understand it.

(2) Those hearing only some part of it, and capable of deriving some benefit.

(3) Those who will derive no benefit.

Group (1) covers approximately 30 per cent. of the children. Groups (2) and (3) cannot be estimated without more research, and trials, with consideration of teaching methods, psychology of the child, and many other factors influencing the use of residual hearing. The benefit derived may only be an improvement in the tone of voice, accent, rhythm or intonation of speech, which do not necessitate full hearing of speech.

An ideal instrument would allow for complete control of amplification in standard units, and a known alteration of amplification above or below a known frequency. This would allow rapid adjustment of controls by reference to audiograms, and while avoiding harmful use of excessive amplification, ensure the best approach to normal conditions for each child.

Miss E. L. S. Ross.—*The psychological effects of aids to hearing* (12.5).

Main characteristics of the mental make-up of the deaf and the semi-deaf child, as compared with the hearing. Comparison with the blind and the partially sighted. Psychological effect of the special methods of education commonly employed.

Report of a preliminary investigation into the psychological effect of the regular use of an amplifier with a group of senior children attending a school for the deaf. Various types and degrees of deafness were included in the group.

Some theoretical considerations especially with regard to the education of deaf children.

General Discussion (12.20).

Afternoon.

Excursion to the Cider Works of Messrs. Wm. Gaymer & Son, Attleborough (2.7).

Friday, September 6.

Mr. T. W. Adams and Dr. E. P. Poulton.—*Some further applications of a new study of heat production in man* (11.10).

At the Aberdeen Meeting we showed that the output of CO_2 was the measure of the amount of combustion in the body, while the oxygen intake was a resultant of combustion and conversion. There was no time to bring the further conclusions of our study before the Section, but these appear in the Report for 1934.

Some results of Benedict and Milner throw an interesting light on the metabolism of muscular work, which is a perplexing problem, because the respiratory quotient is above unity when the work is extreme. Since Krogh and Lindhard's experiment (1919) it has been generally accepted that with muscular work on a carbohydrate diet the CO_2 is greater and the O_2 less than on a fat diet, which might mean that more carbohydrate was being oxidised, and they argued that with fat more heat was produced ; but in the similar experiments of Benedict and Milner (1903–4), who used a respiratory calorimeter, the measured heat was the same on the two diets. When the three hourly results are analysed it is necessary to assume that there is some kind of partial reduction of carbohydrate towards fat of a temporary nature. The results for the whole period suggest either that more carbohydrate was oxidised on the carbohydrate diet or, as we prefer to think, that carbohydrate and fat were oxidised in a fixed proportion, and carbohydrate was also converted into fat.

Dr. F. W. Edridge-Green, C.B.E.—*The colour of the positive after-image of a colour* (11.30).

In certain conditions the colour of the positive after-image of any colour or white is purple. It is best to use only one eye, and to have both eyes covered with a black cushion before performing the experiment. The object should then be viewed for the shortest possible time and the black cushion be replaced over the eye. If tried with a spectrum the whole of the after-image becomes purple. If on a piece of white cardboard eighteen inches square a series of small squares of red and blue cardboard, each about three-quarters of an inch square, be pasted to cover a surface of about nine inches square, be placed in sunlight and viewed as previously mentioned at a distance of three feet a brilliant positive after-image, red, blue and white, will be seen for a fraction of a second ; then all changes to purple, which becomes brighter and then disappears from without inwards in about eight to twelve seconds without becoming negative ; the last thing to be seen is a whirlpool movement in the centre of the field of vision. With spectral colours projected on a screen in a dark room, the positive after-image of all becomes purple and disappears without changing to negative when viewed for the shortest possible time. When the eye is moved the after-image spreads out, a portion of the retina not previously stimulated being affected. These facts prove conclusively that the photo-chemical stimulus in vision is liquid and movable in the retina.

Monday, September 9.

PRESIDENTIAL ADDRESS by Prof. P. T. HERRING on *The pituitary body and the diencephalon* (10.0). (See p. 143.)

Dr. J. BEATTIE.—*The relation of the pituitary to the hypothalamus* (11.0).

The posterior lobe of the pituitary gland is connected to the hypothalamus by nervous and chemical links. Nerve fibres from the pre-optic area of the hypothalamus make their way into the pituitary stalk and end in the posterior and intermediate lobes. The existing evidence favours the secretory nature of the fibres. No fibres are known which pass into the anterior lobe from the hypothalamus. Chemical links between the posterior lobe and the hypothalamus have been denied, but the weight of evidence for posterior lobe hormones is in favour of the presence of at least some hormones in the intact animal. The cells from which these hormones are elaborated and the method of their transference to their places of action are not yet proved. The various theories are discussed. The relation of the pituitary and the hypothalamus to problems of water, fat, and carbohydrate metabolism throw much light on the neurohormonal control of the autonomic nervous system and on the place of the hypothalamus in the animal economy.

Dr. A. S. PARKES, F.R.S.—*Relation of the pituitary to reproduction* (11.20).

Dr. J. M. PETERSON.—*The relationship of the pituitary gland to carbohydrate metabolism* (11.40).

Observations by Houssay, Cushing and others have clearly demonstrated that the symptoms of diabetes may be controlled by the agency of the anterior lobe of the pituitary gland. Implantation of this lobe, or injection of an extract from it, has a diabetogenic effect, while excision of the gland alleviates the symptoms of diabetes.

The diabetogenic substance has been shown to act without the mediation of the pancreatic islets, thyroid, or the adrenal medulla ; evidence with regard to the possible mediation of the adrenal cortex is as yet scanty. The postulate that it acts on nerve centres, which control carbohydrate metabolism through the autonomic nervous system, is interesting in view of the recent observations with regard to the relationship of the hypothalamus and the pons to the blood sugar level. The evidence for such a mechanism is, however, inconclusive.

It is claimed that the diabetogenic extract is divisible into ketogenic and blood-sugar-raising fractions, and has not been identified with any other known physiological agent extractable from the pituitary gland.

The rise in blood lactic acid which follows intravenous injection of the pressor substance of the posterior lobe is attributable to a diminution in transference of oxygen from blood to tissues (Geiling and others).

Dr. F. R. Winton.—*Relation of the pituitary to the kidney* (12.0).

Dr. Geoffrey Jefferson—*Pituitary dystrophics* (12.20).

General Discussion (12.40).

Tuesday, September 10.

Joint Discussion with Section F (Economic Science and Statistics) on *The economic aspects of diet* (Section F room) (10.0). See under Section F, p. 408.

SECTION J.—PSYCHOLOGY.

Thursday, September 5.

Dr. W. Brown.—*Character and personality* (10.0).

In English usage the term ' character ' refers to an organisation of the affective and emotional aspects of the mind, leading up to the development of more or less tenacity of purpose and strength of will. ' Personality,' on the other hand, has three different connotations, viz. (1) the sum-total of the powers of the individual, both inherited and acquired (German scientists use the word ' Charakter ' in this sense) ; (2) the more *dramatic* aspects of individuality, especially the power of the individual to stimulate and influence the imagination of other individuals in art, science and public affairs ; the psychology of leadership and the general problem of the psychology of personal influence fall to be considered under this heading ; (3) the philosophical or metaphysical view of the individual as having the power to live in, or partake of, a super-individual and (to some extent) super-temporal world of values (the good, the beautiful and the true), and to be capable of spiritual development in this sense.

Methods of psychotherapy (analysis and suggestion) help the development of character, and of personality in both its dramatic and its philosophical aspects.

Prof. C. W. Valentine.—*The origins of laughter in young children and suggestions towards a genetic theory of laughter* (10.45).

I. Theories of laughter usually suffer through over-simplification, and through inadequate attention to a genetic point of view. The theories of Hobbes, Herbert, Spencer, Darwin, Bergson, Freud, McDougall. Laughter may have general causes.

II. (*a*) Laughter first as an expression of pleasure (at one month), associated with satisfaction of hunger. (*b*) Laughter in third month in response to laughter of another—indicating the fundamental social aspect of laughter. (*c*) Laughter at tickling. (*d*) Laughter at simple shock or surprise (age 0.4). (*e*) Mere repetition as a cause of laughter (0.6). (*f*) Laughter at the incongruous or unusual (0.6). (*g*) Laughter of joy or excitement at new accomplishment (about one year). (*h*) Laughter at mild discomfiture of another only noted after all others had occurred.

III. Parallels of these early forms of laughter as they appear in adults. Laughter as a social means of approach.

IV. The significance of the order of development.

V. Suggestions towards a theory of laughter. Laughter an original expression of pleasure—with physiological and social value—at the earliest and later stages. Such laughter continues in adulthood, but laughter also becomes particularly attached to a situation in which energy is suddenly set free, as in the sudden linking of divergent apperceptive masses (by the pun). This is exemplified also in various types of laughter observed in infancy; for example, laughter at the unusual, the incongruous, in mild surprise. Such setting free of energy is analogous to that when mental elements isolated by repression (complexes) are linked up with other elements. Laughter in response to laughter may be a special case of suggestion needing no separate explanation; but the great suggestibility of laughter points to a special value as a means of social blending. Laughter at discomfort of another often due to incongruity, strengthened sometimes by release of repressions. But McDougall's theory seems the more fundamental one for such types of laughter.

JOINT DISCUSSION with Section I (Physiology) on *Hearing and aids to hearing* (Section I room) (11.0). See under Section I, p. 430.

Dr. M. M. LEWIS.—*The conceptual speech of infants: individual and social factors* (11.30).

Observations show that the growth of a child's conceptual use of words depends much more upon his own *activity* and his *social environment* than has hitherto been suggested. The main factors are:

(1) The child's *growth of discrimination* among the situations which he encounters results in the wider or narrower use of a word according to the objective, affective or functional features of these situations.
(2) The *instrumental* function of language: the child uses words declaratively (in the effort to draw attention to things) or manipulatively (in trying to cause others to satisfy his needs).
(3) *Social selection:* a constant interplay of activity between the child and those about him acts selectively upon his varied uses of a word.

As a result of the operation of these factors, the application of a word undergoes changes, until its meaning begins to conform to adult usage. Thus actual observation of children bears out recent views of the nature of concepts and of the growth of conceptual thinking, derived from pathology (Head), ethnology (Malinowski), and the analysis of cognition (Spearman). Concepts are found to be determined by the activity of individuals attempting to satisfy their needs in communal intercourse.

Prof. T. H. PEAR.—*Mental imagery and style in writing* (12.15).

The mental 'apparatus' used in remembering may affect not only a person's general attitude towards life, but his way of expressing this attitude in writing, speaking, music, drama, and the arts. The distinction between 'thing-thinkers' and 'word-thinkers.' Galton's researches into mental imagery now appear to have been directed towards the persons least likely to possess it. The use of visual imagery by modern writers. The view that the image's function is the utilisation of the past in the solution of difficulties set by the present. This might be called 'thinking-out,' and is characteristic of scientific thinking. Does it, however, include 'thinking-of,' and apply to the thinking of artists, poets, and musicians?

The view that words are social, and are therefore distinguished from sensorial images. Can a simple meaning be attached to the ' social function ' of words, especially spoken words ?

How can the non-verbaliser be persuaded to think ? The uses of ' pictorial statistics,' the cinema, the radio-talk and discussion. If visualisers are needed to evoke images in film and radio, can the verbalising literary critic appraise their attempts ? What will be the worth of his criticism, if he adheres tightly to the present criteria of style in writing ?

Afternoon.

Dr. C. J. C. Earl.—*Affective-instinctive factors in the imbecile child* (2.0).

The affective-instinctive deviations found in low grade children are at least of as great importance as the inferiority in the intellectual sphere. The affective-instinctive deviations may be found both at the temperamento and characterological levels. They may consist of an emotional subnormality or an emotional abnormality. In the former heading we may find (*a*) an absolute quantitative emotional lack, or (*b*) an immaturity or infantilism. The abnormalities take the form of psychoses or of psychoneuroses or behaviour disorder. The psychoses in these children are apparently endogenous and are played out principally at the psychomotor level. The psychoneuroses are indefinite and of a very simple order. Behaviour disorder, rarely serious, is a very common finding.

The clinical and pedagogic importance of the various syndromes built upon these emotional deviations is discussed.

Mr. R. J. Bartlett.—*Lowenfeld's mosaics with psychotic patients* (2.45).

Two or more designs each were obtained from convalescent men and women, and also from men far removed from normality. Comparison was made with designs from a group of University students and tentative norms given by Dr. Lowenfeld.

Computation of number of colours, shapes, varieties and pieces used, revealed a marked tendency for psychotics to use fewer shapes and pieces than normals, but little difference in the numerical use of colours.

When designs were graded into seven grades the lowest two grades were occupied exclusively by psychotics, while median grades were : Normal 3, Psychotic women 4, Psychotic men 5. Correlation between gradings of the two designs from each person was 0·65 (P.E. 0·06).

Judged by one with considerable experience of designs from children and normal adults, much of the work of the psychotic men was similar to that of intelligent boys in the middle school, showing arrest of emotional development, while comment was made on the slight use of the smallest triangle, the absence of floral designs and the frequency of representational designs.

Diagnostic and prognostic guesses made by this worker, on the basis of the designs only, show an interesting measure of agreement with the physicians' reports on the cases.

Mr. Whately Carington.—*Word-association tests of trance personalities* (3.30).

Word-association tests have been repeatedly applied to the personalities of mediumistic trance, to the ' mediums ' in their normal state, and to ordinary people. The reaction time, the reproduction test and, to a less extent, the psychogalvanic reflex, have been used as indicators. Some 30,000 observations have been collected.

Statistical analysis of the data shows that the method is competent to give a set of measurements characteristic of the personality studied, and that significant differences are observable in many cases between the normal medium and the trance personalities. It was at first believed that the discovery of such differences would support the claims to autonomy made by the personalities themselves, but control experiments on a normal person in two different ' poses ' have shown that this is not the case.

In two typical instances studied, the kind of personality usually styled a ' control ' has been found to be related to the normal personality in an inverse fashion (described as ' countersimilarity ') such that there is a negative correlation between the two sets of reaction times. This leads to the conclusion that such ' controls ' are secondary personalities of the medium probably developed round a nucleus of repressed material, or perhaps representing a mood antithetic to the normal.

This is not true of ' communicators ' proper, which accordingly represent a different type of personality. Certain considerations regarding the association between reaction time and reproduction seem to indicate the influence of two components in these cases, which is not easily explicable in terms of existing theory.

Friday, September 6.

PRESIDENTIAL ADDRESS by DR. LL. WYNN JONES on *Personality and Age* (10.0). (See p. 157.)

Prof. E. RUBIN.—*A problem of pictorial art arising from the psychological nature of vision* (11.0).

(1) It is a well-known fact that, in connection with different visual attitudes, one and the same outer object can condition visual perceptions which differ in a quite elementary way. Instances of this are demonstrated.

(2) The left-to-right reading habit involves a special left-to-right visual attitude. This attitude can be shown to have a marked influence on the composition of pictures. Only in so far as the Japanese, with their vertical reading habit, acquire our left-to-right visual attitude or we acquire their vertical attitude do they understand our and we understand their paintings.

(3) There are some experimental data which make it seem probable that the technique which the painter uses in making his pictures conditions some very special visual attitudes with elementary influences in his visual perceptions. Therefore, there can be quite a difference between that which the painter, on account of his special visual attitudes, sees in—and wishes to be seen in—his pictures and that which the public sees in them.

Prof. B. EDGELL.—*Consideration of the immediate and delayed recall of four tasks differing in structure* (12.0).

The aim of these experiments was to see how the formal characteristics of a short task influenced its recall. The material used in two of the tasks consisted of five such clues as might be used in a crossword puzzle together with the solutions. In one case all the solutions involved a play upon words, in the other the solutions were all names of fish. In a third task the clues were given, but the solutions, all five-letter words, were indicated by the initial letter only. The material for the fourth task was a short passage of prose wherein a biological hypothesis was made clear by a simple chemical analogy.

Two minutes were allowed for the study of each task and an immediate recall was asked for two minutes after the study of the last task. After a week's interval a further recall was made. The possible score for each task was ten, a mark for each correct clue or solution and for each essential point in the prose passage.

Afternoon.

Mr. C. A. Claremont.—*The psychology of proof* (2.0).

How do we apprehend the causal relation? Is it (1) by habit; (2) by some kind of innate pre-disposition of the mind to arrange and regard its content in that manner, or (3) is it by a process of direct perception not at all resoluble into terms of sensation, memory and so forth?

Recent work (Kohler, McDougal, Montessori, etc.) leads one to suppose that the latter view is correct. The same work indicates that the power which operates is *limited*; that is to say, it is possible to 'perceive direct' *certain* forms of causal relation, but not others; and this limitation varies in scope not only from individual to individual but from species to species.

Examples are given to show the limitation in man's case, together with the need for an extended notion of causality to include static causal relations and also abstract relations of necessity. The latter may or may not involve movement (which introduces a time factor) without altering the fundamental fact that they are causal *in se*.

If we can accept this direct perception and its limitation, it gives the key to the psychology of proof; since proof is only necessary for those causal relations which we *cannot* see direct, and proof can be shown to consist in all cases of a reduction of such causal relation to an assembly of those which we *can* see direct. The logical syllogism is itself a direct perception of this kind.

Because the human mind has a range sufficiently great to include not only a variety of causal relations, but also the syllogism, it is possible for man to creep outside the limited circle of his own 'direct perceptions,' in a way that no animal could do. Thereafter he can proceed indefinitely but he must go one step at a time.

Dr. M. Collins.—*A comparison of tests of colour-blindness* (2.45).

Candidates for entrance into the printing industry in Edinburgh are given, as part of their psychological examination, tests of colour discrimination. Any boy suspected of being colour-blind is given extra tests to confirm or otherwise the diagnosis. It was thought it would be of interest to compare a number of tests of colour-blindness, by giving them not only to colour-blind individuals, but also to individuals with normal colour vision. Accordingly, all boys, coming up for vocational testing during the past year, were given a series of colour-blind tests. The same group of tests was also given to a number of colour-blinds. This has resulted in the tests being given to 121 boys with 'normal' colour vision and to twenty boys who are red-green colour-blind. An estimate of the validity of each test is therefore possible from the practical point of view.

Dr. F. W. Edridge-Green, C.B.E.—*The principles of a test for colour-blindness* (3.30).

(1) It should be able to detect colour-blind persons.
(2) It should show quite clearly who is, or who is not, dangerous when

coloured signals are used by sea or land and the test is used to ascertain whether the examinee can distinguish the colours of the lights used. When a test is used for any other purpose, as, for instance, ability to match colours, it should show the extent of this ability.

(3) The test should be of such a character that the examinee cannot be coached to pass it.

Mr. C. B. Nickalls.—*A liminal method of determining colour sensitivity suitable for group testing* (4.0).

An attempt to grade people, both colour-blinds and colour-normals, with regard to colour sensitivity. The subject is shown a number of cards containing circular patches of colour of varying hue and saturation. Some of the patches are above and some below the limen for that colour. The score obtained indicates the colour sensitivity.

The tests have been applied to school children in groups and the results indicate that a fairly fine grading is obtained and that the tests are reliable. A demonstration of the application of the tests accompanies the paper.

Monday, September 9.

Joint Discussion with Section L (Educational Science) on *The place of psychology in the training and work of teachers* (Section L room) (10.0). See under Section L, p. 461.

Afternoon.

Miss M. D. Vernon.—*The perception of distance* (2.0).

It is important in determining the factors subserving the perception of depth and distance to distinguish the various modes of experience connected with spatial perception, viz. : direct and immediate experience of distance, similar experience of depth or relief, immediate quantitative estimation of distance, secondary ideational inference and judgment of depth or distance. It is probable that the mode of experience differs according to the type of perceptual and ideational data supplied by the experimental situation. If a conflict is set up experimentally between the various types of data, there may result : (1) a direct and immediate response to a single set of important sensory data, e.g. the convergence sensations, or (2) a deliberate inferential judgment based upon other less obvious data, or (3) if the conflict is severe, a complete breakdown and inability to judge distance. Even if much of the important data is eliminated, provided that the remaining data are mutually consistent, the observer will in general be able to make some type of inferential judgment, and may with practice develop an adequate mode of immediate reaction. Thus it is the structural relationship which is important, rather than the actual nature and extent of these data.

Mr. L. S. Hearnshaw.—*Some recent advances in selection tests* (2.45).

The selection of personnel on a scientific basis depends on research into human abilities and the determination of group factors, and also a scientific analysis of jobs to determine what factors enter into their performance. Research of this nature has been undertaken, but not on an extensive scale.

Meanwhile the work of selection must proceed on an empirical basis. The experience of the psychologist, however, enters in making the job analyses, devising tests, and in validating the tests. This procedure may not add much to our knowledge of human abilities, but often provides a series of tests of undoubted value in selection. This may be illustrated by examples of tests recently devised on this basis for a number of occupations, e.g. chemical process workers, machine operators, glass inspectors. Information on the technique of making job analyses and on the type of tests that prove of value is accumulating.

Prof. T. North Whitehead.—*An observation of an American industrial group* (3.30).

This paper describes an analysis by some members of the Harvard School of Business Administration of an experiment initiated and conducted by the Western Electric Company at their Hawthorne Works, Chicago, Illinois.

A small group of experienced assemblers engaged in repetitive work were minutely investigated for five years whilst pursuing their ordinary occupation. Their minute to minute outputs were automatically recorded and many other records were obtained, both numerical and qualitative.

This industrial group simultaneously performed two distinct functions.

(1) A technological, or economic function.

(2) A social function, by which the group secured and maintained cohesion, both within itself and in its external relations. The success of the former function was bound up with that of the latter.

Marked variations in working rate were recorded ; but these were insensitive to changes in physical circumstance, temperature, relative humidity, hours of work, etc. ; they were mainly due to changes in social circumstance, both intra- and inter-group, chiefly the former.

Statistical methods are elaborated showing that in this instance interpersonal cohesion manifested itself in imitative, as distinct from merely related, behaviour ; and that antagonisms resulted in unlike behaviour (negative correlation). Social disruption, as distinct from mere antagonisms, resulted in independent (uncorrelated) behaviour.

Mr. J. R. Jennings.—*The methods of industrial psychology applied to agriculture* (4.15).

Tuesday, September 10.

Joint Discussion with Section G (Engineering) on *The applications of science to the control of road traffic* (Section G room) (10.0). See under Section G, p. 417.

Dr. R. H. Thouless.—*The distinction between test unreliability and fluctuations of mental functions* (10.0).

The results of a mental test applied twice to the same group of subjects do not generally give complete correlation. This failure in complete correlation may be due to either or both of two causes : (*a*) the test may be unreliable, i.e. when applied successively as a measuring instrument for the same unvarying quantity, it may not give self-consistent results ; (*b*) the function which is measured by the test in any one subject may vary quantitatively from day to day. It is important to distinguish between these two cases. Test unreliability is no doubt always present, but it is of importance to know whether fluctuation of the function measured is also present and to be able to estimate its amount. If two tests (X and Y) of the function in question are applied simultaneously on two successive occasions, function fluctuation is indicated by $r_{X_1Y_1}$, and $r_{X_2Y_2}$ being greater than $r_{X_1Y_2}$ and $r_{X_2Y_1}$; if no function fluctuation is present, these will all be equal. Alternatively, $r_{(X_1-X_2)(Y_1-Y_2)}$ will be positive if function fluctuation is present, zero if it is absent. This we may call the *double test re-test criterion*. Other methods of solving the problem are available for somewhat different kinds of test data.

Mr. E. J. G. Bradford.—*The reliability of test measurements* (10.45).

The reliability of a test measurement is frequently estimated by comparing the results obtained from several applications of that test. Variation in the results may be due to experimental conditions (environmental), to different samples of the population tested, to different speeds at which the subjects of the experiment adapt themselves to the tests, to the different methods by which this adaptation is brought about. The term reliability can be used in connection with each of these sources of variability.

One test form or application may be reliable in one sense and a second test form or application in another sense; the correlation between them gives no indication as to the sense in which each is reliable.

Considerable attention has been devoted to the first two sources of variability, and the deviations of the 'reliability coefficient' from unity have been ascribed to these sources; whereas the remaining two sources of variation have probably more psychological significance. Differential cumulative adaptability (learning) and differential methods of adaptation (vicarious functioning) need to be considered in connection with the reliability of test results. Reliability is not entirely a statistical problem.

Dr. W. Stephenson.—*Some applications of the inverted factor technique* (11.30).

Dr. S. J. F. Philpott.—*Problems in the field of output and oscillation* (12.15).

(*a*) Ambiguities in description: When there is fluctuation with a sound of minimal intensity (it being now heard, now lost) we tend either to say it is coming 'in and out' of awareness, or that auditory ability is 'rising and falling.'

It is usual only to use the in-and-out conception when describing fluctuations with reversible perspective, one meaning being said to come in, as the other goes out. It is as customary to say that ability rises and falls when computation or a like task is being performed, although there is in-and-out switching in the sense that individual units of work come successively to the focus, or that we switch from one way of 'doing' the task to another and back again.

(*b*) Levels of rivalry: Whatever its nature, a task is performed in competition with others ready to supplant it. Within it there is rivalry between its various aspects. Within any one aspect there is conflict between the ways in which it may be cognised.

(*c*) Switching and Spearman factors, fatigue, etc.: Speed of switching in *g*-tests and *p*-tests means high ability and low inertia respectively. In reversible perspective it is normally held to indicate tiredness. In computation and like tasks it is a necessary condition of high output. These various notions need harmonising. Incidentally, the narrower the field in which switching may take place, or the more intense the rivalry, the greater the degree of fatigue, and *vice versa*.

AFTERNOON.

Mr. W. J. DEARNALEY.—*Character-formation* (2.0).

Dr. P. E. VERNON.—*The matching method of studying personality* (2.45).

An example of matching is to show to a group of judges six photographs of unknown individuals and six brief descriptions of their personalities, numbered in a different order. The judges try to fit or match the photographs with the personality sketches. The proportion of successful matchings, it is found, can be expressed as a modified contingency coefficient; the formulæ for the coefficient and its probable error have been established by empirical statistical experiments. The psychological advantage of this method is that the features may be compared with the *individual* personality considered as a whole; whereas the usual correlation methods of approach have to deal with separate traits (or sets of traits) which are abstracted from a *group* of personalities. Matching may be applied also to the voice, handwriting, manner and gestures, emotional expression, artistic style, etc., and it is found that these 'modes of expression' definitely reveal more about personality than when they are studied by correlation methods. A person's ability to judge personality through matching is found to vary with his intelligence, artistic and social qualities, age, sex and practice.

Dr. R. B. CATTELL.—*The measurement of interests* (3.30).

Interest measurement has practical importance in vocational guidance, but its greatest significance is in connection with research into character development; for a study of the alterations in sentiment attachments is an essential part of characterology.

Some experiments are described on the growth and decline of various interests in children between the ages of seven and fifteen years. Discussion of methods of measurement, e.g. (1) by extent to which individuals talk or write about subjects; (2) by observing the selective action of retentive memory on facts presented; (3) by surveying the individual's fields of stored knowledge; (4) by noting the selections made by involuntary attention among presented stimuli. The value and practicability of other criteria and experimental methods.

Experimental comparison of various methods of interest measurement. Some results in clinical work with a standardised interest test. Profiles of individuals in different occupations, of relatives, of friends. The effect of intelligence.

Definition of interest. Interest and the unconscious. Is there any value in a conception of 'interest' which ignores qualitative differences?

Dr. G. SETH.—*Some psychological characteristics of contemporary English poetry* (4.15).

There are two principal lines of approach to the psychological problems of the work of art. The one, which may be called broadly the clinico-historical approach, is concerned primarily with the work as an expression of the individual artist, and with its place in his development. The other is concerned rather with the psychological problems that are apparent in the handling of a particular medium, with the nature of the æsthetic effects which it makes possible, and with the extent and manner of their utilisation by the artist. In this paper the second line of approach is followed, in a study of some of the psychological aspects of the handling of the medium of language in contemporary English verse. The problems involved may be subsumed under the rubrics of communication and meaning.

SECTION K.—BOTANY.

Thursday, September 5.

Prof. E. J. Salisbury, F.R.S.—*The East Anglian flora* (10.0).

The East Anglian flora is a peculiarly rich one. The Continental Component is the most fully represented, with 78 per cent. of the total species of this category present in Britain. All the steppe species of the British flora are found in East Anglia, and over 90 per cent. of those more definitely restricted to continental climatic conditions on the European mainland. It is therefore apparently paradoxical to find that the other Component best represented is the 'Oceanic Component,' with 59 per cent. of the British species of this category. Forty-eight per cent. of the 'Southern Component,' 13 per cent. of the 'Northern Component,' and about a quarter of the British endemics, are also present.

The apparent heterogeneity of the flora of East Anglia can be related to a striking diversity in the edaphic-climatic complex and by comparative study it can be shown that the migration factor is unlikely to have played any significant part in determining the richness of the flora of this region as compared with others. The flora of East Anglia is a striking testimony to the importance of ecological conditions in determining the distribution of species. Under favourable environmental conditions, historical factors would appear to affect abundance far more than frequency.

Miss E. R. Saunders.—*Some floristic problems and their solution* (11.0).

It is generally acknowledged that the regular alternation of successive floral whorls is the outcome of an inherent rhythm. Such rhythm is undoubtedly common to all flowering plants, yet in many species it appears to break down. The explanation hitherto offered of such breakdowns is either that an intervening whorl, originally present, has disappeared, or that one of two successive superposed whorls is not of the order of a true whorl, but is an appendage of the other. Neither explanation is satisfactory. The former is unsupported by evidence, the latter is not even a plausible fiction. A study of the vascular ground-plan shows that both assumptions are gratuitous. Except in one particular set of conditions an alternating rhythm is maintained throughout the flower, but this alternation is primarily between successive whorls of vascular units and may or may not hold between successive whorls of floral members. If the midrib bundles are initiated independently for each whorl the whorls of *members* alternate as well as the whorls of *midribs*. But if the midribs of two superposed whorls are derived from a common source, i.e. are organised from the same vascular unit, then two such whorls behave as a single whorl in the scheme of alternation. It follows that the solution of problems of whorl arrangement is to be found in the vascular scheme.

Prof. D. Thoday.—*The apical growth of the strands of mistletoe in the cortex of the host* (11.40).

Re-examination of the cortical strands of *Viscum album*, by some regarded as modified roots, suggests that a deeper study of their development and behaviour is necessary before homologies can usefully be discussed. The apex is fringed by hyphal cells with thick gelatinous walls, but the actual growing point of small embryonic cells is superficial. The tip of the strand, in growing longitudinally, presses radially inwards till it reaches the host cambium. There its radial growth *pari passu* with the cambium establishes a sinker, which is therefore not comparable with a lateral root.

The corresponding strands of *Arceuthobium pusillum* begin as filaments and grow in thickness by longitudinal division of the cells; the xylem is endarch. In *Loranthus* the parasite spreads as an amorphous mass of tissue. A *Viscum* from Mauritius shows a very irregular system. None of these justify homologising with ordinary categories of plant members.

Having classified them as organs *sui generis*, progress is possible in two related directions. These endophytic systems of the Loranthaceæ offer an opportunity for the study of tissue correlations—the behaviour of equipotent cells in different micro-environments. Secondly, a wide comparative study of them may yield clues to the evolutionary process in the group, which has evidently involved in a very special way changes in the behaviour of the developing organism.

Dr. F. W. Jane.—*The seeds and seedlings of Utricularia vulgaris* L. (12.10).

Capsules of *Utricularia vulgaris* L. were collected in Norfolk in August 1932. Germination of the seeds did not start until May 1933: those from one capsule germinated over a period of eleven to twelve months.

On germination, some six primary leaves emerge, to be followed rapidly by about as many more; while it is not possible always to separate these two apparent whorls, they are usually distinct.

Associated with the primary leaves there is usually a primary bladder, a shoot and a small 'adventitious shoot.' The 'adventitious shoot' does not develop farther.

The primary leaves are nearly always subulate and unbranched. The cauline leaves of the seedling generally consist of two lateral leafy segments, more or less branched, and a median bladder. The vascular strand to the leaf divides, shortly after leaving that of the axis, into three, one branch going to the bladder, the other two to the leafy segments of the leaf. There is, as a rule, a single leaf at each node, but sometimes there are two. The cauline leaves are subject to considerable variations, but these are nearly always due to reduction of parts of the trifurcate leaf of the seedling, which is above described, or to the replacement of the median bladder by a leafy segment.

Most of the seedlings perennated as minute turions, which formed in November. Some seedlings were grown satisfactorily on moist soil and formed winter buds in autumn, but the opening of such turions in the following spring was erratic, this being due, it is suggested, to the unusual environment.

Prof. J. Small.—*Quantitative evolution* (12.30).

Quantitative evolution. Yule's mathematical theory of evolution is confirmed in detail but modified by the old-age death of species. The apparent ages of groups, plotted against time in years, follow an exponential curve with the formula $Dp.k + nd = T.2^n$. For *Compositæ*, grasses, and angiosperms in general, $k = 0{\cdot}6$, $d = 0{\cdot}9$, $T = 1{\cdot}09375$ m.y. From the properties of this *BAT* curve the following items are deduced: Species of angiosperms double in number each two million years and die when they have existed for 12 m.y., of senescent sterility, with chance playing no essential part in their decease. Ordinary genera become senescent after six doubling periods and die at 26 m.y., but primordial genera have a longer lifetime. Backward extinction is traced at a level 16·6 per cent. for each 2 m.y. and the number of existing species of angiosperms showing senescence should be between 2,500 and 250. The *BAT* curve is based upon observed points for *Compositæ*, but it applies to Reid's Pliocene extinctions, Lyell's shell curve, to species-number in angiosperms back to Jurassic and to grasses back to Cretaceous. The principles apply also to conifers and oligochete worms, but the data for birds indicate modifications of the mathematical forms, which may be due to competition between related species.

AFTERNOON.

Excursion to Rockland and Wheatfen Broads (2.0).

Friday, September 6.

JOINT SESSION with Department K* (Forestry).

Mr. T. R. PEACE.—*Dutch elm disease in Britain* (10.0).

The Dutch Elm disease, which is caused by the fungus *Ceratostomella ulmi*, is most serious in the south-east of England, and decreases in severity towards the north and west, and is not known to exist in north England and in Scotland. In a few limited areas it has done severe damage, but over the bulk of its range, though common, it has as yet killed few trees. Prophecy of the future of the disease is complicated by the very varied rate of progress of the attack in different trees, and by the recovery, temporary or permanent, of many. In view of these recoveries and of the difficulties of eradication, a policy of *laissez faire* in this country is probably justified.

This disease, which is probably largely disseminated by bark beetles, forms a very good example of the connection between fungi and insects.

In Scotland, and more rarely in England, other dieback diseases are causing considerable damage to mature elms. The symptoms are in most cases somewhat different from those of Dutch Elm disease, and the causes are as yet obscure.

Dr. W. J. DOWSON.—*The watermark disease of the cricket bat willow* (10.30).

Approximately 25,000 willows, ten to twenty years old, in Essex, are useless for bat making, and are acting as sources of infection of the disease which is steadily increasing. In 1922–24 W. R. Day investigated this disease and concluded that the causal agent was a bacterium which he named *Bact. Salicis*. His description of the organism was not complete nor were his successful inoculations numerous enough to leave no doubt that his bacterium was the true cause. In 1930–32 Miss Lindeijer investigated a similar disease of willows, other than *S. cærulea*, in Holland, and also showed that a bacterium was involved but differed in certain characters from Day's organism. She named it *Pseudomonas Saliciperda* and stated that the two diseases were identical. She further concluded that infection was spread by the weevil *Cryptorrhynchus Lapathi*. This insect is rare in Essex and has never been found in association with the disease.

During the last three years the position in this country has been reinvestigated, the chief result so far being a confirmation of Day's work. He undoubtedly isolated the real bacterial pathogen of the watermark disease, although his description needs amendment.

Mr. E. Wyllie Fenton.—*The need for a permanent organisation for undertaking periodic botanical surveys of Great Britain* (11.0).

The type of Botanical Survey suggested is similar to that of Smith and Rankin and Smith and Moss in England, and the brothers Smith in Scotland.

Such surveys have both academic value as well as great practical value, indicating the suitability or otherwise of certain areas for particular types of husbandry or afforestation. They would also reveal how human activities were affecting vegetation.

Periodic re-surveys are necessary to keep pace with changing conditions, and to indicate whether certain activities are harmful or otherwise. Periodic re-surveys in the past would have been of great value to-day.

The real ideal is a Scientific Survey including all sciences. With such a survey the maps would be both complete and valuable. The Geological Survey took time to establish, but its value to-day is unquestioned. So it would prove if a Botanical Survey were established. The question of aerial photographs should not be forgotten, but perhaps co-operation in certain quarters would overcome the difficulty.

To commence with, it would probably be best for botanists to be attached to the Geological Survey, and to develop gradually from this small staff. The ideal of a Scientific Survey should not be unduly delayed or forgotten.

Prof. S. E. Wilson.—*The fate of reserve materials in the felled tree* (11.30).

Forest trees are usually felled in the season (winter) when the sapwood contains abundant reserve food-materials. These, as starch, sugar, fats, etc., occur within the protoplasts of the living storage cells which constitute the medullary rays, and wood-parenchyma if present. The fate of the reserve materials is now shown to depend on the treatment of the timber after felling. If the log is kept whole, and the bark retained to prevent rapid drying, the storage cells continue alive until all reserves are exhausted; whereas if the timber is converted quickly and the cells killed by desiccation or kiln-heat the reserve materials remain intact and cannot thereafter be removed by any known treatment.

Timber containing reserve materials is shown to be a ready prey to wood-tunnelling beetles and sap-staining fungi. In particular, *Lyctus* powder-post beetle larvæ feed on the starch occurring in oak, ash, elm, walnut, etc., so that removal of the starch by the 'log-seasoning' process serves to immunise the timber against *Lyctus* infestation. The experimental evidence for this is described, and samples of immunised common hardwoods, of commercial size, are demonstrated.

A gravimetric method of determining the total amount of respirable cell-contents in experimental samples is discussed, and the further bearings of the occurrence of reserve materials in technological research are outlined.

Suggestions are put forward for the co-operation of forest botanists with timber technologists in extending our knowledge of these important reserve materials, with a view to the better utilisation of our native timber trees.

Dr. K. M. Smith.—*Some aspects of the plant virus problem* (12.15).

The last decade has seen the beginning of intensive study of plant virus diseases and a large body of knowledge has been compiled. Among the interesting facts discovered may be mentioned new knowledge concerning the relationship of plant viruses with insects, the alteration in flower colours due to virus infection, the existence of closely similar virus strains, the immunity conferred upon a plant by one strain against other strains or related viruses and the possibility of using this immunity as a means of virus differentiation. Improved methods of ultrafiltration have rendered it possible to measure the actual particle-size of viruses. Many problems, however, still await solution ; the origin and method of spread of certain viruses are unknown and the actual nature of these disease agents is still a matter for speculation.

Afternoon.

Dr. A. S. Horne.—*The resistance of the apple fruit to fungal invasion* (2.0).

An account is given of further application of the statistical method of studying the course of invasion and its bearing on the nature of disease resistance (see *Proc. Roy. Soc.*, B., **102** (1928)).

For invasion to take place the fungus concerned must overcome (1) the external resistance, and (2) the internal resistance.

Many fungi are able to penetrate the skin *via* lenticels or stomata.

The internal resistance is mainly conditioned by chemical composition of the fruit. In general, high acid content tends to check invasion : on the other hand, high nitrogen content favours fungal advance.

Chemical differences between fruit from individual trees, fruit from different stocks, or fruit from trees receiving varied manurial treatment are reflected in rate of fungal invasion. Statistical treatment of data of radial advance has in many instances given results of considerable significance.

Radial advance is found to be very highly correlated with rate of growth, based on microscopical measurement, of fungal hyphæ in living sections of apple.

Mr. P. W. Brian.—*Investigations on the germination of mould spores* (2.30).

In this study the spores of *Penicillium expansum* Link. and *Fusarium lateritium* var. *fructigenum* (Fr.) Wr., were used.

Desiccation of dry spores of these moulds has little deleterious effect ; in the case of *Fusarium* desiccation of previously wetted spores results in considerable loss of viability. If the desiccation is only slight the latent period of germination is lengthened.

Fusarium spores, like many others, will germinate in water alone. A nutrient causes prolongation of the latent period and increase of the rate of subsequent germination.

For the complete germination of a sample of *Penicillium* spores suitable sources of nitrogen and carbon, together with a phosphate, are essential. Such a simple nutrient will not suffice for continued growth.

In the case of *Penicillium* spores there is found to be two distinct stages previous to the actual extrusion of the germ tube—a change in the refractivity of the spore wall, and swelling of the spore. The occurrence and extent of these stages is related to the concentration and composition of the nutrient, and to temperature. Under certain conditions germination takes place without their occurrence.

Dr. C. E. Foister.—*The white tip disease of leeks* (3.0).

The White Tip disease of leeks occurs in Scotland and has been found near Bristol, causing a serious deterioration of the crop, followed by a rapid wilting and rot in the market. The main characteristic is the whitening of the leaf tips followed by rotting at or near the leaf bases.

Phytophthora Porri has been found to be the cause. The main source of this disease is the contaminated soil; the ploughing in of diseased leeks is thus deleterious. The fungus enters by the leaf and proceeds down the stem. Onions and *Allium fistulosum* are immune. The resistance of certain parts of the host plant is associated with the method of entry of the fungus. Susceptibility varies with the age of the plant, resistance being highest at the seedling stage. This disease may be compared with certain diseases of the onion where resistance is associated with the presence of a special chemical in certain tissues. Control of this disease is not practicable by means of spraying. Selection for resistance and crossing for immunity is promising. Trials of interspecific crossings using *Allium* species are in hand, to see if immunity can be transferred to the commercial leek.

Mr. A. R. Wilson.—*The relation of Botrytis to the 'chocolate spot' disease of beans (Vicia Faba)* (3.20).

'Chocolate spot' disease of *Vicia Faba* is characterised by the appearance of chocolate brown lesions on the shoots. The disease has been attributed by various authors to different causes. These are summarised as follows: Paine and Lacey (1923), *Bacillus Lathyri*; Riker and Riker (1932), unnamed bacteria; Magee (1933), exudate of *Aphis rumicis*; Ikata (1933), *Botrytis Fabæ* Ikata. Research carried on during 1931–35 at Cambridge has shown that 'chocolate spot' lesions may be due to various causes, chief among which is infection by *Botrytis spp*. The original inoculum comes from rotting debris on the ground and later from leaves which have been killed by the first attack. There are two definite types of infection, 'unlimited' resulting in extensive blackening and death of the shoots and 'limited' resulting in true 'chocolate spot.' This latter type does not often seriously damage the plants unless environmental conditions remain favourable to the growth of the fungus. Other factors, however, determine to a large extent the severity of the outbreak, such as soil deficiency in lime, potash, etc., poor drainage and frost. Poor growth resulting from one or more of these causes predisposes the crop to severe attack should suitable environmental conditions arise.

Mr. C. G. Dobbs.—*The life history of Dicranophora fulva* (3.50).

This member of the *Mucorales* possesses sporangioles containing large reniform spores, as well as sporangia of the *Mucor* type. Studies of the sporangial stage confirm the presence of a columella in the sporangiole, a distinction from *Thamnidium* which has been denied by Vuillemin, and further show that the sporangioles grade into the large sporangia by intermediate forms. The columella, which is spherical, not conical as previously reported, sometimes branches and may give rise to the two short points from which the genus is named. The range in spore size (5–50 μ) is extraordinarily wide, and occasionally a sporangium may liberate its contents as a single spore.

The remarkably heterogamic sexual stage has been further elucidated. The lobed female hypha, about 60 μ in diameter, which may form a branch system up to 1 mm. long, forms zygospores wherever it comes in contact with a male hypha. Passage of contents from the male to the female gametangium has been observed. The fungus is remarkably sensitive to light, very short illumination being sufficient to inhibit the development of the sex organs, and to induce the formation of sporangia, which are not produced in the dark.

Miss C. H. Lang.—*A yeast-like fungus in the pollen and pollen-tubes of Camellia japonica* (4.15).

Pollen from a single variety of *Camellia japonica* obtained from Chelsea Physic Garden was germinated in sterile water. The protoplasm of the tube shows active streaming and is found to contain small bodies having the shape of dumb-bells or rods. These bodies may be clearly observed both in the grain itself and in the pollen tube. On two occasions a budding stage was observed in the pollen tubes.

A number of varieties of *Camellia japonica* from various sources all show these bodies in the pollen grains and tubes. They are also distinguishable when the pollen is grown on agar media.

When the pollen grains and tubes are ruptured, these bodies grow and then divide by fission into two. The next stage observed in the development is the budding of the products of fission in the manner of a typical yeast.

In pure water cultures of *Camellia* pollen and on agar, mycelia appear which show typical budding. The evidence seems clear that one of these forms is derived from the endophyte. It is intended to continue the investigation when further material is available.

Saturday, September 7.

Joint Excursion with Department K* (Forestry) to Breckland (10.0).

Sunday, September 8.

Excursion to Wroxham and Barton Broad (10.10).

Monday, September 9.

Mr. R. Bourne.—*Aerial surveys* (10.0).

In the past, the majority of soil and vegetation studies have been based on localised observations. The significance of mapping over considerable areas has not been fully realised. Human actions have generally had a great influence on the phenomena to be observed and, without a record of past events, observers have been frequently at fault in their attempts at a correlation of vegetation with local factors. The independent mapping of site and vegetation over large areas enables comparisons to be made between different treatments on similar sites and the same treatment on distinct sites. In consequence, conclusions can often be safely drawn which would have been impossible had the investigations been localised. The problem is to map large areas in any detail, and it is in this connection that aerial photography is primarily of value. Aerial photographs provide the most perfect form of map yet devised for recording detailed observations on the ground. If pieced together into mosaics, in order to furnish an air view of relatively large areas, they facilitate the delimitation of regions, the differences in landscape being presented in a manner impossible on any other form of map. These facts have been demonstrated by many workers in various parts of the world and the sole reason why air survey is not yet more generally employed is its initial cost. The cost varies with circumstances, particularly the prevalent weather conditions, the scale of photography and the size of the area to be photographed. Hitherto, photography on scales smaller than

1 : 20,000 has rarely been possible or attempted, but the production of wide angle lens and multi-lens cameras on a commercial rather than on an experimental basis is imminent, and it may be predicted that small-scale photography will shortly be possible in many circumstances at a cost not exceeding one halfpenny per acre.

Dr. G. F. Asprey.—*The effect of washing on the subsequent absorption and exosmosis of electrolytes by potato tissue* (11.0).

When discs of potato tuber tissue are washed in running tap-water for periods varying from 24 to 120 hours it is found that their subsequent exosmosis into distilled water varies inversely as the length of the washing period. The subsequent absorption of ions from ammonium chloride solutions by similarly treated tissue, on the other hand, varies directly as the duration of the previous washing. It would seem then that high absorption of ions by the tissue is associated with low outward diffusion of electrolytes. This conclusion is contrary to expectations based on ionic interchange, nevertheless it is confirmed by experiments in which are ascertained both exosmosis into, and absorption of ions from, ammonium chloride solutions by differentially washed tissue. The bearing of these results on our knowledge of the process of salt intake is considered.

Presidential Address by Mr. F. T. Brooks, F.R.S., on *Some aspects of plant pathology* (12.0). (See p. 169.)

Afternoon.

Joint Discussion with Department K* (Forestry) and Section M (Agriculture) on *The utilisation of light land, with special reference to Breckland* (Section K room) (2.0).

Dr. A. S. Watt.—*The climate, soil, and vegetation of Breckland.*

Breckland is a well-defined physiographic unit, whose vegetational features are determined by a dry soil in a dry climate. The significant climatic factors are thrown into relief by a comparison of the meteorological data from places with an oceanic and sub-continental climate respectively. This brings out the combination of the relatively high summer temperature with a summer rainfall which is absolutely low. Other important factors are the high number of hours of sunshine and the shortness of the frost-free period.

There is a wide variety of soil type from calcareous shallow soils through deeper soils deficient in calcium carbonate to very acid heavily podsolised soils. Wind erosion has played and still plays an important part; some soils are maintained in an immature state; podsols have been truncated to different levels, whilst the soil which has been removed forms a blanket of varying thickness over much of the area. Thus the soils vary much in chemical, less so in physical properties, for (with some exceptions of small extent) all are highly permeable with a small water retaining capacity.

The flora, under this combination of dry soil and dry climate, is essentially drought resistant or drought escaping. But while dry conditions stamp the vegetation as a whole, vegetational variation closely follows physical and chemical variation in the soil. The chief vegetational types are mentioned and their relationships outlined.

Mr. W. L. Taylor.—*New forests in East Anglia* (2.40).

The Forestry Act, 1919. The commencement, in 1920, of the afforestation scheme propounded by the 'Acland Committee,' of the War-time Ministry of Reconstruction, providing for the planting of 1,770,000 acres with conifers within eighty years, with additional broadleaved plantings. Afforestation in East Anglia; suitability of extensive areas; progress of land acquisition in the Norfolk and Suffolk light sandy districts; total area in possession of Forestry Commissioners now 57,818 acres mostly situated in Breckland. The Forest of Thetford Chase the largest of the new forests; area 35,411 acres, of which 25,577 acres already planted. The local geology and soils, botany, climate and meteorology, natural history and previous utilisation. Species planted and argument for the choice made, particularly with regard to climatic conditions. The forest nurseries, plant production and seed collection. Planting for amenity. Planting methods and costs, types of plants used and the employment already created by the work in hand. Risks and dangers; the fire hazard, rabbits, deer, insects and fungi. The establishment of Forest Workers' Holdings as a means of practical land settlement. The estimated yield of timber from the new plantations; the ultimate local gain in new industries and employment and the influence of afforestation on the neighbourhood.

Dr. L. Dudley Stamp.—*The present use of Breckland* (3.5).

This paper summarises some of the main results of the survey of existing land use in Breckland carried out in 1933–34 by the Land Utilisation Survey of Britain. The survey in this area was directed by J. E. G. Mosby, the hon. organiser for Norfolk, and land use was recorded on the six-inch Ordnance maps. The classification scheme is that used over the whole country: into F (forest and woodland, distinguishing twelve types and indicating young plantations separately); H (heathland, moorland and rough pasture); A (arable or crop land, including rotation pasture); M (meadow and permanent pasture); G (gardens, with subsections for orchards, nurseries, etc.), and W (waste land or land agriculturally unproductive). The field survey has now been edited and the results published in sheets on the scale of one inch to one mile. The limits of 'Breckland' are discussed with reference to these maps and reasons given for distinguishing between Breckland proper and Breck Fen. Within the limits of Breckland so defined the areas at present under the chief utilisations have been calculated and are discussed and comparisons made with previous periods during the past century, of which some records exist. By eliminating areas under woodland and recently planted, attention is focused on those parts of Breckland for which the most suitable use has still to be determined.

General Discussion (3.45).

Mr. W. E. Hiley.—*The economics of woodland cultivation and the marketing of woodland products* (4.15).

Where bad forestry occurs in the plantations on British estates it is more often due to inability to market woodland products than to ignorance of silviculture. This applies particularly to thinnings, and every forester knows that in those parts of his woodlands where he can obtain profitable sales for small poles, thinnings will be made punctually, whereas in other parts they are liable to be neglected. The clearing of scrub is another operation which will be carried out so far as markets for firewood, pea and bean sticks, hurdles, etc., are available.

The successful marketing of many species of timber, poles, stakes, pea and bean stakes, firewood, Christmas trees, and estate manufactures, such as gates and hurdles, demands very special knowledge and application, and, in order to save foresters from giving an undue amount of time and study to it, co-operation between estates is essential. Such co-operation is now being arranged by branches of the Home Grown Timber Marketing Association, which is devising several different schemes of marketing. The methods adopted by two of these branches are instructive and illustrate the difficulties which are being experienced. The Association is also attempting to secure more standardisation in methods of measuring and selling timber.

Improvements in methods of marketing and in the utilisation of timber and other woodland products should also result from the work of the new National Home Grown Timber Council which has been set up by the Forestry Commission in conjunction with the various interests concerned and is undertaking investigations with these objects in view.

Semi-Popular Lecture by Mr. A. C. Forbes on *Tree planting since the Roman occupation* (5.0).

Tuesday, September 10.

Dr. H. Godwin.—*The conditions of formation of British peats. The topogenous peats of the British coasts and of the Fenland basin* (10.0).

An examination of micro and macro fossils of these peats suggests that they are all of the *niedermoor* or *Zwischenmoor* type. Pollen analyses of the submerged peat beds of the British coasts and of moor-log from the North Sea show that this peat formation is not referable to any single period. Peats of all the periods from pre-Boreal to sub-Atlantic appear to be present. The peat beds and even some of the so-called forest beds overlie salt-marsh deposits and there is evidence of vegetational succession from salt-marsh through brackish water phragmitetum to fen-woodland on peat. These peat beds appear to be closely connected in origin with the marine transgression.

The conditions of formation of fenland peats are in many respects similar, being closely determined by relative movement of land and sea. Periods of marine transgression led to marine conditions, and stability or retrogression led to vegetational succession towards fen-carr and fen woodland, often slightly acidic in character. There is no trace of *hock-moor*.

Prof. H. Osvald.—*Some notes on peat land vegetation and peat soils in the British Isles* (10.30).

In 1925 I classified the European moss [1] types as follows [2]: (*a*) ‘ raised mosses ’ with trees ; (*b*) naked (treeless) ‘ raised mosses ’ ; (*c*) ‘ flat mosses ’ ; (*d*) ‘ concave mosses ’ ; and (*e*) ‘ cover mosses ’ ; type (*a*) being the most continental and type (*e*) the most oceanic. Types (*d*) and (*e*) are poorly represented on the continent of Europe but very frequent in those parts of the British Isles which have the most humid climate. On the other hand, type (*a*) is absent from this country, and type (*b*) is represented only by its

[1] The term ‘ moss ’ is here used for the type of plant community forming wet or moist acid peat, and dominated either by *Sphagnum*, or by *Eriophorum* or *Scirpus cæspitosus*. ‘ Moss ’ is the regular place name applied to such wet peat vegetation in the north of Britain.

[2] The terms are translated here.

western facies, at low altitudes (' valley moors '). The peat of these British-raised mosses seems to be built up mainly by *Sphagnum magellanicum*, which is also the most important peat former in the west of Sweden. The pure, undecomposed *S. fuscum* peat, characteristic of the raised mosses in great parts of Europe, does not seem to occur in the British Isles. Types (*d*) and (*e*) are the characteristic mosses of Great Britain ; in these, *Sphagna* grow less vigorously than in the other types, the most important species being *S. magellanicum*, *S. rubellum* and *S. plumulosum*. On the other hand, *Scirpus cæspitosus* and *Eriophorum vaginatum* are rather prominent peat formers. Consequently the peat in these mosses may be characterised as *Scirpus cæspitosus-Sphagnum* peat, *Eriophorum vaginatum-Sphagnum* peat, or, especially in the Pennines, pure *Eriophorum vaginatum* peat, all of them being fairly well decomposed.

On the mosses in the British Isles wind erosion plays a rather important rôle, forming a complex of hummocks and depressions. On the hummocks, *Rhacomitrium* is often abundant, forming a *Scirpus-Rhacomitrium* or a pure *Rhacomitrium* peat.

An interesting feature of the vegetation of these British peat areas is the relatively high frequency of many plants, which do not grow on the typical raised mosses of the continent, for example, *Polygala vulgaris*, *Potentilla erecta*, *Narthecium ossifragum* and *Molinia cœrulea*.

Dr. A. Raistrick.—*Conditions of peat formation in the Pennines* (11.0).

The peats of the Pennine area can be grouped under four distinct types : (*a*) Fell top peats, on the flatter summits above 1,500 ft. O.D. ; (*b*) Valley head peats, in sheltered hollows about 1,000 to 1,600 ft. O.D. ; (*c*) Channel peats, in areas of anomalous drainage, mainly glacial overflow channels at all levels ; (*d*) Pond and lake peats, in the glacial lake sites, mainly in the valley bottoms.

The longest record of conditions is preserved in the deposits of the glacial lake flats. These start with a great depth of laminated clays and silts, followed by fine sands with peaty material or pollen, and then by coarse sands or boulder gravels. Above this may be two true peat beds, separated by gravels, and covered finally by river terraces. Peat formation in the lakes and the valley heads commenced in the upper Boreal period, the base of the Atlantic being marked by the boulder gravels in the lakes, and by occasional erosion levels in the peats. The increase of run-off led to the breaching of the lake morainic dams, and resulted in a marked change of physical conditions over the whole area. Peat accumulation continued through the Atlantic period, the peats spreading to the fell top areas, and marked by at least two ' forest ' layers, of birch twigs, and stools of birch, oak, and (rare) pine trees. The hill top peats may be from 15 to 20 ft. thick, but almost everywhere have now an eroded upper surface. The upper part of both fell top and valley head peats is of sub-Boreal type, but shows marked increase in sphagnum and cotton grass, and decrease in the quantity of tree pollen present. A sub-Boreal peat is present in some of the lake sites. Peat formation slowed down or stopped during the sub-Boreal and sub-Atlantic on all the higher sites. The channel peats are all soft and wet, and very difficult to investigate ; they are largely sphagnum peats, but their growth has been continuous in many cases to the present. Archæological remains are associated with many of the lake sites and with some of the hill-top peats, and these confirm the dating suggested by the tree pollen.

Dr. I. M. Robertson.—*The peat mosses of Scotland* (11.15).

Discussion.—Prof. Dr. L. von Post, Prof. A. G. Tansley, F.R.S., Dr. Frazer, Mr. Mitchell.

Dr. F. K. Sparrow.—*Interesting aquatic fungi from Cambridge* (12.20).

During 1932–33 an investigation of the aquatic fungous flora in the vicinity of Cambridge was undertaken. Representatives of all the aquatic orders of the *Phycomycetes* were collected and significant data on their morphology, biology and taxonomy noted.

Forty members of the *Chytridiales*, including three new genera, six new species and many forms hitherto unreported from England, were found. As representative of the *Blastocladiales*, six species of *Blastocladia*, including one new to science, were collected, while five members of the *Monoblepharidales*, one of the *Leptomitales*, five of the *Saprolegniales* and a new species of *Myzocytium*, a genus of the *Ancylistales*, were found. Four genera of the *Pythiales* were collected. The paucity of species of filamentous *Phycomycetes* was not due to the lack of these elements in the flora, but rather to the investigator's greater interest in the rarer and lesser-known uniciliate forms.

Afternoon.

Exhibits.

Wednesday, September 11.

Mr. T. G. Tutin.—*Eel grass* (10.0).

Eel grass, *Zostera marina* L., is one of the few marine flowering plants found in temperate seas. It has a creeping rhizome, long linear leaves, and erect flowering stems, bearing several inflorescences, each enclosed in a leaf-like spathe. The flowers are unisexual and devoid of perianth, the female consisting of a single ovary, and the male of a single stamen which produces thread-like pollen. *Zostera* occurs on the coasts of Europe and North America in considerable abundance, and is of economic importance, so that the sudden appearance of disease in the Atlantic, about 1930, was speedily noticed.

A number of different organisms were suggested as the cause of the disease, and two at least seem to be serious parasites, but the underlying cause is almost certainly the rare occurrence of good crops of seedlings over most of the plant's range. A fairly high temperature and good illumination in the autumn seem to be the necessary conditions for germination, and these are seldom forthcoming on the Atlantic coast of Europe. Continued vegetative reproduction gives an opportunity for the spread of a normally mild parasite, so that a season slightly adverse to the plant may produce widespread destruction.

Dr. E. Ashby and Mr. P. O. Wiehe.—*Quantitative studies in the ecology of a salt marsh* (10.30).

The distribution of individuals in a pure stand of *Salicornia* has been studied by statistical methods. Toward the sea there are fewer plants per unit area than toward the land. This is due to the fact that the seedlings require for their establishment a 'threshold period' free from submergence by the tide. When they are covered by the tide every day the mortality of seedlings is high. If they have a 'threshold period' free from tides the mortality of the seedlings is low. Density of individuals depends, therefore, upon frequency of submergence.

Within a uniform 'tide environment' the individuals are distributed approximately at random. There is a slight tendency to aggregation, which it is possible to estimate statistically. There is no obvious reason why the individuals of such a population should be aggregated.

Dr. W. E. Isaac.—*The distribution and zonation of marine algæ on the coasts of South Africa* (11.0).

West coast of South Africa subject to influence of antarctic Benguela current. Sea temperatures fall northwards to Luderitz, then rise. East and south coasts (to Agulhas) directly under influence of tropical Mozambique current. Sea temperatures of region between Agulhas and Cape Point only partly affected by warm current; marked seasonal temperature fluctuations in this region due to summer south-east winds.

Algological investigations conducted at various points from Lamberts Bay to East London.

Different temperature conditions have marked effect on species distribution and algal ecology. Colder waters chiefly characterised by presence of extensive sub-littoral zone of large *Laminariaceæ—Ecklonia buccinalis, Laminaria pallida, Macrocystis pirifera. Champia lumbricalis,* essentially a cold water species, where it characterises lowest littoral zone. In warmer waters, *Gelidium pristioides* dominates a mid-tidal zone. Species of *Caulerpaceæ* prominent in regions directly influenced by Mozambique current but absent from colder waters. Throughout region investigated, *Porphyra capensis* the dominant species in highest littoral zone. This zone poorly developed in warmer waters, but dense, extensive, and with large-sized individuals in cold waters.

Common features of *littoral area* in regions investigated: (1) *Phæophycea* not prominent; (2) *Rhodophyceæ* prominent as dominant and common species; (3) *Porphyra capensis* persistent as uppermost littoral alga.

Mr. N. Woodhead.—*Algal periodicity in an Anglesey lake* (11.30).

The algal periodicity in Llyn Maelog, Anglesey, has been studied over a period of two years, plankton samples collected daily being available. Several species of *Myxophyceæ* form a succession of water-blooms early in the summer; the dominant organisms have changed within the last twelve years. These are succeeded by a *Tribonema* phase occupying the position often taken by *Myxophycean* maxima in other lakes. The winter and spring months have a diatom plankton, rich in species. Of them, only *Asterionella* becomes abundant. It shows two maxima, a major one of longer duration in December and a secondary one in May. Between May and the rise of the *Myxophyceæ* is interpolated a short but well-marked *Dinobryon* phase as the temperature increases. Daily sampling reveals that the *Myxophyceæ,* during their period of maximum development, show great and rapid fluctuations in quantity. This appears to occur simultaneously in different parts of the lake. Over a hundred algal species have been added to the recorded flora of the lake.

Afternoon.

Cruise on Ranworth Broad (2.0).

DEPARTMENT OF FORESTRY (K*).

Thursday, September 5.

Mr. W. R. Smith (Chairman).—*Economic aspects of forestry* (10.0).

Mr. A. L. Howard.—*Our British-grown hardwood trees* (11.0).

Mr. J. M. B. Brown.—*The pine shoot moth* (*Ryacionia buoliana* Schiff) *and its control in East Anglia* (12.0).

The Pine-Shoot moth is a familiar pest of pine in Europe and the Near East, and has recently invaded the North American Continent. The life-cycle is annual, the eggs being laid in July and August on the shoots of the current year, the young caterpillars crawling up to the buds, entering these and commencing feeding. Enclosed in the buds and covered by a protective web, they pass the winter, and in the early spring, once flushing begins, they leave the winter buds and migrate to others, often those on other branch whorls. Their general direction of movement is upwards. Intensive feeding proceeds from early spring until mid-June, when the full-grown caterpillars, now plump, reddish-brown in colour with black heads, form brown pupæ, from which the mottled reddish-brown moths emerge in two to three weeks. Damage consists in the killing or deformation of buds and shoots. If the leading bud is attacked, the form of the tree is affected. If the leader is destroyed, its place may be taken by the strongest lateral shoot, and recovery is good or ill according to the distance of this new leader from the stem axis. Sometimes, the leader may be injured but not destroyed. It may then fall over and re-establish itself as the familiar ' Posthorn ' shoot. Artificial measures of control have been tested out in East Anglia on the Forestry Commission's plantations, the results of which are discussed in this paper.

Afternoon.

Excursion to Lakenham Hall, Hethel Church, Hengham Hall (2.0).

Friday, September 6.

Joint Session with Section K (Botany), *q.v.*, p. 445.

Saturday, September 7.

Joint Excursion with Section K (Botany) to Breckland (10.0).

Sunday, September 8.

Excursion to Holkham and Weasenham (10.0).

Monday, September 9.

Mr. R. Bourne.—*Aerial surveys* (Section K room) (10.0).

Joint Discussion with Section K (Botany) and Section M (Agriculture) on *The utilisation of light land, with special reference to Breckland* (Section K room) (2.0). See under Section K, p. 450.

Mr. A. C. Forbes.—Semi-popular lecture on *Tree planting since the Roman occupation* (Section K room) (5.0).

SECTION L.—EDUCATIONAL SCIENCE.

Thursday, September 5.

Discussion on *Teaching and learning of appreciation* (10.0).

Literature :—

Mr. P. H. B. Lyon (10.0).

Love of literature, like religion, must be caught rather than taught. Poetry especially can be taught by no single known method. The communication of a love of poetry to boys and girls demands first of all sincerity and enthusiasm in the teacher : next, a removal of all those real or fancied obstacles to appreciation which the child absorbs from his environment or companions ; such as its alleged difficulty, or mawkishness, or unnaturalness, or artificiality. Pupils must then be shown how to listen to poetry, how to see what the poet sees, and feel what he feels. Careful choice of material is needed to bridge the awkward gulf between the age of uncritical acceptance and the mature appreciation of the adult. The teacher must himself be converted before he seeks to convert others ; he must never attempt to exact respect for that to which he is himself indifferent. Methods of spreading appreciation include the frequent reading of lyrics, without comment, the learning of good poetry, the general and individual criticism and discussion of poems, and the thorough absorption of an occasional masterpiece. Poetry speaks not only to the mind but to the spirit of man.

Rev. M. R. Ridley (10.30).

The appreciation of literature : (*a*) what it means ; (*b*) how to help students to achieve it.

(*a*) Not in itself the same thing as ' literary criticism '—but cannot be achieved without some critical process. A vague reaction of liking or disliking is not ' appreciation ', and soon palls.

(*b*) (i) At school. Fatal to try to teach it directly, since this involves the imposition of the teacher's appreciation on the pupil, leading probably to resentment, and certainly to distortion. Aim should be to secure that the pupil looks at the work long enough for it to produce its own effect on him. This most easily secured (especially with poetry) by concentrating on the *technical* elements.

Most pupils enjoy this kind of analysis, and, while conducting it, unconsciously appreciate other elements. Dangerous to try to make children enthusiastic about works that are 'beyond' them (though often surprising what is not beyond them); begin with works of obvious appeal. Children grow out of literature as they do out of clothes.

(ii) At University. The problem quite different. Here one has to try to teach criticism. Most students at first flounder hopelessly (more perhaps than in any other subject), because they have no idea what they are trying to do. Help the student by discussion and argument to analyse his own 'reaction' in progressively greater detail, from 'I like (or dislike) this' through 'why? is it the structure, or the sound or the sense? is the appeal to the senses or the emotions or the intellect?' to a reasoned and considered judgment. The best type of literature for early 'exercises in criticism' is drama, since the questions that a student can propound to himself about a play are more varied and cleaner-cut than with, say, a lyric, and it is easier to get a comprehensive view of a play than of a novel or a long narrative poem.

MUSIC :—

Prof. F. H. SHERA (10.50).

Appreciation defined as evaluation leading to intelligent enjoyment. Music defined as a communication presented by the composer to the listener in the medium of ordered sound.

The necessity of training in aural discrimination, and of the cultivation of the musical memory. The uses of melody writing.

The post-primary study of musical forms and the history of music. Song-forms the basis of independent instrumental music. Study of the Rondo, Minuet, etc., leading to the symphonic 'first movement.' The question of Opera.

Method and apparatus.—Analysis, synthesis, and the use of 'bad' music. School pianos and gramophones. The problem of the non-pianist teacher.

The teaching of history: knowledge of environment more important than knowledge of biographical details. The difficulty of correlation with the ordinary history lesson.

Choral Societies and Orchestras: the importance of learning by doing. School libraries of music.

Reasons for the systematic teaching of appreciation: economy of time, wider dissemination of enjoyment, the abundance of music to be heard. Two dangers.

How far can æsthetic discrimination be taught? A vague impression can be made more distinct.

The aim: to increase the number of intelligent amateurs. The problem of the supply of competent teachers. Conclusion.

Mr. HERBERT WISEMAN (11.20).

Musical education—three aspects—children should learn (*a*) to read music; (*b*) to interpret music; (*c*) to listen to music with intelligent love—all necessary for complete appreciation.

Reading implies four-fold mental effort: (1) appreciation of pitch; (2) appreciation of rhythm; (3) vocal facility; (4) speed of visual recognition.

Interpretation mainly through songs. The child should gradually build up a sense of style and learn to discriminate between types and to grasp simple forms. Percussion bands and pipe-making give chance of self-expression by means of instruments. Class instruction in instrumental playing, prevalent in America, might lead to more school orchestras, etc.

Listening still too much neglected in primary schools. Why? The system of appointing teachers does not always ensure there is even one in each staff fit to take the music of the school. Teacher of appreciation should have keyboard facility—mechanical aids, gramophone, wireless, etc. Specialists or class teachers? The problems of the infant room. Two ideals of beauty; (*a*) beauty of material; (*b*) beauty of performance. Festival movement has done much for both. Reaction on composers. General position of music in schools: (*a*) to-day; (*b*) to-morrow.

ART :—

Mr. J. E. BARTON (11.40).

Art should be regarded as a pervading and necessary element in all civilised activity or creation. Art education has suffered by academic isolation of the so-called fine arts from the whole body of human self-expression. The idea of art in education should cover the general ground of public idealism, planning, amenity, and recreation. Æsthetic values must permeate the normal and mechanised industries of modern society. Functional and constructive principles, not decoration nor romantic sentiment, are the basis of art understanding to-day. For citizenship and for a true internationalism, the study of art in its communal aspects is indispensable. Executive art teaching in schools has shown remarkable progress, but is only a means to an end. What primarily matters is the education of the future art-consumer. The influence of good or of bad art is universal, however unconscious of it we may be. Appreciation can only be learned through the eyes and, while orderly historical instruction is essential, the effectiveness of teaching must depend on personal contagion.

Mr. E. M. O'R. DICKEY (12.10).

The problem falls naturally into (1) the school and (2) adults. In the school, environment comes first. Children must have well-designed surroundings. Next in importance is the teacher, who must himself have learnt to appreciate and enjoy beautiful things, for otherwise he cannot teach his pupils to do so any more than a tone-deaf teacher can teach singing. The youngest children will lay a foundation for enjoyment of good colour and design by working freely from imagination. Those over eleven who cannot draw will learn to appreciate by making things. Girls can learn many crafts associated with dress and furnishing; for boys there are wood and metal crafts and those associated with book production. Children who have learnt to make things they can use will look in shop windows with new eyes. Boys and girls in the Sixth can take pleasure in theoretical discussions.

Then adults. To-day we are all encouraged to take an interest in design, good and bad, as never before, through the increase in the amount and improvement in the quality of advertising and through the cinematograph. Manufacturers of hats and dresses have to make a large variety of designs for the cheapest lines, whereas formerly one or two would have sufficed. The general public discriminates more than in the past. Specially organised exhibitions interest the average man more than permanent collections in galleries and museums, as witness the crowds at the well-advertised Italian and Dutch Exhibitions. The best way to tackle the adult population is by organising exhibitions of articles of daily use of good design, preferably at a price which the average man can afford.

DISCUSSION (12.30), led by Dr. CLOUDESLEY BRERETON (Literature); Mr. BASIL MAINE (Music); Mr. G. L. THORPE (Art).

Friday, September 6.

PRESIDENTIAL ADDRESS by Dr. A. W. PICKARD-CAMBRIDGE on *Education and freedom* (10.0). (See p. 189.)

DISCUSSION on *Discipline* (11.10).

Mr. J. H. BADLEY.

Our attitude towards discipline depends on

(*a*) Our view of human nature;
(*b*) Our social outlook.

(*a*) The traditional view: human nature radically bad, to be repressed. The modern view: it is radically good, to be allowed free growth. Both views partial truths: instincts neither good nor bad, but directed to higher or lower ends. Hence need of training, to distinguish and encourage higher ends. Can experience alone give this? Nature's methods too slow and too costly, so must be supplemented by discipline. But how much and of what kind depends on purpose in view.

(*b*) If to produce efficient servants of the State, the completer the discipline the better. If to develop individual responsibility, need of all freedom that is possible with what discipline is necessary. Two doctrines of advanced school considered: that repression is always harmful; that children should decide everything for themselves. Freedom needs a framework of discipline (examples in Montessori method and Dalton Plan). Discipline must change with growth—need of increasing trust and responsibility. Freer methods more difficult for the teacher, but alone allow of true education: i.e. fostering of self-activity guided by self-control.

Mr. T. F. COADE.

The function of education is to present life or mediate reality to the child, so that there shall be evoked in him a willingness not only to submit to discipline but to respond actively to it.

Discipline in a modern school may resemble that of a club rather than that of a dictatorship. This does not mean that such discipline is lax. It means that those who frame it aim at making discipline attractive and its hardness worth while, and aim too at giving all possible zest to effort. Discipline, to be of use, must be voluntarily accepted and co-operated with. The chief value of the 'habit-forming' discipline of early years is that it gives the child a sense of an orderly world, from which sense there should gradually proceed a perception that every sphere is governed by law. True discipline, leading to true freedom, consists in the understanding of, and conscious co-operation with, law. Therefore, not only must school discipline be founded on universal law, but the connection between such discipline and law must become by degrees understandable to the child. For if he can see purpose in and behind the discipline of school life, he will more willingly co-operate with it at school, and will achieve a sense of security in the general scheme of things outside school as well.

Miss Addison Phillips.

Freedom and discipline are not antithetic. Freedom is the goal of discipline.

The school, like the State, should be ' the framework within which man shall have room to lead the good life ; but since youth is growing as well as living within the framework, this must possess an organic adaptability enabling it to provide for increasing freedom as youth grows to maturity.'

In the pre-adolescent period, discipline is largely concerned with the right direction of instincts and the formation of habits.

For the adolescent, periods of solitude should alternate with periods of company, opportunities of self-development and self-expression be given in and through the life of the community ; above all there should be gradually increasing freedom from rules as the spirit of law develops.

Kant's saying ' When the " Thou shalt " of the law becomes the " I will " of the doer then a man is free,' sums up the whole position.

Education is of the whole man and moral discipline cannot be separated from that of the body and the mind.

' The only avenue towards wisdom is by freedom in the presence of knowledge, but the only avenue towards knowledge is by discipline in the acquisition of ordered facts ' (Whitehead).

Mr. Spencer Leeson.

This paper starts with the assumption—by no means universally accepted, but fundamental with the reader—that the primary and governing aim of education is to bring men to know and to love God and to do His will. To this end it is necessary to try to train the power of spiritual, intellectual and æsthetic apprehension and the will : it being understood that neither can so easily reach its perfect working without physical health. With the first this paper is not concerned, but with the will it is. Right action depends on the condition of the will, which—another fundamental assumption—is free. The purpose of discipline is to help train the will, by assisting boys and girls (i) to keep in their proper places those necessary elements in their nature which would, if uncontrolled, lead to lawlessness and slavery ; and (ii) to understand what are the conditions of healthy, corporate life in which alone the proper life for man can be lived. Discipline as an end in itself has no meaning ; nor at the other extreme have such expressions as ' the full development of personality.'

Discussion opened by Dr. W. W. Vaughan, M.V.O., Miss L. E. Higson (12.30).

Afternoon.

Visit to Gresham's School and Blickling Hall (2.0).

Monday, September 9.

Joint Discussion with Section J (Psychology) on *The place of psychology in the training and work of teachers* (Section L room) (10.0).

Prof. J. Drever (10.0).

The view taken of the nature and aim of school education, and of the teacher's function, will largely determine the place given to the study of psychology in the preparation of the teacher for his professional work. Not only so, but this will determine also the standpoint from which psychology is approached, and the range of the psychology deemed essential. But, whether a wide view is taken of education, as the whole process by which the behaviour, character and personality of a child are moulded by influences deliberately brought to bear upon him, so as to produce a certain type of civilised adult, or a narrow view of education, as a process of acquiring skills and certain kinds of knowledge regarded as necessary or desirable by the adult community—in either case, it will be admitted that the training of the teacher must include at least *some* study of psychology. The great educators of all times have almost invariably taken the wider view, and this has come to be the prevalent view among the educationists of to-day. The recognition, indeed, of teaching as a profession depends upon, and at the same time involves, this wider view. The acceptance of this view necessarily involves in turn the further position that psychology is the very foundation of that educational theory which underlies educational practice, with all that this implies.

Prof. H. R. Hamley (10.30).

An analysis of criticisms and suggestions made by students of education on courses in educational psychology and text-books available for study leads one to the conclusion that the time has come for a restatement of this subject for training colleges. While admitting the interest of the subject as presented, students maintain that much of it is useless to them in their work as practical teachers or in their understanding of children, normal or abnormal. The topics generally approved may be set forth as follows :

(1) The nature and needs of the school child ; individual differences ; sex differences ; stages and characteristics of normal growth ; adolescence ; general intelligence and its measurement ; temperament ; character.
(2) The learning process. The development of knowledge—memory, reasoning, imagination. Transfer of training. The psychology of school methods—the Project Method and the Dalton Plan. Backwardness, general and specific. Remedial treatment.
(3) The emotional life of the normal child. The importance of the social background. Abnormal emotional behaviour. Principles of mental hygiene.

Practical work : eliminate psychological experiments of the laboratory type and base the whole work on study of individual children and groups of children (including the administration of group tests of intelligence and attainment, and observations on children's interests, temperament and character).

Mr. A. W. Wolters (10.50).

The communication was based upon the opinions expressed by a number of graduate teachers of several years' experience regarding the value of psychology in their training. Consideration of the topics which should be included in a course for teachers in training.

Miss E. Doreen Davies (11.10).

How far, and in what ways, has the psychology I learnt at College helped me in my work of teaching since ?

My contribution to the discussion, as that of an assistant teacher in an elementary school, a product of the Training College of fifteen years ago, confines itself to an answer to this question.

(1) Difficulty of setting limits to the influence of a psychology course whose principles, in application, could be seen shaping a society. Theory and practice. Importance of the right attitude.

(2) Some particular problems of school in the light of the psychology learnt :

(*a*) The teaching of English.
(*b*) Corporate life ; discipline.
(*c*) Religious teaching.

(3) Psychology as an introduction to philosophy ; reality in the Central School.

Miss A. Lloyd Evans (11.30).

Training Colleges in the past.—Thirty-five years ago 'academic' and 'professional' work were kept separate. The 'master of method' was responsible for all work in the principles of teaching. The students' course was the same for all ; they learnt a set technique of teaching ; they were taught through precept rather than principle.

The stages of change.—(1) Sully's Teachers' Psychology ; (2) Child Study ; (3) 'Academic' psychology ; (4) The present stage in which students are taught through principle and practice rather than precept by psychologists who are also teachers and subject lecturers who have studied psychology as applied to the art of learning.

The opinion of students.—Students about to leave college expressed their views on the use of their study of psychology. In their relations with (*a*) themselves : they gain in self-confidence and the power of self-criticism ; (*b*) others : they gain in tolerance, sympathy, and power to live in a community ; (*c*) children : they gain in interest in, patience towards and understanding of normal children and in the power of dealing with difficult children.

The fundamental change.—There is a complete change of relationships. The centre of importance used to be the teacher ; now it is the child.

Mr. N. F. Sheppard (11.50).

As psychology is a young and rapidly developing science, and as general opinion about the aims of education is changing rapidly at present, this is a better time for reviewing present tendencies and the consequent requirements than for laying down a definite final policy. Changes in schools are increasing the opportunities for psychologists of the right type ; a plan for their work will be considered.

Probably one of the most important influences upon the young mind is imitation of the teacher, who should have a fully integrated personality. Any shortcoming may be exaggerated in the next generation, and thus faults are cumulative. During the period of training every teacher should be considered and if necessary be treated as a clinical case.

Teachers should be made to realise that pupils' difficulties can be treated and overcome, but here a little knowledge is dangerous. More particularly they require a specification of the ideal conditions for full and healthy mental development, and the permissible degree of variation from that ideal to suit practical conditions—a study of mental dietetics.

DISCUSSION (12.10), opened by Dr. C. W. KIMMINS and Miss WINNINGTON INGRAM.

AFTERNOON.

Visit to Norwich Schools (2.0).

Tuesday, September 10.

DISCUSSION on *Physical education* (10.0).

Col. R. B. CAMPBELL.—*Physical education in relation to University students and adolescents of that age* (10.0).

I. *Scope and principles of physical education.*
  (1) Knowledge of the body and its functions.
  (2) Constructive purpose of physical exercise.
  (3) The purpose and nature of bodily movements.

II. *The science of bodily movements.*
  (1) Progressive stages in bodily movements.
  (2) Movement and structure.
  (3) Movement and the mind.
  (4) Movement and the trend of evolution.
  (5) The development of mind, body and spirit.
  (6) Leadership.

III. *Teamwork in education.*
  (1) Natural forces in education.
  (2) Rhythm in education.
  (3) Work and leisure.
  (4) Co-operation between the gymnasium, class room, playground and countryside.
  (5) Physical education to be concrete and purposeful.

IV. *Assessment of physical ability.*
  (1) Fundamental importance of measurement.
  (2) What constitutes physical ability for the purposes of measurement.
  (3) Physical ability tests and their application in and outside education.

V. *Direction of physical education.*
  (1) The meaning of education.
  (2) Creative instincts.
  (3) Natural progression in education.
  (4) Continuity in education.
  (5) The ethics of fitness in national and racial life.

Mr. M. L. JACKS (10.20).

(1) Physical education not the same thing as physical training. The latter, long practised, not very intelligently, in many schools : the former, a new conception. Education hitherto associated exclusively with the mind : the new conception makes the body also an object of education ; not only to be exercised, kept in health, developed, but to be *educated*.

(2) Evidence of a physically uneducated people: typical city crowds: bodies never taught to breathe, to sit, to walk, to stand, or to move as they should: boys entering public schools with remediable but unremedied physical defects: comparison between public school boys and post office boys of seventeen: bad effects of unthought-out physical exercises—neglect, in these, of elementary educational principles.

(3) Physical education means the education of the whole φύσις or nature, i.e. the whole man. No division of education into watertight compartments—body, mind, character. Reciprocal interaction of these on one another.

(4) *Methods to be adopted:*

- (*a*) Raise status of subject, by creation in schools of recognised departments of physical education.
- (*b*) Appointment in every school of University graduate as Director of Physical Education.
- (*c*) The type of man wanted: personality, qualifications, training, experience. His duties. Relations with medical authorities and other members of the staff.

(5) Difficulties: (*a*) Financial; (*b*) Personal—lack of adequate training facilities in Great Britain.

Miss Helen Drummond (10.40).

Freedom and rhythm in modern school work.
Corrective work and posture training.
The place of physical education in the school curriculum.
The 'Keep Fit' movement.
Recent developments in physical education in other European countries and their influence on work in this country.

Mr. E. Major.—*Physical recreation in relation to unemployment* (11.0).

In this country it is now generally acknowledged that a well-organised scheme of physical training, designed to develop a fit, vigorous and healthy people, is essential to the well-being of the nation. Hitherto systematic physical training has been mainly restricted to children and young people in attendance at schools and educational institutions. A comprehensive national scheme of training must, however, also provide facilities and training for young people of both sexes who are not in attendance at schools or other educational institutions.

The provision of facilities and means for healthy physical recreation for unemployed adolescents, and unemployed men and women, is an essential and important part of a national scheme of physical training. Wisely directed physical recreation results in a healthy refreshment of mind and body and enables physical fitness, courage and hopefulness to be maintained, so that when an opportunity of work presents itself, the person concerned is ready physically and mentally to undertake it.

Physical recreation schemes for the unemployed must be carefully and thoughtfully planned. They must be comprehensive in character and include, wherever possible, not only physical exercises, but also games, swimming and camping.

Suitable indoor and outdoor facilities are essential and the ultimate success of any scheme of physical recreation depends largely upon the knowledge and personality of the leader.

Mr. S. F. Rous.—*Public sport and school games* (11.20).

The necessity for accurate instruction in sport of every type—careful organisation required for this purpose. The same is true of school games where haphazard methods do more harm than good—a typical scheme of physical education working successfully in a large day secondary school.

Dr. S. Lewis Walker (11.40).

Physical education for the older boy, i.e. 14 plus. Functions of muscles and joints. The action of flexors and extensors. Shortening of flexors and stretching of extensors due to occupation—consequent interference with freedom of movement of muscles and joints and the damage that arises from this in the growing boy.

Value of knowledge of these facts to keep up a boy's interest in physical development during the critical years 14 to 17.

Demonstration of co-ordination exercises suitable for boys of 14 plus.

Discussion (12.0).

Demonstration of films, with spoken commentary by Major Gem (12.10).

Physical education. Boys aged 10 (in an industrial area).

Physical education. Girls aged 11 (in an industrial area).

Physical education. Infants aged 4–7.

(Films supplied and demonstrated by Gaumont British Instructional Films Bureau, Wardour Street, W. 1.)

SECTION M.—AGRICULTURE.

Thursday, September 5.

Symposium on *State control of agriculture* (10.0).

Presidential Address by Dr. J. A. Venn on *The financial and economic results of state control in agriculture.* (See p. 203.)

Rt. Hon. Lord Hastings.—*A landowner's view of state control of agriculture* (11.0).

Dr. R. McG. Carslaw.—*Recent changes in the organisation of farms in the Eastern Counties* (11.20).

The purpose of this paper is to draw attention to the very marked adjustments to farm organisation which have recently been made in this arable area. Emphasis is laid on the economic rather than on the technical aspects of these adjustments, which may be grouped under two main headings, viz. (1) changes in types of production, and (2) changes in methods of production.

The stimulus to change in farm organisation arises from variations in price and cost levels. Recent fluctuations in these are traced, and their unequal distribution stressed. Examination of the official agricultural statistics shows that livestock numbers, in six eastern counties, increased during 1932 and 1933, at the rate of 7 to 8 per cent. per annum, and that although the total area under crops and grass declined slightly, there was an increase at the rate of about 6 per cent. per annum in the area under cash crops. The question as to how the rising numbers of livestock were maintained, in view of the falling area of fodder crops, is asked and answered.

The gross production of crops rose, in the two years following 1931, partly as a result of favourable climatic conditions, and partly as a result of increased applications of fertilisers by farmers. Purchases of feeding stuffs were also largely augmented, but it appears that there has also been material improvement in the efficiency of the farmers' livestock rationing methods—at least the livestock output per unit of fodder has risen. Further, both the volume and value of the gross output per unit of labour show evidence of increase. The combined effect of all the adjustments which have been made has been to raise net farm profits above the low level at which they stood in 1931, in spite of the decline in the official general price index which was characteristic of the period.

Mr. A. W. Menzies Kitchin.—*The economics of land settlement* (11.40).

(1) Under existing economic conditions, land settlement on a large scale offers little hope of creating new employment; it is likely to lead to displacement of labour elsewhere, and/or to a general reduction in the standard of living of those already engaged in agriculture.

(2) It is a fallacy to expect a large net increase in agricultural employment by stimulating consumption in a certain direction, as, unless spending power increases at the same time, this increased consumption will be at the expense of some other commodity.

(3) While restriction of certain imports, e.g. bacon, eggs and vegetables, may enable holdings of the 3- to 5-acre type to carry on successfully for a time, they will eventually come into direct competition with more economic units of production, against which they will be unable to compete, as a result of their unstable character.

(4) If Land Settlement, for reasons other than economic, is considered desirable in this country, the mixed family farm of 30 to 50 acres, on account of a flexibility of organisation which enables it to adapt itself to sudden price changes, and of the capacity of the family to live off the holding during a period of low prices, is the most suitable unit of settlement.

Discussion on above papers (12.0).

Friday, September 6.

Discussion on *Recent changes in arable farming* (10.0).

Mr. C. T. Joice.—*Vegetable growing on a large scale.*

Mr. W. B. Adam.—*Some problems in the growth of vegetables for canning* (10.30).

Of the problems directly connected with the growth of vegetables for canning, the selection of suitable varieties and the bio-chemical changes occurring during ripening, have been studied closely during the past few years at the Campden Research Station.

Peas are canned both in the fresh state and as resoaked dried peas; in the former case—for a number of reasons associated with cropping power, colour, size of peas and pods, uniformity of ripening, etc., the varieties *Lincoln*, *Thomas Laxton*, *Gregory's Surprise*, *Canners' Perfection*, *Charles the First* and *Alaska* have been found to be suitable for canning.

The changes in the carbohydrates during ripening have been recorded on all the varieties of peas mentioned, and in every case an abrupt alteration in the composition of each size of pea was noted at a date three or four days after that on which the peas would normally be canned. The causes of toughness in dried peas are being investigated, the effect of manurial treatment receiving special attention. In trials on soil types, varying from a light sandy loam to a heavy clay, the colour of beetroots and carrots have not been found to vary appreciably. Problems connected with other vegetables have mainly been concerned with varietal differences.

Discussion on the two preceding papers (10.50).

Mr. R. T. Proctor.—*The utilisation of power in general farming* (11.10).

(1) A comparison of the pre-war and the current costs of producing cereals, potatoes and other crops by (*a*) pre-war methods and implements; (*b*) similar current methods with improved implements and higher labour costs; (*c*) the same cropping with the fullest possible use of power methods.

(2) The uses of power methods in the cultivation of (*a*) sugar beet, and (*b*) vegetables which are now grown under regular rotation.

(3) Machinery used on modern farms for fruit-growing and for crops for the rapidly developing canning industry.

(4) Applications of power in connection with livestock; the use of mills, mixers, etc., for preparing foodstuffs on the farm for cattle, pigs and poultry.

(5) Power methods for new crops now produced on a commercial scale, and possible extensions.

Mr. J. C. Wallace.—*Recent progress in potato cultivation in the Eastern Counties* (11.40).

Deeper cultivation has become general since the war, and subsoiling for potatoes is now common practice. Apart from ploughing and subsoiling, there has not been any great development in the use of the tractor.

The introduction of sugar beet into the rotation has resulted chiefly in a reduction of clover acreage. Many farmers, however, still have one-sixth of their acreage under clover, the potato crop, therefore, alternatively following clover and a straw crop. Sugar beet tops are ploughed under as green manure, but beet is not regarded as the best preceding crop for the potato.

Sprouting of seed potatoes was becoming common before the war. Much of it was done in barns, but now almost every farm and small holding has a properly constructed glasshouse for the purpose. The use of immature seed is becoming common. Planting tends to become much earlier, and is carried out more expeditiously. The date of lifting early varieties has advanced ever since 1920.

The most striking progress has been made in the type of artificial compound used for both early and maincrop varieties. In 1920 phosphate was regarded as of great importance and the usual mixture contained well over 9 per cent. of soluble phosphoric acid. This has now been reduced to 5·5 per cent. or just over, and the nitrogen and the potash, especially the latter, increased. Yields have considerably increased, although the average yield for the area has been restricted owing to the spread of eelworm and virus diseases.

Wet spraying against potato blight was practised to some extent up to 1914. Dry spraying or dusting was introduced in 1910. There has been great improvement in machinery for dusting, and to-day the method is generally practised.

The use of potato diggers or spinners has not increased. The majority of farmers still prefer to use the potato plough for maincrop varieties, as they are of opinion that much less damage is done by the plough.

DISCUSSION on the two preceding papers (12.0).

Monday, September 9.

DISCUSSION on *Sugar beet problems* (10.0).

Mr. F. RAYNS.—*The beet crop in Norfolk farming.*

The sugar beet crop in Norfolk increased from 3,017 acres in 1920 to 99,834 acres in 1933, when the combined mangold, swede and turnip acreage was less than the sugar beet acreage for the first time in the history of Norfolk farming.

In an arable county like Norfolk, dependent upon livestock for the maintenance of arable conditions, the development of the beet crop has revolutionised the farmer's methods. The winter feeding of livestock is now largely obtained from beet by-products—the beet crowns and leaves, and the beet pulp returned from the factory after the sugar has been extracted.

Feeding trials at the Norfolk Agricultural Station have determined the comparative value of beet tops, dry and wet pulp, and mangolds and swedes for stock feeding purposes, and the extent to which the stock carrying capacity of the farms is influenced by the replacement of the older stock-feeding roots by the beet crop and its by-products. Similarly, the manurial value of the beet tops and of various methods of their disposal have been determined by field trials.

The cultivation of sugar beet in Norfolk has had a profound influence on the labour employed and number of men on County Council relief work varies with the seasonal activities of the local beet industry.

During the last ten years, when Norfolk farming has experienced an unprecedented depression, the beet crop has helped appreciably to improve the financial position of the farmers and has been chiefly responsible for maintaining a high level of arable cultivation and labour employment in the county.

Dr. E. M. CROWTHER.—*The manuring of sugar beet* (10.30).

The sugar beet crop absorbs relatively large quantities of nutrients, and it is commonly stated that it needs heavy manuring. Although the crop is particularly sensitive to soil acidity and poor physical conditions, there is insufficient experimental evidence to justify the liberal use of artificial fertilisers on the better class of soils. A summary of more than sixty recent replicated experiments on commercial farms shows that profitable responses to the three main fertilisers were obtained in only about one-half of the experiments. Unit weights of sulphate of ammonia, superphosphate and muriate of potash gave on the average 8, 1, 2 units respectively of sugar beet roots, as compared with 13, 3, 8 units respectively of potatoes in similar experiments. Sulphate of ammonia almost always increased the tops and generally increased the roots, but it also caused small reductions in the percentage of sugar, and in the purity of the juice. Superphosphate had little effect on either yield or composition. Muriate of potash generally increased the sugar percentage. Salt was often beneficial. It appears probable that the sugar beet obtains nutrients as well as water from the deeper soil horizons, and at present there is no convenient method of enriching these except by continued high farming, deep cultivation and early application of certain fertilisers.

Mr. H. H. Stirrup.—*The diseases of sugar beet* (10.50).

Black Leg is the most serious disease affecting young seedlings of the sugar beet. When either climatic or soil conditions are unfavourable for good seedling growth, the plants become weakened and rendered more susceptible to attack by the fungi associated with this disease. The question of whether seed should be disinfected to prevent Black Leg or not is an economic one. Strong winds occurring when the seedlings are just showing above ground can cause severe losses, particularly on light sandy soils.

'Strangle disease' may cause a severe loss in plant population after 'singling.' The exact cause of this trouble is not yet known.

Heart Rot is most prevalent on alkaline soils. Recent work has shown that the primary cause is the absence of boron from the soil in a form in which it can be utilised by the plant.

There are three distinct virus diseases of the sugar beet, viz. Mosaic, Virus Yellows, and Crinkle. Crinkle is confined to certain parts of Germany and has not yet appeared in England. Other forms of 'Yellows,' not caused by viruses, also occur.

Downy Mildew is very sporadic in appearance because its occurrence and spread are dependent on certain definite climatic conditions. Leaf Spot (*Cercospora beticola*) causes severe losses in certain countries. The special conditions that favour it are high temperature and high humidity of the surrounding atmosphere. Violet Root Rot is caused by a soil inhabiting fungus, but attacks are usually strictly localised in certain fields.

Mr. T. G. Fowler.—*The production of the sugar beet crop from the factory point of view* (11.10).

Before the introduction of the sugar beet crop into this country the majority of the farmers were accustomed to selling their products under very elastic terms and conditions. The factories have gradually educated their growers to accept and welcome business-like methods for the sale of their sugar beet under a standard form of contract.

Although a fair crop of sugar beet can be produced by adopting cultivations and manures similar to those which the farmer has been accustomed to apply to his ordinary roots, a maximum crop, equal to continental standards, requires more intensive and careful attention to detail. In order to educate the farmer to produce a maximum crop it has been necessary for the factories to provide a large and well-trained agricultural staff.

Sugar beet is, comparatively, an expensive crop to grow, so the factories assist the grower by cash advances before the roots are delivered. The delivery and reception of a very large tonnage of roots from a great number of growers over a very short period requires an elaborate system of controlled delivery in order to secure level and regular supplies throughout the manufacturing season.

Dr. W. L. Davies.—*Beet taint in milk* (11.30).

Home-produced beet molasses contain about 5·4 per cent., molassed beet pulp about 1·8 per cent., and the dry matter of beet tops about 1·5 per cent. of betaine. When fed to cows, these foods sometimes impart a beety or fishy taint to milk.

When betaine is metabolised in the ruminant, from 20 to 40 per cent. of the nitrogen is excreted as *trimethylamine oxide* ; a well-defined peak of excretion is shown at 3 hours and onwards after feeding, the time taken to reach the peak depending on the amount of betaine fed. A high concentration of the oxide therefore exists in the blood before this peak is reached and the possibility of infiltration of the oxide into milk secreted in this period is greatest at this time. Elimination of the oxide from the blood is accompanied by its elimination from the milk back into the blood. Milk fat interacts with the labile oxygen of the oxide, forming either an addition compound at the double bond of the oleic acid radicle or a peroxide and free trimethylamine, thus conferring a fishy flavour to the milk.

Prevention of the taint rests in minimising the amount of trimethylamine oxide entering the milk by feeding reasonable amounts of the by-products as far off from the subsequent milking as possible and not feeding to cows which in secreting abnormal milk allow larger quantities of soluble blood constituents to enter the milk.

Discussion on above papers (11.50).

Afternoon.

Joint Discussion with Section K (Botany) and Department K* (Forestry) on *The utilisation of light land, with special reference to Breckland* (Section K room) (2.0). See under Section K, p. 450.

Tuesday, September 10.

Dr. J. Hammond, F.R.S.—*The quality problem in relation to meat production* (10.0).

The definition of quality in meat is that which the consumer likes best. This has been changing in three main directions lately, towards : (1) smaller joints, (2) leaner meat, and (3) more tender meat. The main factors affecting quality in the different classes of meat are discussed in detail. Veal is the only meat in which the value per stone increases as the carcase weight increases. In beef, tenderness is the main requirement : this can be obtained, from young beef, by ' finishing ' the animal well, and by proper hanging before sale. For the three reasons mentioned above, the demand for lamb is increasing ; an animal with short bones and thick muscles, giving a blocky joint at an early age, is required. The general proportions of the carcase needed for both bacon and pork are the same, but the weight at which the pig should attain these proportions differs in each case. The demand is for a carcase with thick muscular development, giving a deep ' eye ' and thick streak with a low proportion of fat along the back. If the British farmer is to obtain a larger share of the market for meat in this country, he should be prepared to supply a produce of the highest quality, and be paid for it on this basis, for otherwise the large cities will not support him in this undertaking. If subsidies are to be used to help the British producer of meat, they should be given on a quality basis. The logical course of procedure would be to divide carcases into weight classes and then to subdivide these into quality grades.

Dr. C. Crowther.—*The protein requirements of the pig* (10.30).

The amount of protein that will satisfy the protein needs of an animal will vary according to the ' biological value ' of the food protein, and other defects of the ration, such as defective vitamin and mineral supply.

It will also increase if the supply of fat and carbohydrate is inadequate to cover the energy needs of the animal.

It will also vary according to the size and condition of fatness of the animal, its activity, and its rate of growth on full feed.

The protein requirement of the non-pregnant sow for maintenance is given as 60 gms. per 100 kg. live weight, or 120 gms. (4 oz.) for a sow weighing 440 lbs. This is covered by 4 lbs. daily of a ration of equal parts of sharps and ground cereals.

For the pregnant sow the requirement rises from 230 gms. daily for the first 5 or 6 weeks to 260 gms. for the middle period, and 320 gms. for the last 5 or 6 weeks. These amounts are covered by $4\frac{1}{4}$ lbs., $4\frac{3}{4}$ lbs., and 6 lbs. respectively of the cereal ration plus 5 per cent. of protein concentrate, or about 2–3 lbs. less than these amounts where the sow is on good grass.

The average needs of the lactating sow for the first 4 weeks are assessed at 850 gms. of digestible protein per day, or 12–13 lbs. of food containing 15 per cent. of digestible protein.

The experimental evidence as to the protein requirements of the growing pig is reviewed and a scale of requirements proposed ranging from 150 gms. digestible protein per day for a 44-lb. pig to 240–250 gms. for the 200-lb. pig.

Where growth rate is not high a lower standard of protein supply will suffice. Harper Adams experiments are quoted in support. In these no improvement in either rate of growth or leanness of carcass was obtained by raising the protein content of the ration above a level which for the lower stages of live weight is appreciably lower than the Scandinavian standards.

Capt. J. Golding and Dr. S. K. Kon.—*Vitamin A in relation to pig feeding* (11.0).

In two pig feeding experiments, started in May 1933, at the National Institute for Research in Dairying, the control animals received a practical ration consisting of barley meal 50 parts, middlings 35 parts, soya bean meal 8 parts, meat meal 5 parts, ground limestone $1\frac{3}{4}$ parts, and salt $\frac{1}{4}$ part ; the experimental animals receiving dried milk addenda. Several pigs died and others exhibited marked symptoms of ill-health, later found to be associated with a lack of vitamin A in the diet. All these pigs received the control diet only.

In a third experiment on 36 pigs, the symptoms were further investigated and are described and illustrated by photographs.

Preventive and curative experiments, using a vitamin A concentrate, definitely proved the trouble to be due to a deficiency of vitamin A in the diet.

Independent experiments at Cambridge and Rothamsted indicated that a deficiency of vitamin A in the food of sty-fed pigs may frequently occur in practical pig feeding. Since the conclusion of our experiments, examinations have been made of the reserves of vitamin A in the livers of pigs from our experimental animals. These have shown that vitamin A reserves may persist for some weeks in the livers after the source of vitamin A in the diet had been discontinued. Experiments on the practical value of a single dose of vitamin A, after weaning, are being carried out.

Dr. H. H. Green.—*Pig anæmia* (11.30).

The Agricultural Research Council has initiated a survey of obscure disorders of young pigs and provisional information indicates that pig anæmia is one of the commonest of these. The cause and occurrence of the disorder are considered in relation to the method of pig-rearing and preventive measures are discussed.

CONFERENCE OF DELEGATES OF CORRESPONDING SOCIETIES

THE Conference was held in the Stuart Hall and the Girls' Old High School, Norwich, on September 6 and 11 respectively, under the Presidency of Prof. P. G. H. Boswell, F.R.S., 47 delegates attending, representing 52 societies, in addition to a large audience.

Friday, September 6.

ADDRESS ON

THE PRESERVATION OF SITES OF SCIENTIFIC INTEREST IN TOWN AND COUNTRY PLANNING

BY PROF. P. G. H. BOSWELL, F.R.S.,
President of the Conference.

IT is now twenty-eight years since Sir Halford Mackinder, in his Presidential Address to this Annual Conference of Delegates, directed attention to a new and broad conception in geography—the regional aspect. The new point of view, as a friend of mine remarked at the time, invited us to replace the old line-and-dot geography of our childhood by consideration of vast spaces. But, while a close attention to lines and dots (and for that matter, lines and beacons) is still a necessity of modern life—indeed has been revived by the rapid development of the internal combustion engine—we cannot but rejoice at the impetus given since 1907 to regional studies. I may be forgiven for exhibiting a particular and personal interest in these historical reflections, for the British Association Meeting at Leicester in 1907 was the first that I attended; moreover, I listened to Sir Halford Mackinder as a delegate from an East Anglian corresponding society.

The regional aspects of geography are intimately connected with the subject of this address, which is the consideration of the part the Association can play in the safeguarding of sites and objects of scientific interest which may be threatened in the course of town and country planning, for without the systematic recording of areas and objects of scientific interest, the active prosecution of which Sir Halford Mackinder urged to the Conference of Delegates in 1907, it will not be possible to take advantage of the opportunities now afforded for their appropriate preservation.

Another predecessor of mine in this Chair devoted his address to the same general question. In 1924 Prof. J. L. Myres discussed in his usual scholarly fashion the problem of 'The Conservation of Sites of Scientific Interest.' He then indicated four categories of objects which were worthy of preservation: ancient buildings and other monuments raised by the hand of man; sites of historic interest on account of some human achievement; districts of natural beauty, preserved for public enjoyment; and places of scientific interest, necessarily also often picturesque, such as haunts of wild life, or instructive geological sections. Acting upon resolutions from the Conference of Delegates and several of the Sections, which dealt with the need for more adequate protection of sites of scientific and historical interest, the Council had in 1923 summoned a Conference at which H.M. Office of Works and many learned societies and institutions were represented. In the report of the Council for 1923–24 it is remarked that 'the discussion in general revealed cordial agreement with the suggestion contained in the letter summoning the Conference that the sole effective remedy appears to be that learned societies not immediately concerned in a particular problem of conservation should take concerted steps to promote legislation wider in scope and more strictly worded than the Ancient Monuments Act now in force for the protection of such sites.' In the twelve years that have elapsed there has undoubtedly been real progress, although much remains to be done. Sites and objects belonging to Prof. Myres' first category are protected under the Ancient Monuments Act and watched over by H.M. Office of Works. Those of the third category, and in part of the second, are accumulating in public hands through the admirable activities of the National Trust, whose fortieth anniversary was celebrated this year ; and public attention has been drawn to other districts worthy of preservation by the Report of the Committee on National Parks, and the evidence presented at its sittings, and by the Councils for the Preservation of Rural England, Wales and Scotland. But what of the fourth category ? It is a pleasure to take note of one of the most enlightened enactments placed upon the Statute Book for a long time, in the form of the Town and Country Planning Act of 1932, wherein it is laid down that a local authority or joint committee must obtain the approval of the Ministry of Health before it can implement any resolution relating to a scheme of planning. Among the objects of such a scheme, as cited in Section 1 of the Act, are 'preserving existing buildings or other objects of architectural, historic and artistic interest, and places of natural interest or beauty, and generally of protecting existing amenities whether in urban or rural portions of the area.'

Formerly the success of efforts directed to the preservation of sites and objects of scientific interest was due to the enthusiasm of advocates, and the broadmindedness and public spirit of landowners and benefactors. While this good work will, it is hoped, still continue, much more power is now in the hands of the people. But, as ever, knowledge is a prerequisite of useful action. And the question before us is—how can the British Association, and in particular the Corresponding Societies, inform the people and assist them to safeguard their natural heritage ?

If we are to judge from the frequency of references to this and to cognate subjects in the columns of the daily press, there can be no doubt as to the public awareness of the desirability and necessity for preserving sites and objects of scientific interest and natural beauty. The Ministry of Health has given opportunity to the Association to advise as to when action ought to be taken—that is, to conserve, concentrate and direct energy which might otherwise be dissipated in isolated action or unprofitable controversy. The areas in which planning schemes are proposed are notified to the British Association, a body admittedly well fitted to advise the Ministry, by its aims and constitution, by its liaison with the Corresponding Societies, and by the call it can make upon scientific experts within and without its ranks.

Obviously, before the Association can act effectively, the requisite information regarding the existence of objects and sites worthy of preservation must be available. At the present time only a small amount of information has been collected and collated, but it is necessary to take account of all sites and objects throughout the kingdom. So far as botany and zoology are concerned, no systematic attempt to compile a list appears to have been made, but in the case of geology an inquiry was instituted some years ago by the Geological Society among local geologists and learned societies, with the result that a valuable though incomplete list was drawn up. In order to make the list as complete as possible, the Association is in a position to call to its assistance (*a*) its Corresponding Societies and their delegates; (*b*) the specialist learned societies; (*c*) officials of local museums and libraries; and (*d*) teachers in universities, colleges, and in public, grammar, secondary and technical schools. The information likely to be furnished by local societies must be supplemented by appeal to other institutions, for a glance at the map showing the location of our Corresponding Societies reveals the fact that there are numerous and extensive areas not covered by them. The delegates here present are invited to urge their Societies to begin (if they have not already begun) the compilation of a list of sites and objects of exceptional botanical, zoological or geological character within their area, and to communicate their results at frequent intervals to the central office of the Association. The reference list which will thus be compiled will be available for consultation as each scheme of planning is notified; and where there is doubt as to the best policy to pursue, the advice of experts on the panel already drawn up for the purpose by the Council can be sought.

It is desirable here to refer to two aspects of preservation which are in some measure conflicting, as was very clearly shown in the Report of the National Park Committee of 1931. Already some beautiful areas—we could wish that there were more—have been preserved for the full access of the public. Already, also, certain areas are under protection as nature reserves—and a nature reserve, whether for flora or for fauna, implies the prohibition, or at least the close control, of public access. Now, with the provision of nature reserves as such the Town and Country Planning Act is not concerned, and it is not advice as to nature reserves that is invited from the Association by the Ministry in connection with that Act. It is true that the communication on the question of planning which the Association addressed to the Societies last year has brought some answers relating to potential reserves; and the possibility that planning of an area in such manner that it might become a nature reserve would naturally weigh strongly with any scientific body. But I am not directly concerned with nature reserves at this moment; they offer ground for discussion, as, for instance, between the relative value of either a large number of small reserves or a small number of large ones; I am not proposing to argue that question now.

Reverting therefore to our specific consideration, we have to ask how far we ought to attempt to put forward our requests for preservation on scientific grounds? There cannot be any large number of cases in which protection could be demanded on scientific grounds and no other. But scientific interest in this connection is rarely dissociated from some measure of natural beauty, and the cases in which scientific arguments might be used to support æsthetic and other arguments must be numerous—the question is, how numerous?

To illustrate this question, I will take an area in which the British Association happens to be deeply interested—that surrounding Downe in Kent, where, as you know, the Association, thanks to the generosity of Sir Buckston Browne, owns and maintains Darwin's House as a national memorial. Here is a district still purely countrified, within 16 miles of London Bridge, and on the very edge of suburban development in its most rampant form. In justice to the authorities of the urban district to which rural Downe belongs, it must be acknowledged that they are doing their best within their powers to guide that development away from the grosser excesses. Within this district, and as yet unspoiled, are certain features of scientific interest. There are two very beautiful examples of the dry valleys characteristic of the North Downs—that of Cudham, and that in which the Downe Golf Course is situated. Also, some fine areas of woodland, characteristic features where a capping of clay-with-flints rests on chalk, are still existent ; and there are examples of enlightened tree planting, as notably on the estate of the late Lord Avebury (High Elms), whose name, next to Darwin's, will always be held in reverence by us in memory of the close bonds which science forged between those two great men. We have recently been favoured with a full account (which is available for perusal by any who are interested) of the trees on the estate, and are thus able to appreciate the care and forethought with which the area was planted. We can see how exotic species, gathered from many lands, may grow in perfect harmony with their indigenous neighbours—giant sequoias and Himalayan cedars forming a picturesque contrast to the beeches characteristic of this chalk area and the magnificent elms after which the estate has been named

When the Town and Country Planning Act is applied in detail in this area—as soon it must be—shall we be justified in bringing forward these arguments in the name of science if (of course, only if) the planning proposed should threaten ultimately to obscure these scientific interests ? Or should we be suspect of carrying scientific interest too far ? Should we lay ourselves open to the retort that such argument cannot be allowed to prescribe that a valley shall not in future carry a road and a few hundreds of houses, that a few more trees shall not be cut down ? Such an answer might very well be justified on administrative grounds alone, and then if any such features are to be preserved, it becomes a matter for individual effort—the town-planning authority alone, or the landowner alone, cannot reasonably be expected to say that a valley or a few trees ought to be protected simply because they are good examples of their kind. But if it were a choice between planning such a valley or woodland tract as a good residential area or as an industrial district, then I see no reason why we should not endeavour to make the scientific interest known.

This, however, would necessitate a highly detailed survey of the whole country, for if the little area of Downe in Kent contains such features of scientific interest as I have indicated, then any other little area in England and Wales may, and most areas will, also contain some such features. I dare not demand that science should undertake so huge a task ; on the other hand, I would urge all who appreciate the idea of using scientific considerations as adjuncts to æsthetic arguments for the preservation of the countryside, to keep a constant watch on the work of planning, and to make known to the local scientific society and the British Association any areas or sites which are the subject of their watchfulness and ought to be of ours.

In further illustration, I will refer briefly to a few of the many sites of scientific interest in the area in which we are meeting. Among the numerous claims to distinction possessed by East Anglia are a number of scenic types not exemplified elsewhere in Britain. I need only call to mind the shingle-spits of Blakeney and Orford, the heaths immortalised by George Borrow, the world-famous Cromer Moraine, the historically-rich Breckland and the popular Norfolk Broads. But the British Correlating Committee for the Protection of Nature submitted, in evidence before the National Park Committee in 1929, a more comprehensive list of areas where nature reserves are most required. In addition to some of those I have mentioned as characterised by their own peculiar scenic qualities, the Correlating

Committee included the following localities—chiefly on account of the necessity for preservation of birds, insects and plant life—Royston Heath, Cavenham and Tuddenham Heaths, Mildenhall; Bradfield St. Clare, Monk Park Wood; Blythburgh, Foxburrow Wood and part of the surrounding heath and fen; Martlesham Common; part of the erstwhile estuary of the river Waveney; and Horsey Mere, Yarmouth.

In considering such reserves, however, we may be contemplating park-like areas (excluded from this address) rather than sites and objects of scientific interest. But that is only a question of scale. We can, for example, urge that a small area at least of Breckland shall be free from afforestation (and I understand that there is a likelihood that Cavenham Heath will be saved for science), to preserve its peculiar ecology, and such historical features as infields and outfields, its geological character, and archæological interest. On archæological grounds I would make a strong plea for the preservation of the site known as High Lodge, famous for the discovery there of an advanced Clactonian industry of early man. Not far from Mildenhall also, the 'Drove Road' runs through part of southern Norfolk to join the well-known Peddar's Way. The 'road' is an ancient trackway, in parts grassy, dating from the Bronze Age or even earlier times. Part of it could with advantage be preserved.

It would be a simple matter to prepare a list of sites (as distinct from large areas) in East Anglia which should be preserved on account of their geological and archæological interest, for the district has long been a Mecca for students of Pliocene and Pleistocene geology and the records of prehistoric man. A real danger is imminent here that material will be forever lost to science once the builder gets to work. From many examples, I choose only a few as representative. The small outlier of the Oakley horizon of the Waltonian zone of the Red Crag near Manningtree is probably only a few hundred acres in extent. Yet from this locality the late F. W. Harmer of Norwich collected more than 600 species of mollusca, including many rare northern forms which, migrating into the area in Pliocene times, are regarded as the heralds of the oncoming Great Ice Age. This small outcrop of crag should be kept for future generations to study. Again, exposures of shelly Norwich Crag are now very uncommon. In the whole of the area, 800 square miles in extent, where the Norwich Crag is believed to be present, I know of only two localities, those at Bramerton and Thorpe, where characteristic fossils are abundant. The latter has yielded in recent years the richer fauna, but the sections are now obscure, and the pit is being filled in with rubbish. Both these sites should be carefully preserved. A further Pliocene section which should undoubtedly be preserved is the classical exposure at Sutton, near Woodbridge, where Prestwich described a reef of Coralline Crag with Red Crag banked against it, and a *Mytilus* bed in place. Still another classical geological section is that of the type-locality of fossiliferous Chillesford Crag, at the Chillesford Church pit—the only example of the deposit now known. For some years the exposure has steadily become more obscure, but there is still time to save the site.

So long ago as 1797 the first British palæolithic implements were recorded in Britain by John Frere from Hoxne, near the county boundary of Suffolk and Norfolk. Later investigations, in part by Research Committees of the British Association, have demonstrated the great geological and archæological interest of the succession of ancient lake-deposits and early human industries at this famous locality, with the result that it has proved to be unique in Britain on account of the detailed evidence that it affords of interglacial climatic fluctuations. The lake-like area is of limited extent, and its uppermost deposits are being slowly but continuously removed for brick-making. If ever there was a site in Britain which called for preservation on geological and archæological grounds as a national scientific monument, it is this area at Hoxne.

A similar plea can be made for the preservation of the remarkable tributary valley to the Gipping valley-system, north-west of Ipswich, where there occurs the brickfield of Messrs. Bolton & Co., Ltd. The site has become famous from the labours of Mr. Reid Moir, who here made the original discoveries of sub-Crag rostro-carinate implements and flakes in 1909–10. In the years that have followed, the succession of glacial and post-glacial deposits has yielded a series of human industries unequalled at any other site in Britain. The whole area comprises only about 100 acres. Apart from its archæological importance, it displays features of exceptional geological interest, of which especial mention should be made of the evidence of glacial tectonics described by Dr. George Slater.

The Derby Road (or Foxhall Road) brickfield, east of Ipswich, formerly yielded evidence of another interglacial lake-like area, similar to that at Hoxne. From this locality Miss N. F. Layard, Mr. Reginald Smith, Mr. Reid Moir, and others obtained remarkable collections of Acheulian and other implements. In this case the site may be lost to science, for it has now been in part built over. The fate of this site should be a warning to us and should prompt us to act now as trustees for the future. For our duty as trustees lies clear before us if only we adopt the view that, by acting now to safeguard sites of scientific interest, we are in effect taking steps to preserve some of the very title-deeds of our intellectual possessions.

Dr. L. Dudley Stamp.—*The Land Utilisation Survey of Britain.*

The main object of the Land Utilisation Survey of Britain is to record the present use of every acre of England, Wales and Scotland. The record has been made in the years 1931–35 on the Ordnance Survey maps on the scale of six inches to one mile. Each quarter sheet covers normally an area of six square miles and the permanent collection comprises nearly 20,000 of these sheets. The field work has been done entirely by volunteers, drawn from universities, colleges, schools and local societies. All these field sheets are being studied and edited, and the results shown on a series of maps on the uniform scale of one inch to one mile. Wherever there is local support these maps are being published, and present a clear picture of local conditions, land use being shown in six colours. Forest and woodland are in dark green ; permanent pasture in light green ; arable land in brown ; heathland, moorland and rough pasture in yellow ; gardens, allotments, nurseries and orchards in purple ; land agriculturally unproductive in red. Twenty sheets, each covering about 500 square miles, are now on sale.

The record provides a standard of comparison with the past and a basis of planning for the future. Comparison with the past has been carried out for selected areas in southern England and suggests that the best use of much of the land of Britain has already been proved by long experience over hundreds of years of settlement. Thus land which was arable in the Middle Ages was arable a hundred years ago, and is still cultivated to-day. Similarly the poorest land has always been in woodland or heath. The greatest changes—from arable to grass—have taken place on land of intermediate quality. This suggests that, in planning the land for the future, not only must any plans start from the present position as shown by the Land Utilisation maps, but that any radical change from the present use must be carefully justified scientifically. This is work which must be watched by local scientific societies throughout the country.

Mr. J. L. Holland.—*The Land Utilisation Survey of Northamptonshire.*

This was the first survey of an area as large as a county to be carried out in Great Britain through the agency of the schools. It was made in 1926 to 1928, and the map was published by the Ordnance Survey Department in 1929. It led directly to the National Survey described by Dr. Stamp and its methods were similar. The children worked on tracings taken by themselves from the 6-in. Ordnance maps. The work was done on the ground, the children taking their 'observer tracings' out into the fields and woods, verifying them and entering the land utilisation observed field by field. The completed map is a valuable contribution to knowledge, but the underlying motive was purely educational. It was a practical study of one aspect of the local geography. The parish was taken as the unit area of study, and as there are some 305 parishes in Northamptonshire, it was a considerable task to keep the army of observers and teacher overseers moving in some kind of step. The work was entirely voluntary, no compulsion being put upon schools or teachers. The categories used were those already enumerated by Dr. Stamp, except that gardens and allotments were not separated from tilled land. There are, therefore, none of the instructive purple patches so conspicuous in the National Survey maps on the Northamptonshire map. The controller of the survey was Dr. E. E. Field; he was entirely responsible for the scientific side of the work. He also undertook the drudgery of reproducing the schools' maps in a form suitable for handling by the Ordnance Survey Department. For this purpose the distributions recorded on the 6-in. tracings were transferred to bromide prints which the Survey Department prepared specially by photographing the 6-in. map down to a 1-in. scale.

The children derived a good deal of pleasure from the enterprise; to them it was not a school task at all. They learned the lesson of co-operation on a scale which is not possible in the team work of a single school. They did their part in trust that other schools and children whom they did not know would do theirs. They got a firm hold on the geography of their several localities. And, best of all from the geographer's point of view, they were able at the finish to read the map, to pass with confidence from the facts to the symbols. The map is an essential instrument of geographical study; the power to understand it is not easily acquired. Many educated people never do acquire it. Learned practically as these children learned it, it is never likely to be entirely lost.

Dr. Sydney H. Long.—*The Bird Sanctuaries in Norfolk.* (Illustrated with cinematograph films of Norfolk nesting birds by Lord William Percy.)

It was in 1888—forty-seven years ago—that the first Wild Birds' Protection Society, the Breydon Society, was formed in Norfolk. This date precedes by one year the foundation of the Royal Society for the Protection of Birds, so that Norfolk would seem to have been the pioneer county for employing bird watchers. At about the same time Charles Hamond, with the co-operation of Col. H. W. Feilden, formed the Wells Wild Birds' Protection Society; and two years later a similar society came into existence for the protection of the nesting birds on Blakeney Point, with Mr. Q. E. Gurney as hon. secretary; and in or about 1905 the late Col. George Cresswell started a fourth society for protecting the ternery at Wolferton. In 1921 these various societies were amalgamated, their funds pooled and their administration taken over by a committee of Norfolk naturalists called 'The Norfolk Wild Birds' Protection Committee,' which is now a committee of The Norfolk Naturalists Trust.

Breydon Water is a tidal estuary, but it is not a breeding ground, though of late years an increasing number of sheld-ducks have nested in the vicinity, especially in the neighbourhood of Burgh Castle. The estuary is of interest, because it is the halting place of many passing migrants during the spring and autumn migrations and, in the old days, any rare visitor—and there have been many—stood but a small chance of escaping from the gun of the collector or his agent. Our watcher is on duty during the summer months in a houseboat moored in the middle of the estuary, and his presence is undoubtedly a deterrent to illicit shooting.

At Wolferton, which adjoins the Sandringham Estate, there was formerly a considerable colony of common and little terns nesting on an extensive shingle flat on the edge of the Wash, but in 1927 the birds were driven away by workmen removing shingle from the nesting grounds for the manufacture of cement ; since then this site has been practically deserted by the terns.

The Wells ternery was situated on the north boundary of the saltings between Wells and Stiffkey, a part of the Holkham Estate, and, to the writer's personal knowledge, was in a flourishing condition as long ago as the 'eighties of last century. Trees have since been planted on the boundary dunes, and in 1921 an extensive fire occurred, burning all the maram. In the following winter most of these dunes were swept away by high tides and gales, and in the next summer only about half a dozen pairs of terns nested on the area. They have not since returned. One interesting fact may be recorded in connection with this ternery. For seventeen years a common tern returned and nested, her identification being made by the nest being always placed in the same position—adjacent to a piece of wreckage—and by the eggs being unspotted and red in colour. She met with an untimely end at the jaws of a stoat.

Although Blakeney Point had been under protection for several years, it was not until 1911 that it became the property of the National Trust, since when a whole-time watcher has been employed. The number of terns nesting here is variable, for this nesting ground is an alternative site to Scolt Head Island. As the result of protection the number of the different species of birds nesting on the Point has undoubtedly increased, especially the common terns. The following is the result of a carefully taken census during the past season :

Common terns . . .	2,177 nests.	
Little terns . . .	46 ,,	
Sandwich terns . . .	10 ,,	
Oyster-catchers . . .	17 ,,	
Redshanks . . .	23 ,,	
Sheld-ducks . . .	40 ,,	(estimated).

The increase in the number of nesting oyster-catchers, both at Blakeney and at Scolt Head Island, has been very noticeable, for whereas in 1923 the numbers were five and nine respectively, the numbers this year were eighteen and thirty-eight. In 1921 we have the first record—two pairs—of Sandwich terns nesting on Blakeney Point, since when the numbers have varied from about 1,000 nests in 1928 to ten this year, when all the eggs were pecked and deserted. Occasionally a pair of Roseate terns have nested on the Point, though during the last few years these birds have selected Scolt Head Island. Now and again one has been able to identify a pair of Arctic terns in the colony.

Scolt Head Island.

On June 2, 1922, that is before protection was given, the writer visited Scolt Head Island and found only seventeen nests of the common tern and nine of the little tern. There had been a ternery here from time immemorial—the local name of the island was 'Bird Island'—but the eggs had been consistently taken by the local people and by collectors. In the following year, 1923, a public subscription was raised in the county for the purchase of the island, which was then handed over to the National Trust. Since then a watcher has been employed and there has been a very noticeable increase in the number of nesting birds. For example, the staked and numbered nests of the common tern during the past season totalled 1,340, with about 100 nests of the little tern. The first record we have of the Sandwich tern nesting on Scolt Head was in 1923, when there were 59 nests, which increased to 640 nests in 1925. Since then the numbers have fluctuated considerably. This year there were 30 nests.

The great increase of nesting oyster-catchers on Scolt Head has already been mentioned, and there has also been a marked increase in the number of sheld-ducks. It is impossible to count the nests of these birds in the rabbit burrows, but on April 20 of this year, on the top of a morning tide, when the birds were resting in pairs either in the dunes or on the uncovered shingle ridges, the watcher and I, from elevated positions about half a mile apart, counted 170 pairs. We estimated that something between this number and 200 pairs were breeding on the island.

The Cley Marshes.

Up to this time, and for the next fifteen years, our protection work had been confined to our coastal areas, but in 1926 some 400 acres of partially inundated marshes at Cley were purchased by a few anonymous donors, and to take over these there was formed The Norfolk Naturalists Trust. At that time these marshes were largely flooded by inroads from the sea and were the resort of numerous ducks and other wild fowl. Since then, however, a natural shingle bank has formed in the place of an old concrete wall, and it rarely happens nowadays that the sea overtops this barrier. At the same time, in normal seasons there are many pools with reed beds on the marsh, which are the resort of ducks and waders during the autumn and winter. The whole marsh is kept undisturbed throughout the nesting season and a number of ducks, including the garganey, nest on it. We hope that the black-tailed godwit, ruff, black tern and spoonbill will be induced to nest there; perhaps also the avocet.

To meet the outgoings—tithe, etc.—the marshes are let for winter duck shooting, the lessees being selected men of judgment who are as anxious as we are not to do harm to the breeding stock, nor to kill the rare visitors.

Having formed our Trust we then, naturally, began to look round for other suitable places in the county that we could secure as nature reserves. We purchased a reed bed of about 25 acres, known as 'Starch Grass,' in Broadland, as it was a favourite nesting site of bitterns and harriers and other Broadland birds. Bitterns still nest there, but of late years the harriers have nested just over the boundary, on the Horsey Estate, which adjoins the property. Major A. Buxton undertakes the protection of the property for us.

Alderfen Broad.

It was but natural that our Trust should be anxious to own one of the Norfolk Broads, in view of the way that these unique English waterways are being spoilt by 'development.' It was not, however, until 1930 that an opportunity presented, and Alderfen Broad was purchased. This is a property of 68 acres with some 20 acres of open water surrounded by reed beds and marshland and three arable fields. It is ideal for our purpose, for it is one of the very few broads that is not in navigable communication with the river or other public waterway: it is also removed from any public highway. It is a place of quiet beauty, particularly attractive to the botanist. It also affords nesting sites for many of the Broadland birds, but there is no evidence that either bittern or harrier has ever nested on the property. It is left undisturbed throughout the year and is looked after for us by a farmer who lives near by. To help to meet the outgoings we sell the reeds and let the fishing.

Hickling and Horsey.

In 1909, Whiteslea Lodge, a residence on a small island area of Hickling Broad, was bought by the late Lord Lucas, and in the following year he was joined by the late E. S. Montagu and Sir Edward Grey, who came in to help to run the place as a bird sanctuary. In this year, 1910, Sir Harold Harmsworth (now Lord Rothermere), who then rented Horsey, gave permission to the Hickling syndicate to protect a pair of Montagu's harriers that nested on a marsh known as Horsey Brayden. Two watchers were put on, night and day, for ten weeks, and three young harriers were hatched and got away. In the following year, 1911, four pairs of Montagu's harriers nested on the Hickling-Horsey area, but two of these pairs were shot. Since then Montagu's harriers have nested each year on the property. In 1912 Lord Lucas took over the remainder of the Horsey lease from Lord Rothermere.

In 1915 the first pair of marsh-harriers nested on Horsey Brayden; but it was not until six years later, in 1921, that the marsh-harriers returned to nest. After another interval of six years, in 1927, a marsh-harrier returned and laid three addled eggs, but in the following year three pairs nested on the sanctuary. Since that date, 1928, one or more pairs have nested each year.

In 1917 Lord Lucas was killed in aerial combat in the war and left the property to the Hon. Ivor Grenfell (Lord Desborough's son), and E. S. Montagu continued his share in the management of the property until he died. At the lamented death, from a motor accident, of Ivor Grenfell, in 1926, the property was taken over by Lord Desborough, the present owner, who has since enlarged the estate by the purchase of surrounding properties. The Horsey Estate has been purchased by Major Anthony Buxton, who, to the great satisfaction of all ornithologists, is carrying on the traditions of the estate set by Lord Lucas.

I have thought it fitting to give this brief history of the Hickling sanctuary to show you our indebtedness to those I have mentioned for the preservation of some of our rarest nesting birds.

In connection with Broadland there is one other bird and name that I must mention. It is now a matter of history that after an interval of about forty years the bittern returned to nest in Norfolk on a reed bed on Sutton Broad, owned and protected by the late Sir Eustace Gurney: that was in the year 1911. Since that date our Norfolk bitterns have so increased under protection that they are now found nesting over most of

Broadland and are spreading to other parts of the county, and into Suffolk. The most characteristic of our Norfolk birds is, I think, the bearded tit, because, in spite of rumours of its having been recently reported as nesting in one of the southern counties, I believe East Anglia—there is good evidence that one or two pairs now nest in East Suffolk—is still its restricted home in these islands. Cold is its greatest enemy, and in a severe winter, such as that of 1916–17, our Norfolk race is very nearly exterminated. However, mild winters come along again, and at the present time the head keeper at Hickling, Mr. Jim Vincent, tells me that the census of these birds in that area is the greatest he remembers.

Breckland.

Our Trust has not, I regret to say, been successful, so far, in obtaining the ownership of any part of Breckland, though we are alive to the importance of securing a suitably sized area of this part of England. Already some 40,000 to 50,000 acres have been bought by the Forestry Commissioners and are either planted or about to be planted, mostly with Scots firs, and there would seem to be no limit to the activities of the Commissioners in that district. During the past summer we made a strong appeal to them to resell to us 1,200 acres from a plot of 6,000 acres of the Culford Estate that they had purchased, but we were not successful. Indirectly we hope we have saved Lakenheath Warren, some 2,000 odd acres, by purchasing property in Lakenheath to which common rights are linked, because we are assured that without the consent of all the commoners the warren cannot be planted or built upon.

The Management of Sanctuaries.

A word as to the management of sanctuaries. The first essential is to make continuous war on all four-footed vermin. I have been told that on an isolated area like Scolt Head Island it would be wise to leave the stoats so that they may keep in check the rats and rabbits. Putting aside the question of trying to differentiate between suitable traps, I have never yet met anyone who has seen a stoat attack a full-grown rat, and I have evidence of the work of stoats on a ternery. Only this summer did our watcher on Scolt Head find on one early morning fifty young terns that had been killed during the night and hidden under a suæda bush. He suspected stoats and located the culprits, a male, female and three fully-grown young, in a nearby rabbit hole and succeeded in killing them all. This was the work of one night only : had they been left they would have cleared the ternery of chicks in a week. On Scolt Head, which is practically treeless, all the birds are ground roosting, and we have evidence that the stoats on the island live principally upon feathered food.

Other marauders are gulls and skuas. Any attempt at nesting on the ternery by black-headed gulls must be immediately checked : they suck the eggs and eat the chicks of the terns. The immature larger gulls that hang about the ternery must also be controlled. Skuas are annoying to the terns, but they do no real mischief.

We have had short-eared owls nesting on Scolt Head Island, which made visits to the ternery every evening after their young were hatched. We did not intervene. In the last two years a male and female hen-harrier and two merlins have wintered on the island and took heavy toll of the large flocks of linnets and snow-buntings. They gave pleasure to many field ornithologists.

Is a ternery a menace to the local fishermen ? This is a question we had to settle a few years ago with the Blakeney fishermen, who were convinced that the birds were the cause of the yearly diminishing number of flat fish in the harbour. With the fishermen's co-operation we instituted an enquiry into the birds' food, which was carried out by Dr. Collinge on strictly scientific lines, and although the verdict entirely exonerated the birds the fishermen remained unconvinced, being quite certain that the whole enquiry was 'a put-up job.'

Abnormal high tides and sandstorms will result in the destruction of hundreds of nests and chicks in a few hours. Such natural curtailment of numbers probably adds to the vigour of the survivors. After a year of abnormal mortality from any cause we have never noticed any decrease in the population in the succeeding year.

Our greatest *bête noir* is the egg collector: he is a curse and a source of continual anxiety to us and involves us in considerable expense. However, he stands but a poor chance in this county, for as soon as he arrives word is sent round and extra hands are put on.

General.

In what other ways has our protection work had effect? In the first place I am convinced that, speaking only of our own people, the creation of these sanctuaries has resulted in a feeling of pride of possession. Outside of the inhabitants of the immediate coastal villages, Blakeney Point was known to but few people in Norfolk before it was bought for the National Trust and its beauties and interests brought to light by Prof. F. W. Oliver and his research workers. Similarly, not one person in a thousand in Norfolk, let alone the rest of England, had ever heard of Scolt Head Island before its existence was made known through the local press and subscriptions invited for its purchase, and that only twelve years ago! Through the medium of a wider press and the circulation of our Protection Reports, such as are presented to the members of this meeting, both these coastal bird sanctuaries have now an almost world-wide reputation.

Has this publicity had any bad effect upon the birds themselves? I cannot see that it has, and the evidence that I have brought before you supports this opinion; but rather would I say that the sanctuaries have created a natural and keen interest in the protection of nesting birds. And this is reflected in the subscriptions one receives from all parts of the country for our protection fund. In return for their financial support it is only fair to subscribers that they should have the pleasure of seeing the results of your labours. But if you allow the public to visit your nesting grounds you must employ reliable watchers as guides, and to secure such men you must be prepared to pay a fair wage and not desert them during the winter, when there is much to be done in the way of vermin killing, judicious planting, etc.

So far, we have not restricted the public to the terneries, except during the hours between 7 P.M. and 8 A.M., but it may be that we shall be obliged to make the nesting ground out of bounds during the height of incubation.

Monday, September 9.

Mr. Frank Leney.—*The Norfolk Room Dioramas in Norwich Castle, their purpose and achievement.*

The Norfolk Room in the Castle Museum has been adapted to illustrate in a realistic manner the Natural History of Norfolk by means of a series of well-illuminated dioramas. One of these, measuring 13 ft. in width, exhibits the fauna and flora of a typical mud flat at Breedon Water near Great Yarmouth in October, while another, the Broadland case, measuring some 26 ft., shows a characteristic scene in June on the Norfolk waterways, with the bittern, bearded tit, great-crested grebe, etc., with their nests and young, together with associated water plants.

A third case shows in a similar manner a typical Norfolk loke or lane, displaying the tints and colours of the hedgerows in autumn, with abundant animal, bird and insect life, fungi and berried plants.

Surrounding each case is a series of transparent photographs, which are changed according to the season of the year, while in the Gallery study collections of plants, animals and geology are housed for the benefit of students desiring more detailed knowledge of the natural history of the county of Norfolk.

Miss C. A. Simpson.—*A regional study in the Cotswolds by members of the Leplay Society.*

Aims of the Leplay Society. Their application in and near a Cotswold valley. Scope for varied interests and for detailed, intensive study. Need for training in observation. Map reading and map making. Specimens of work by members and students. Application of the method in schools.

Capt. T. Dannereuther called the attention of delegates to the publication by the British Museum (Natural History) of a booklet containing five plates of coloured illustrations, together with explanatory text for the easy identification of the principal migrant butterflies and moths. This booklet (Set E. 57) can be obtained from H.M. Stationery Office, price ninepence. Responsible officials of local natural history societies can obtain bulk supplies on sale or return at the rate of thirteen for ten shillings; such applications should be addressed to the British Museum (Natural History), South Kensington, London, S.W. 7. A pair of lantern slides for class and lecture purposes, illustrating all the sixty-eight species of butterflies now recognised as British, together with their authorised names, are obtainable at cost price, four shillings, from Capt. T. Dannereuther, Windycroft, Hastings.

The following resolutions were passed:

(1) That this Conference of Delegates of Societies in correspondence with the British Association for the Advancement of Science, assembled at Norwich, welcomes the facilities afforded by the Town and Country Planning Act, 1932, for the preservation of individual sites and objects of scientific interest, but views with grave apprehension the indiscriminate building development over wide areas of exceptional natural beauty and scientific importance; and requests the Council of the Association to represent to H.M. Government the urgent necessity for taking immediate steps to schedule such areas, as recommended by the National Parks Committee (Report, Section 28*b*), 1931, to be developed as national parks.

(2) That the attention of the respective Councils for the Preservation of Rural England, Scotland and Wales be called to the serious effects upon the insectivorous bird population through the cutting of hedgerows during the breeding season, and the consequent destruction or desertion of the birds' nests; and recommends that the said Councils urge upon local administrative authorities the desirability of suspending such operations during the nesting period.

EVENING DISCOURSES.

FIRST EVENING DISCOURSE

FRIDAY, SEPTEMBER 6, 1935.

DIESEL ENGINES IN RELATION TO COASTWISE SHIPPING

BY

DR. S. J. DAVIES.

This Discourse has been published, complete with illustrations, in *Engineering*, **140**, 3642, p. 486, Nov. 1 (1935); *ibid.*, **140**, 3644, Nov. 15 (1935); *ibid.*, **140**, 3646, Nov. 22 (1935).

SECOND EVENING DISCOURSE

TUESDAY, SEPTEMBER 10, 1935.

THE HELP OF PSYCHOLOGY IN THE CHOICE OF A CAREER

BY

DR. C. S. MYERS, C.B.E., F.R.S.

I HOPE this evening to be able to indicate to you the valuable help which Psychology can render in the choice of a career. But before I attempt to do so, it seems to me desirable to spend a few minutes in considering whether *any* help is necessary for the young person choosing his career. For, strange though it may appear to many of you, there are people who, on various grounds of general principles, feel opposed to vocational guidance. Some of them maintain that it is really a good thing to let young persons discover for themselves their most suitable occupation by the 'rough-and-tumble' process of repeated trial and failure. Others urge that most young persons show no special 'bent' for any particular career, but are endowed with the ability to adapt themselves equally well to a wide variety of occupations. Others, again, question the value of vocational advice in these days of difficult employment when so often the young person must needs accept the very first vacancy which he is offered—whatever be the nature of the occupation.

To these various objections, the following replies may be made. Experience shows beyond question that the majority of young people suffer, instead of benefit, when they are left to discover their most suitable occupation by a series of unsuccessful efforts. They lose self-confidence owing to their successive failures. Too often they only change their occupation when the misfit is so glaring that they are discharged by their employer. And when they remain in an unsuitable post, either it may bore them almost insufferably, or it may strain them to such a degree that they become 'nervy,' unhappy and restless, even rebellious against society: indeed an important cause of social unrest and even of crime, especially among young people, has with good reason been ascribed to an unsuitable occupation.

It is quite true that only rarely can an ideally suitable occupation be found. For very few of us are 'pegs' which will fit to perfection the 'hole' of any one occupation: we can do equally and fairly well and we can be equally and fairly happy in the work of several different occupations. But it is not less true that there is a far larger number of other occupations in which we shall do far worse and be far from happy. In point of fact, the expert vocational adviser hardly ever limits his recommendations to one particular career. He believes, rightly enough, in limited powers of human adaptation; but he insists that while there are certain careers which are to be recommended to a particular applicant, there are other careers which, owing to their unsuitability, should on no account be attempted.

He insists, too, that in times of vast unemployment it becomes all the more important to make the best possible initial choice, when the difficulty of finding another post will make the mal-adjusted young person hesitate before relinquishing one that proves unsuitable, despite the mental or physical strain, boredom, irritation, and dissatisfaction which it provokes.

But vocational guidance is important not only for the benefit of the person who receives it and of those with whom he is brought daily into social contact. The adoption of an unsuitable occupation, and its subsequent abandonment, mean inevitably a huge national loss—a loss in productive efficiency, a waste of effort and material, and a waste of time—in needlessly interviewing, training and employing successive unfit applicants until a suitable worker is found.

Moreover, in actual practice, if left to himself, the young person does not, as a rule, make a wise choice of a career. It is found, more often than not, that he drifts or tumbles by mere chance into an occupation; and a special inquiry among those who have been educated at secondary and public schools has shown that about one-half of them intend to take up occupations which, on grounds either of ability or of temperament and character, are judged unsuitable by the psychologically trained vocational adviser whose guidance has proved correct in the vast majority of his cases. Sometimes the decision of young people is determined by parental wishes. And too often the influence which a parent may be able to exercise in finding for his child a position either in his own occupation, or in the business of a relative or friend, blinds him to the utter unsuitability of such a career for his boy or girl. Or the father may be so ambitious for his son, or the mother may play so exclusively for a 'safe' occupation, that again a hopelessly unsuitable career is selected for a naturally unadventurous or adventurous youth, as the case may be.

It is, therefore, not surprising that when left to himself, the young person appears usually to exercise a rather better choice than when subject merely to parental influence. But his own choice is so often wrong because, as a rule, he knows nothing, or virtually nothing, of the different requirements of occupations for success in them, and because he neither recognises nor takes into account sufficiently his own abilities or disabilities. He is guided principally by his interests and ideals, and these are apt only too often to lead him astray. Thus in a spirit of devotion to humanity a girl may decide to take up hospital nursing or school teaching, quite unmindful of her lack of physique, accuracy or patience so necessary for successful nursing, or of her inability to preserve discipline which will make her future life in a school one of almost intolerable strain and even torture. Endowed with some literary talent, a boy may embark, with similar failure, on journalism, because he has disregarded his lack of pushfulness and of speedy writing which are so essential for success in this occupation. Or again, a physical weakling may compensate for his disabilities by day dreams or phantasies of flying; he aims therefore at being an aviator. Other choices may be dictated by fashion, imitation or hero-worship.

The school teacher is hardly a better guide to a career than the parents or the young person himself. He may or he may not know his pupil well: if he knows him well, he may know him only from one particular standpoint—the relation of pupil to master or mistress. Moreover, the teacher cannot be expected to know the various requirements of different occupations, of the abilities and qualities of temperament needed for success in each, and of the kind, length and cost of training and of the future prospects of each. It is, therefore, not surprising to receive from one headmaster the following observation: 'Realising that my knowledge of the boy is imperfect and one-sided, and my knowledge of occupational requirements grossly inadequate, I always feel more or less of a charlatan when called upon to advise. My only consolation is that my advice is so rarely followed that there is no real cause for my distress!'

Of late years, in certain secondary and in most public schools, a single teacher has been appointed to give special attention during part of his time to vocational guidance. He has received the name of 'careers-master,' but no training whatever in this part of his duties. He may even apply tests and other psychological methods, although often unqualified to do so, thus bringing into popular contempt methods which are unquestionably helpful when properly used. Many secondary and a few public schools have recourse to the voluntary Committees formed under the auspices of the Ministry of Labour by the Headmasters and Headmistresses Associations. But they would be the first to admit the imperfection of their present methods of advice. The Juvenile Employment Officers, for whose work the Ministry of Labour is responsible, are mainly concerned, together with the voluntary Local Juvenile Advisory Committees appointed for this purpose, in the guidance and placement of elementary school children. But they too receive no systematic training in their work, and at present there are no adequate official prospects, nor, in consequence, is there any permanence, in their work. Very often a conference is held terminally in elementary schools at which the school-leaver is advised as to his future occupation. But the interview of each child and parent is necessarily restricted to an inadequately brief interval of time; and too often the child's own wishes, so often erratic or irrational, tend to receive undue consideration. If the data which I now exhibit to you can be regarded as reliable and representative, the vocational guidance given at such conferences leaves much to be desired.

We may conclude, then, that help in the choice of a career is not only necessary but is also capable of great improvement. And for such help and improvement we may naturally look to psychology—the science which is concerned with the mind and resulting behaviour. The directions in which psychology is actually helping—both by research and by practice—lie (i) in occupational analysis, (ii) in the assessment of mental abilities and qualities, (iii) in insistence on a very broad attitude and a carefully balanced judgment in guidance, and (iv) in systematic methods of training vocational advisers.

In occupational analysis much has been done to determine the requirements for success in different occupations. But a vast field still awaits investigation, while much of what has been done is sadly defective from the psychological standpoint. Such matters as courses of training, prospects, seasonal fluctuations, hours of work and wages have been satisfactorily enough treated by those who have been engaged in occupational analysis. But information is still lacking as to the precise physical and mental abilities and qualities of temperament and character which are likely to favour success in different industrial, commercial and professional occupations. When they have been described, they are usually couched in such vague or identical terms that, as has been justly said, they ' are scarcely more illuminating than the remarks commonly made by centenarians when invited to explain the secret of longevity.'[1] Consequently we are very far from being able to classify occupations and processes in such a way that a person who possesses the abilities and qualities required for success in one member of a group of occupations may reasonably be expected to succeed in any other member of the same group, and to fail in other groups of occupations. It is obvious that the analysis and classification of occupations requires the skill of the trained psychologist ; he has already started on this work.

He began it by assessing the general intelligence required for success in different levels of occupational life. He chose general intelligence both because of its importance and because he possesses already a sufficiently reliable means of estimating it. Important as it is that a young person does not enter an occupation which needs higher intelligence than he may possess, it is equally important that he does not enter an occupation of so routine a nature that it makes insufficient demand on the intelligence which he may possess. Excessive boredom must be avoided as much as excessive strain. The result of much psychological research has been to establish the working hypothesis that a certain single factor of general ability runs through all mental and manual work—the ability to discern relevant relations and to make appropriate use of them. This innate ability to discern relevant relations and to make appropriate use of them may be usefully called ' general intelligence.' Mathematically we may isolate it, but in practice it cannot be separated from the material on which it works. For this reason tests have had to be devised for assessing abstract or linguistic intelligence and other tests for assessing practical or concrete intelligence. In the former we employ ' verbal ' tests, tests involving symbols—the use of words, numbers and abstract ideas ; in the latter we employ ' performance ' tests, involving the manipulation of concrete objects.

I throw now on the screen, first, examples of a widely used verbal test of intelligence and, next, examples taken from a battery of performance tests of intelligence. These tests have been devised to estimate, so far as possible, innate intelligence as distinguished from acquired or examination knowledge which, owing to lack of interest, illness, etc., on the one hand, or owing to ' cramming ' on the other, may not yield a true index of intelligence. Repeated researches have definitely proved the greater reliability of intelligence tests than examination marks in the assessment of intelligence. As I have stated, no intelligence test evokes general intelligence and nothing more : indeed no psychological test can be devised which involves the play of only one mental factor ; there is besides intelligence a ' verbal factor ' involved in carrying out a verbal intelligence test ; and there is similarly a ' practical factor ' involved in carrying out a practical intelligence test.

[1] A. Macrae, *Talents and Temperaments*, 1932, p. 148.

It is possible mathematically to regard these various factors as single or unitary, but the psychologist may not always accept the psychological truth of the mathematician's conclusion. As a working hypothesis, however, it has proved valuable to regard the intelligence factor as unitary and to assess it either in terms of the score at the test or in terms of what is called the 'intelligence quotient.' I show now a slide exhibiting the average intelligence quotients of persons pursuing different kinds of vocation. The intelligence quotient is obtained by dividing the 'intelligence (or mental) age' of a young person by his actual (or chronological) age and multiplying the result by 100. The intelligence age of a person is assessed by giving intelligence tests of different difficulty which have been already standardised for different ages and by determining the tests which a given person passes that would be performed by the average person at a certain age. Thus if a person of 10 years old succeeds in passing tests performed by the average person of 11 years, he would be given an intelligence age of 11 years. The intelligence quotient, formed as I have just stated, by dividing the intelligence age by the actual age and multiplying by 100, is nearly constant throughout life, and therefore we may with interest examine the distribution of intelligence quotients among children generally. We see how closely this compares with the proportion of adults engaged in the different levels of occupations that require different degrees of intelligence.

Besides this 'general' factor of intelligence which enters, in various degrees, into all occupations, there are 'group' factors of other abilities common to a number of different occupations or operations and there are also 'specific' factors peculiar to each of them. In vocational guidance there is no time to apply psychological tests of specific factors or the numerous tests devised for many various occupations: we can only apply tests of general and group factors, and supplement these, when occasion warrants, by tests devised for the selection of applicants for the commoner occupations, such as clerical, engineering and dressmaking work. This is what is done by the vocational psychologist in actual practice.

One factor of considerable importance in engineering, architecture, surveying, designing and the like, which has been designated a group factor, is that of appreciating the relations of shapes and geometric forms. I show you now illustrations of a widely used test of this ability to discern form relations, which has proved of great practical service. This factor of appreciating form relations is no doubt closely associated with another factor which has been mathematically regarded as a single group factor—the factor of mechanical ability, i.e. the ability to understand moving mechanisms and to solve problems involving them. I show you a test of mechanical ability which has recently been introduced and promises to be of great value to the psychologist in vocational guidance. It is unquestionably superior to another test, hitherto much used, which without adequate research was believed to measure the same group factor of mechanical ability, but which is undoubtedly complicated by other factors, e.g. the factor of manual deftness.

Special psychological tests of manual deftness or dexterity are now employed in vocational guidance, particularly in advising elementary school children. One example of these I now throw upon the screen. Recent psychological research indicates that the more *complex* the manual operation, the more fully is it saturated by a single group manual factor common to other complex manual operations; whereas into the *simpler* manual operations numerous specific manual factors predominate, each of which is peculiar to each such simple manual operation. I throw on the screen a recently devised psychological test which, on mathematical grounds, is believed from careful experiment to afford a reliable measure of the group factor of manual dexterity: it should therefore prove useful in vocational guidance, but its exact practical value has yet to be determined.

Even more important, however, for vocational guidance, in the opinion of many, than the assessment of mental abilities—or at all events fully as important—is the assessment of qualities of temperament and traits of character. If a young person is emotionally unstable, it is hopeless to recommend him to a post which demands an unusually equable temperament. Indeed in a case of grave emotional instability the psychologically trained vocational adviser will advisedly recommend expert medical treatment before attempting to offer guidance. If a young person shows strong social proclivities, it would be disastrous for him to embark on work which has to be performed in relative loneliness. If he is fond of change or seeks adventure, he cannot without serious risk of failure be advised to take up work of a highly routine nature.

Unfortunately there are no sufficiently reliable tests of temperament and character available for the vocational psychologist. He is compelled at present to collect as systematically as possible—and far more systematically than before—all the information possible from those who have been in the closest touch with the applicant and also directly from the applicant himself by his own questioning and observation. How this is done can be best described by the account which I will presently give you of the vocational examination of a secondary or public school boy or girl who at the age, say, of 16, after obtaining the school-leaving certificate, is seeking advice as to a future career.

But before passing to this, I would stress the importance of a medical history concerning many applicants for vocational guidance. It is obvious that on medical grounds, not only of a bodily but also of a mental character, certain occupations may in certain cases be very definitely contra-indicated. I would also stress the importance of ascertaining the family history, not only medical but occupational. Further, the psychologically trained adviser must take into consideration not only the possible hereditary factors but also the present social environment, home conditions, and the character and influence of the parents of applicants who seek from him vocational guidance. Even the terminal school reports have value, although they are couched so often in vague, non-committal language which gives little or no psychological insight into the real mental make-up of the pupil. He must be guided, too, by the applicant's interests and ambitions, when sufficiently genuine and potent, by his opportunities and his financial circumstances, by the prospects of different occupations and by a vast number of other general considerations. In the exercise of his art, the applied psychologist cannot expect success merely by applying a few psychological tests, computing the scores made at them and translating these scores mechanically into the particular occupation or occupations which seem to demand the special abilities indicated by the test scores. This is what I had in mind when, earlier in my address, I stressed one of the directions in which psychology is helping vocational guidance—namely its insistence on a very broad attitude and on a carefully balanced judgment. This end is undoubtedly attained most easily and effectively by an adequate training of the adviser in psychology.

The time has now come for you to see how the psychologically trained adviser proceeds to deal with a young applicant for vocational guidance. I exhibit successively the different forms which are sent to his (or her) parents, to his (or her) headmaster or house master (or mistress) and to several of his (or her) form masters (or mistresses) before the applicant is interviewed and examined. You will see how, and you are now in a better position to realise why, he seeks so large an amount and so wide an extent of information.

By the time the young person comes up for an interview the adviser has thus at his disposal a considerable body of information—of various degrees of reliability. Before he examines the applicant, he interviews one or both parents and learns still more about the applicant and about his parents, their character, their wishes and their circumstances. Meanwhile the applicant starts to perform one of the easier tests in a neighbouring room, and later he is asked, on the form which I now exhibit, to assess his own qualities of temperament and character. This assessment, which he is found to give in a surprisingly honest fashion, forms a useful starting-point for detailed discussion about his personality in the course of subsequent conversations with him when his hobbies, interests and ambitions are considered. Much information as to his temperament and character is also obtained by observing the applicant in his actual performance of various tests, especially in regard to his emotional stability, patience, accuracy, persistence, systematic procedure and the like.

The whole examination lasts half a day and is followed by the psychologist's evaluation and consideration of all the information he has obtained from so many various sources in the light of his knowledge of occupational requirements, prospects and opportunities. He recommends finally, in a written report, as I have already said, not a single occupation but several, in the order of their preference, when possible. He follows up the applicant in his after career by corresponding with him periodically and asking him how successful and satisfied he is in his occupation. I throw on the screen data indicating the surprising success of his advice, when comparisons are made between those applicants who accepted and those who disregarded that advice.

I show you also data proving the value of such advice when given, with the help of psychology, to elementary school children, and indicating its enormous superiority to existing methods. Realising this superiority, a few English education authorities are now taking steps to have some of their elementary and secondary school teachers effectively trained in these psychological methods. It is clear that the vocational guidance of elementary school children, at least, should be the joint concern of (*a*) the school careers master, on the one hand, who has, for several terms before the school-leaving time arrives, been observing and testing the child and accumulating all possible knowledge about him so as to arrive at a broad occupational recommendation, and (*b*) the juvenile employment officer, on the other hand, who has received sufficient psychological training to appreciate the careers master's data and knows far more fully than the careers master the detailed requirements, opportunities and prospects of particular occupations. For those who are likely to enter into the higher professions from secondary and public schools, an even more widely trained careers master is essential.

The psychological aspects of all such vocational guidance work need to be supervised by a whole-time regional expert who would train those in his area in the psychological methods of guidance and assist them in their difficulties. Such is the future ideal for vocational guidance, if we are adequately to utilise the great help which the science of psychology unquestionably offers in the choice of a career. That help bids fair to render the vocational adviser's predictions at least as reliable as the predictions of the meteorologist. If we could but bring ourselves to spend on psychological work in vocational guidance even what we now spend on forecasting the weather, or, still more, on testing materials and machines—what untold happiness and economies we should produce !

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APPENDIX

A SCIENTIFIC SURVEY OF NORWICH AND DISTRICT

PREPARED FOR
THE NORWICH MEETING
1935

BY VARIOUS AUTHORS

EDITED BY
R. H. MOTTRAM

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A SCIENTIFIC SURVEY OF NORWICH AND DISTRICT

I.

PREFACE: THE NORWICH BLEND

BY

R. H. MOTTRAM.

NORWICH is a county borough of over 120,000 inhabitants, capital of Norfolk, and the largest town for over a hundred miles in any direction. While its self-government dates from A.D. 1194, its ancient importance is shown by the establishment of a mint before A.D. 700. It is thus Anglo-Saxon in origin, for the Romano-British centre of the district was three miles away to the south-east, at Caistor, and it owes nothing to that civilisation except possibly the direction of Ber Street and Holm-street (now Bishopgate) which lie along what may have been a Roman track to Caister by Yarmouth.

It seems obvious that its site was chosen just where the Wensum, midmost and largest of the three rivers that form the estuary that drains the eastern half of Norfolk, passes the most marked escarpment of its course, and immediately receives its tributary, the Yare, under whose name it continues to Yarmouth. The Anglo-Saxon settlement of Conisford, which stretched roughly from the present General Post Office along King Street to the works of J. & J. Colman, Ltd., at Carrow, records the lowest fordable spot on the river, which is here still tidal, and still enables sea-going ships to reach the centre of the City.

The open wooden village which sprang up at this point has ever since been the scene of layer after layer of immigration and repeated disaster, the former absorbed and the latter surmounted with astonishing rapidity. This perhaps accounts for the special character of Norwich. Its racial mixture and subsequently added elements have their source in a sea-crossing. It has no tribal roots in the earth. It is a blend thoroughly mixed by the most strenuous stirring of events.

The first documentary fact about it is an entry in the Anglo-Saxon

Chronicles describing the savage revenge of Sweyn, King of Denmark, for the murder of his sister in A.D. 1003, during the Massacre of St. Brice. By then it was called Norwyk and had already a considerable Danish element. The street names which survive, Colegate, Cowgate, Fishergate, Westwick, Pottergate, and the dedication of some of its churches show this. It had recovered by the time of the Norman conquest, so that over 1000 burgesses were registered in Domesday. A third warring element was then added, the Normans dominating the place from the massive stone Keep which remains (refaced) to-day, to house the Museum. They also planted a hardly less formidable ecclesiastical fortress, to-day the cathedral and its Close, infringing on the old market and common meeting place of Tomland or Tombland, and made a new market and French-speaking quarter west of the Castle. Here, then, were all the racial antagonisms and linguistic barriers which should have made for centuries of hatred and disruption. But the opposite was the case. In about a century the inhabitants of the four rival villages, Conisford of Saxon origin, Westwick with its Danish preponderance, the Ward over the water, with a mixed population, and the Norman quarter had all come to speak one language, and think of themselves as citizens of one community. In 1194 they obtained from King Richard the right to elect their own chief citizen to govern them. They already possessed a charter (1158).

Between 1263 and 1342 the city was surrounded by a wall, portions of which, with some towers, still remain to be seen.

In 1404 the citizens obtained a more formal and elaborate charter incorporating the city as a county, with a Mayor, two sheriffs, Court of Aldermen, and Common Council, which lasted until the Municipal Reform Act of 1835, and they then built the Guildhall still in use. In 1909 Royal Letters Patent granted to Norwich the privilege of calling its chief citizen the Lord Mayor.

The long story of the civic development of Norwich is told in detail hereafter. That of religious bodies planted in the City, but often with their own jurisdiction separate, includes a long strife between the citizens and the Cathedral Priory. A more intimate relationship existed with the various orders of Friars, Black, White, Grey and others established in Norwich, and when they, like the older religious bodies, were disestablished, the great church of the Dominicans was preserved and handed over to the City as a Wool Hall, and its nave and chancel still form the two main assembly halls of the city, known as St. Andrew's and Blackfriars' Halls. The remaining development of religious feeling in the city brings us into closer and closer connection with its commercial growth.

At first merely a centre and market it drew to itself the local trade, but above all the spinning of yarn of the kind made at, and called after, Worstead, a few miles to the north-east. In the early fourteenth century Flemings were brought over to teach weaving, and despite the great disaster of the Black Death, by the end of the century Norwich had become a foremost textile town. Its trade was much injured by the religious wars of the sixteenth century, but the outcome was beneficial to the city, where racial mixture and long independence had fostered a feeling for religious toleration. Dutch and Walloon refugees were allowed to settle and rejuvenated not only the weaving, but allied trades such as dyeing, and gave the city much wealth and many prominent citizens.

The cosmopolitan atmosphere and strong appeal of local tradition is shown by the fact that the sometime chancel of the Black Friars' church was, until the twentieth century, the place of worship of the Dutch Congregation, and an apprenticing charity founded by the French-speaking community still gives preference to those of French descent in Norwich.

The prosperity of the weaving industry made a solid basis for the golden age of Norwich in the latter half of the eighteenth century, when alongside the splendid cathedral presided over by many a distinguished ecclesiastic and the thirty-five remaining parish churches, many very beautiful, grew up the meeting-houses of Dissent. Partly around these, and partly in the Close, around the ancient grammar school of King Edward VI, were fostered the only distinct provincial school of English painting, the musical activities of Crotch and Buck, the inception of the Tonic Sol-fa system, and the literary circle embracing Amelia Opie, the Martineaus, the Taylors, Sarah Austin, Mrs. Barbauld, Dr. Parr and many others. Philanthropy may be represented by Elizabeth Fry and her brother J. J. Gurney, and medicine, always distinguished since the days of Sir Thomas Browne, has many prominent names. Science is represented by the remarkable family of Hooker and for a short interval the Linnæan collection was housed in Norwich.

About 1830 fell a blow as shrewd as the old city has ever suffered. Partly on account of international complications, partly from the progress of the industrial North of England, in about a decade the whole of the textile industry left Norwich. The population became stationary, and very great distress supervened. Nevertheless, the inherited skill of generations of weavers, the accessibility by water, and central position in the county, began to attract new industries. To-day, the works of J. & J. Colman, the two world-renowned insurance societies, and a fair section of the boot and shoe trade are centred in Norwich. The local bank of the Gurneys provided a large element in Barclays Bank. Large packing and hardware industries have settled here. The market has never ceased to have considerable regional importance, and to-day it is one of the largest corn and cattle markets outside London. On Saturdays the broad expanse below the Castle and the surrounding streets give the impression that Norwich is a purely agricultural town. But an entirely different aspect of the city's life is shown in the industrial quarters along the river, and in the neighbourhood of its two main railway stations, and on its outskirts.

Yet a third side of local activity caters for the resident, the visitor and the sightseer. Local and foreign influences have moulded its architecture and lay-out. It is the natural distributing point of the greatly extended transport facilities of the twentieth century. It is an air-port with daily service, a sea-port, a yachting station, and the means of access to a wide district by road and rail. While voluntary effort jealously guards its remarkable heritage from the past, the municipality controls one of the largest of provincial museums, with an art gallery, and no fewer than four branch establishments which specialise in crafts, in folk and domestic collections, and a possibly unique ecclesiastical museum, all housed in buildings of appropriate associations, especially the last, for which one of the many historic churches, that of St. Peter Hungate, has been accommodated. A voluntary Publicity Association places the necessary information at the disposal of the visitor. The Central Public Library has all the resources demanded by the cultural needs of the population, and has opened three branches, while a fourth is projected. This leads on to the mention of the four new suburbs in which portions of the population are being rehoused, and of the many responsibilities undertaken and facilities provided by the City Council on behalf of the inhabitants. A detailed record follows.

Thus it will be seen that the description, 'the Norwich Blend,' is not fanciful. Norwich presents a curiously complete cross-section of English life, not only contemporary but historical. No one industry, no marked physical peculiarity has ever dominated it. It was not suddenly built in a generation or two, or altered in a hurry. It has adjusted itself, not perhaps fast enough to changing conditions, and is not perhaps quite eager enough to display itself to the visitor. It has a strong local, one might say, insular feeling. It has not yet solved its traffic problem, and is only now building adequate municipal offices to supplement the beautiful, but outgrown accommodation of its fifteenth-century Guildhall.

But we need not depend on the opinion of those who were born in it, love it, and prefer to reside in it. In 1909 it was the subject of a most detached study by C. B. Hawkins, a trained investigator from Toynbee Hall. He is worth quoting :

'It is impossible to stay long in Norwich without realising the strength which comes of a great tradition handed down through many centuries of honourable and self-sacrificing labour for the City. It is no small thing that those whose duty it now is to deliberate on the affairs of their City, should meet in the very Chamber, and sit on the very benches, where their fathers and their fathers' fathers sat and deliberated before them.'

II.

NORWICH IN ITS REGIONAL SETTING: THE GEOGRAPHY OF NORFOLK[1]

BY
J. E. G. MOSBY, D.S.O., M.A.

Professor Ian C. Hannah[2] has bestowed upon Norwich the pleasing title 'The Heart of East Anglia,' and by so doing has linked together in one happy phrase the names of two places whose history and geography are almost inseparable. It will be essential, therefore, to consider the general boundaries of East Anglia as a background for a more detailed analysis of a somewhat smaller region. The limits of East Anglia may be taken as roughly coincident with the old kingdom of that name, an area which in pre-Norman times was almost completely isolated from the rest of Britain by forest and fen; and the smaller region, which I propose to treat as the regional setting of Norwich, may be described as Norfolk east of Fenland.

The border-lands of East Anglia which contributed to its isolation were: (1) On the north-west, north and east a long low-lying coast line of varying character extending from the south-east corner of the Wash to the mouth of the Stour; (2) Impassable fenlands consisting of a maze of black meandering streams, swamps, sedge and clumps of willow, alder and poplar flanking the west; (3) To the south thick forests which flourished on the outcrop of London Clay. On the landward side a strip of chalk country separating the fenland from the forest, and a narrow belt of swampland dividing the woodland from the North Sea provided two ways of approach into an almost isolated area.

The approach from the south-west is a tract of open downland varying in width from six to ten miles and rising steeply above the level of the fens, its chalky soil being unsuitable for the growth of damp oak forest.

The influence of the downland upon the movements of many has been considerable from the earliest times up to the present day, this south-western gap being of prime importance as a route into East Anglia in the times before the fenland was drained and the forest depleted. A series of trackways known as the Icknield Way followed this broad ribbon of open downland, and so connected the isolated kingdom of East Anglia with the Chilterns and beyond, and served as a means of access for the

[1] The writer desires to acknowledge his thanks to the authors of the works referred to in the text; to Dr. Dudley Stamp, Mr. Rayns, Mr. J. E. Sainty, and Mr. W. Stephenson for reading the script and giving valuable suggestions; and to a large number of landowners, farmers and land workers throughout the county who have readily given firsthand information about their own locality.

[2] Ian C. Hannah, *The Heart of East Anglia* (*c.* 1910).

invader, and a source of anxiety to the defenders. Within such a region bounded by forest, fen and sea, human occupation may be traced from prehistoric times.[3] 'Yet although these beginnings go far back, the Anglo-Saxon period not only duplicated certain features of early invasion, but was a restart from which all subsequent development has been direct.' The invasions of the Anglo-Saxons took place along the river valleys. They worked their way inland by the way of the coastal inlets and the Fenland rivers, but on the whole they did not penetrate into the woodlands of the boulder clay interior. In their endeavour to hold their isolated kingdom the Anglo-Saxons stoutly defended both the Devil's Ditch, which stretched for seven and a half miles from fen to forest transversely across the open chalky downland; and the outer defence of Fleam Dyke—earthworks which in all probability they themselves constructed. The line of the River Stour formed a natural frontier on their southern limit.

The geological boundaries enabled the kingdom to possess an essential unity, and groups of settlements near Norwich and Ipswich indicate a beginning of the importance of these sites as the principal centres for the North Folk and the South Folk respectively. Within the kingdom itself, along the line of the Little Ouse and the Waveney, is a shallow trough which breaks across the chalk ridge in the west and divides High Suffolk from Norfolk, forming a natural subdivision of the kingdom and fostering a distinction between its northern and southern inhabitants. Later developments show that Norwich became the capital of this isolated region and that its influence was even more pronounced in the land which was the home of the North Folk, a region which now calls for treatment in some detail.

Chalk, undoubtedly the most important solid geological formation of Norfolk, has bestowed many benefits on the inhabitants. It yields an abundant supply of excellent water, and at certain levels are those lines of flint which furnished prehistoric man with a durable material for his implements and provided the folk of the Middle Ages with a building stone. A hard form of chalk called clunch which occurs in some parts of the west and middle west has been used as a building stone too. The marl derived from chalk provided a dressing for the light soils, and many old pits with derelict kilns testify to a widespread utilisation of the chalk as a material for lime. The character, age, thickness, height and slope of the surface of the chalk vary considerably from west to east. On its western margin the chalk is much thinner, the older lower horizons are exposed, and the surface is comparatively free from later deposits, while the surface slope is but 8 to 9 ft. per mile. The strike between the Wash and the Little Ouse—Thet gap is north-north-west–south-south-east, and shows a change in direction from the Chalk; (*a*) on the other side of the Wash where it is north-west–south-east, and (*b*) in Suffolk where the strike is north–south.[4] The junctions of these two changes in direction reveal

[3] H. C. Darby, 'The Domesday Geography of Norfolk and Suffolk.' *Geog. Jour.* May, 1935.

[4] P. G. H. Boswell, 'On the Surface and Dip of the Chalk in Norfolk.' *Trans. Norfolk and Norwich Naturalists' Soc.*, 1919–20.

lines of weakness which in some measure account for the depression of the Wash and the Little Ouse—Waveney Gap. The latter is well marked in the Chalk and the period of its formation was probably post-Eocene and pre-Pliocene. At Hunstanton the chalk passes down into the well-known red chalk which rests directly on the dark brown ferruginous sandstone called carstone or 'gingerbread stone,' used locally as a building stone. Further south, from Sandringham to Stoke Ferry, a stratum of gault occurs between the Lower Greensand and the Chalk; the Greensand in turn resting on Kimmeridge Clay. From this line, Hunstanton to Stoke Ferry, the Chalk dips eastwards, the amount of true dip being about 35 ft. to the mile. Consequently the thickness increases, being as much as 1,150 ft. at Norwich. East of the line Weybourne, Reepham, Hethersett, Dickleburgh, Pliocene deposits, collectively called the Crag rest unconformably on the Chalk, and a small outlier occurs at Guist eight miles to the west of this line. Further eastwards Eocene deposits have been found in borings between the Crag and the Chalk. From a line Woodbastwick—Beccles and the coast the surface of the Chalk has been bevelled off giving rise to a rapid increase of its slope—the fall being as much as 400 ft. in about four miles. It is both interesting and significant to note that the present surface of the Chalk is over 250 ft. above O.D. at a point a few miles to the north of Swaffham, 50 ft. above O.D. at Norwich, and 450 ft. below O.D. at Yarmouth. The whole area of Norfolk was subjected to a series of glacial invasions which occurred at intervals in the Pleistocene period. Dr. J. D. Solomon [5] distinguishes four distinct periods of ice advance. The advancing and retreating ice sheets have been responsible for considerable alteration to the topography. They blunted the edge of the chalk escarpment in the west; re-excavated the Little Ouse—Waveney trough; and created the Cromer Morainic Ridge, which is so youthful that it is almost unmodified by erosion. The moving ice covered the greater part of Norfolk with a mantle of drift varying considerably in thickness and the composition of its materials—large plateaux of chalk boulder-clay, trails of sands and gravels, isolated areas, often several square miles, of laminated clays and loams are in the main the surface materials from which the soils of Norfolk are derived. Post-glacial deposits are almost entirely confined to the low-lying parts of the country: (1) valley gravels and loams in patches situated between the chalk outcrops and the fens; (2) vast deposits of alluvium and peats in the fenlands to the west and the eastern marshlands of the lower Bure—Yare—Waveney; (3) small isolated deposits of alluvium scattered here and there are to be found in the interior, probably the sites of old meres; (4) materials forming the coastal marshes of the northern fringe of Norfolk situated between Holme-next-the-Sea to Weybourne; (5) blown sands at intervals along the coast, e.g. Old Hunstanton to Holme, Brancaster to Blakeney, Happisburgh to Hemsby, Ormesby to Yarmouth.

Obviously such variations in surface geology were predominant factors in moulding the topography and determining the drainage system of the region. The chalk escarpment in the west determined the line of the

[5] J. D. Solomon, 'The Glacial Succession on the North Norfolk Coast.' *Proc. Geologists' Assn.*, vol. xliii, pt. 3.

main watershed whose present position is somewhat to the east of the original line, due in part to the work of the ice invasions and the work done by the obsequent streams Babingly, Gaywood, Nar, Wissey, Thet. The upper parts of these westerly flowing rivers have cut deep and picturesque valleys, the Nar being especially noteworthy for the number of priories, now in ruins, which used to flourish there. On the east side of this divide the longer rivers, the Yare and Wensum are clearly consequent on the dip of the chalk. The Cromer Morainic Ridge rises in places to over 300 ft., is a secondary water parting with its general direction running at right angles to the main divide. The north flowing rivers Glaven and Stiffkey which rise within its hummocks have cut steep-sided valleys both in the ridge itself and in the divide to the west. From the south side numerous streams issue forth, a few of these drain into the Wensum, but the majority form the affluents of the Bure and in the east a tiny rivulet, less than ten miles in length, finds its way to the sea independently. The latter, called the Mun Beck, has cut out for itself a miniature gorge at a spot in Mundesley where cliffs are high and erosion rapid. W. G. Clarke [6] suggested 'Before the land receded so far it may have been connected with a little stream which flows inland from Bromholm Abbey into the Ant.' If this was true then the water from the Mun Beck at one time found its way into the Bure. In their lower courses the Yare and Bure meander sluggishly over the low-lying marshes which now occupy the site of a wide depression forming an arm of the sea in pre-Roman times. The rivers find their way to the sea together by a narrow outlet between Yarmouth and Gorleston. The surface drainage from Mundesley to Yarmouth is inland, and the rivers of this district such as the Thurne and Muck Fleet all help to swell the volume of water carried by the Bure. Two interesting features may be mentioned in passing: first, the gap between Happisburgh and Horsey, most probably a recent outlet to the sea, which has been blocked up by beach deposits and blown sand, and secondly, springs which occur at intervals near the coast and form intermittent trickles which flow seawards and lose themselves by sinking in the sandy beach. The third essential feature in the drainage system is the through valley of the Little Ouse—Waveney. In this narrow trough, at a spot about one mile south of South Lopham the headstreams of the Waveney and Little Ouse are divided by a bank of sands and gravel. This bank, most probably glacial in origin, running transversely across the trough has been almost worn away by erosion, and the construction of a roadway over its site has almost completely cloaked the natural causeway which furnished an easy means of communication between the North and South Folk.

The coast line of Norfolk is charming, yet terrifying and interesting. Its cliffs, sands, quaint fishing villages, seaside towns, salt marshes and sand dunes are a delight to the artist and holiday-maker, but submerged off-shore sandbanks, local currents and north-easterly gales are often a source of danger to the shipping which passes close by its shores. History reminds us of the ravages of the Danes, the exploits of smugglers, the devastating inroads made by the sea when it breached the slender sand

[6] W. G. Clarke, *Norfolk and Suffolk* (1920).

walls and flooded several square miles of country; and, even in the present century, cases of smuggling are not unknown, while the question of a hostile invasion of these coasts during the Great War was regarded as a serious possibility by the military authorities. To the geologist the coast presents subjects of exceptional interest, such as the solution of the baffling problem of the sequence of the glacial deposits revealed in its cliff sections, and the question of keeping accurate records of the rapid erosion which takes place when the waves and wind attack their soft and loose materials, the silting up of the river mouths, and the building up of the new shore lines where the land is gaining on the sea.

A description of the ninety miles of coast line must necessarily be brief. Starting from Hunstanton: (1) The cliff of Hunstanton, which clearly shows a section of the older chalk, white at the top changing to red and resting on carstone, marks the termination of the chalk uplands. (2) To the north the land falls and the scenery changes from chalk cliffs to hummocks of blown sand extending from Hunstanton to Holme. (3) Holme to Weybourne—the characteristics are salt marshes fringed with rapidly changing sand dunes and crossed by meandering channels of the rivers Burn, Stiffkey and Glaven. The mud flats are carpeted with vegetation such as sea lavender, and intersected by a labyrinth of creeks and channels. These creeks and channels devoid of water at low tide are filled rapidly as the tide rises, and as the lower parts are submerged patches of higher land are left as islands. In places, and more particularly in the eastern half, considerable areas of marshland have been protected by sea banks, and the land thus reclaimed utilised for grazing with some plantations of woods to add to the charm of the landscape. Two other features of this section of the coast land must be noted: (*a*) a line of old cliffs is clearly traceable for many miles on the south side of the marsh, and (*b*) a number of old seaports which flourished from the sixteenth to eighteenth centuries, such as Burnham, Blakeney and Cley. All these harbours are rapidly silting up, but Wells still carries on a small import and export trade. (4) Weybourne to Mundesley—this stretch presents many striking contrasts; high cliffs, wide beach of golden sand made accessible by fairly steep cart tracks, called 'gaps,' cut in to the cliff face, absence of river creeks; sea rapidly gaining ground at Trimingham and Mundesley. Old villages with some local offshore fishing, such as the crab fisheries of Cromer, are to be found at intervals along the coast. These towns and villages have become the popular sea-side resorts of the Norfolk coast, and are rapidly becoming linked up with an almost unbroken line of bungalows, hotels and camp sites. A background of morainic hills with its woodland and hummocks gives this part of the coast its characteristic charm, one grass covered hummock, Beeston Hump, is to be seen quite close to the cliff near Sheringham, while the highest spot in the county, 340 ft. above sea level, is within one and a half miles of the sea behind West Runton. The shore lines of this section exhibit some variation in details; at Weybourne the water was deep enough to allow a battleship to approach close to the shore; Sheringham has its well-rounded pebbles to protect its cliffs from the battering of the sea; Cromer is proud of its pier; Trimingham can boast of its high cliffs and its beacon towering

226 ft. above the sea, and one of the finest view points for miles round, and as Mundesley is approached long narrow lagoons, called 'lows,' visible at low tide become a characteristic feature. (5) Mundesley to Eccles. The coast stretches south-eastwards in a line almost straight, the cliffs becoming rapidly lower until Bacton is reached where they are as low as 4 ft. Afterwards they rise gradually to about 50 ft. on the north side of Happisburgh where they gradually lose height until they are lost under blown sand near the parish boundaries of Happisburgh and Eccles. In short this is a zone of low cliffs, alternating sections of rapid erosion and sand-dune formation, off-shore fishing and lows. (6) Eccles to Winterton—here marram hills protect the low-lying hinterland from inundation at high tide, a form of sea defence which has given cause for considerable anxiety. In the latter part of the eighteenth century ten rather serious breaches made by the sea are shown on Faden's map published in 1797, the advance of the line of dunes is clearly illustrated by the fate of Eccles Church in the nineteenth century, when the sand dunes passed from the seaward to the landward side of the church, and the tower fell during a gale in 1895. The natural forms of the sand dunes stand out plainly above the level of the hinterland as a line of irregular hills, attaining in places to a height of 80 ft. The beauty of these natural dunes is being somewhat modified by man who is engaged in the task of converting them into a broad wall of a more or less uniform height, and further strengthening them by planting additional patches of marram grass. Winterton Ness is a point which marks a change from sea encroachments to land gains, accompanied by a change in the design of the sand hills. The area of blown sand widens to as much as half a mile, and, amid a medley of sand mounds at Flatgate Warren, two or more lines of dunes are traceable. (7) Winterton to Hemsby—the higher land of the Fleggs starts here, its seaward edge, at least half a mile from the present high tide line, is marked by a steep sided old sea cliff 50 ft. high. Parallel with the present shore line are two lines of sand hills, while between the inner line of hills and the old cliff a valley covered with sand sedge, marram, furze and brambles extends from Winterton to Hemsby. (8) Hemsby to Scratby—the inner line of sand hills reaches the old cliff line at Hemsby, where the land dips before it rises again at Scratby. The junction of the outer sand dunes with the higher ground at Newport Cottages is quickly followed by an exposure of cliff some 50 ft. in height at Scratby. (9) Scratby to Great Yarmouth—small but scattered patches of vegetation growing on the cliff face, and the presence of small mounds of sands, 10 ft. or so high, on the shore show a tendency for the formation of protective sand dunes here. On the other hand, the possibility of spring tides reinforced by a strong following wind reaching the base of the cliffs may be regarded as an indication that this part of the coast is not entirely safe from sea erosion. The cliffs continue for a mile or so before they are again hidden by blown sand, and as we go southwards the land loses height and the protecting sands gain in width. East Caister marks the southern boundary of the higher Flegg country, the beginning of the marshes, and the northern limit of an old bay. From this point a spit of beach shingle and sand, four miles long and half a mile wide, stretches

southwards across the old bay, and by this means many square miles of valuable marsh land have been reclaimed. Great Yarmouth, the second largest town in Norfolk, stands on this spit, divided from Caister by the North Denes and retaining a small portion of the South Denes to the south; with the sea on the east and the marshes to the west, Yarmouth furnishes a clear example of a town whose shape has been largely determined by physical features, and where expansion to meet modern needs is a difficult problem. Although a part of the North Denes has been used in recent years for the purpose of extending the residential area of Yarmouth the real expansion is taking place at Gorleston on the other side of the river, where there is more width from east to west.

Geographical Sub-regions.[6a]

From a description of the coast-lines where the changes are so distinctive that it is a comparatively easy matter to define the boundaries of each zone, we turn to the more difficult problem of defining the geographical sub-regions [7] of the interior. Location, altitude, geology, configuration, soils, vegetation, land usage, the culture of the earlier inhabitants, are some of the major factors to be taken into consideration in arriving at the character of each zone. At best, the majority of the lines shown as their boundaries must be regarded as approximate. Breckland, for example, is recognised as a sub-region by most authorities, but there is by no means unanimity on the question of its extent and boundaries. My own acquaintance [8] with the locality has led me to suggest yet another boundary-line as a fair indication of the Norfolk portion of this sub-region. (See map, p. 20.)

Breckland.—Breckland, formerly the most thickly populated district of East Anglia, now one of the thinly populated areas of England, presents an interesting example of a region favourable for the development of the culture of prehistoric man by reason of its dry ground, supply of flints, and lack of close vegetation, but is devoid of the natural resources necessary for the development of a prosperous rural or industrial community of the present age. Its unquestioned beauty is to be seen in the rolling uplands which stand out in contrast to the valleys of the fairly fast-flowing rivers, the Lark, Little Ouse, Thet and Wissey, which dissect it. Here the chalk is covered by a thin mantle of materials arenaceous and porous in character, consisting mainly of blown sand mixed in parts with stones. By reason of the texture of the soil and the frequency of strong winds, the loss of moisture by seepage and evaporation is considerable. The land surface quickly dries even after heavy rains, and where the soil is laid bare by the plough or rabbits the surface becomes loose and powdery. Many dust-storms have been recorded, and in 1650 a dust-storm lasting several days

[6a] See Map I.

[7] The sub-regions are based on those of P. M. Roxby. The chief differences are—slight alteration of Breckland boundaries: the division of High Norfolk into two sub-regions; a somewhat larger area for Broadland; and the separation of the Fleggs from the Loam region of North-East Norfolk.

[8] I am indebted to Lord Fisher of Kilverstone for giving valuable information regarding the extent of Breckland, and some of the developments within its borders.

did considerable damage. The low rainfall of about 25 in., sufficient for the needs of arable farming in the adjacent districts, is only adequate for the upland fields of 'the Breck' when the greater part of the rain falls at frequent intervals during the late spring and the early summer. The paucity of the population is closely related to the difficulty of obtaining water supplies, and it is interesting to note that most of the villages are situated near the rivers being, more or less, evenly spaced out at intervals of about 2 miles. The sites of these villages, judging by the place-names, seem to have been selected by the Saxons. The confluence of the Thet and the Little Ouse marks the site of Thetford—a delightful and most interesting old town, which attained considerable local importance from very early times. 'Its [9] pre-eminence in Saxon times is indicated by the name of the town, which is simply "Theatford," "theat" being the neuter form of "the."' Here the Icknield Way, coming from the south-west, crossed the river and subsequently forked, the main route going north-west and a branch north-east. Four miles to the east of Thetford is the Peddar's Way, a trackway leading in a north-north-west direction to Holme-next-the-Sea. The presence of these ancient trackways must have had considerable influence on the growth of the town and the wealth of the townsfolk, and it is of interest to note that in 1086 the number of burgesses, 720,[10] compares favourably with the 665 in Norwich and 70 in Yarmouth.

Small areas of water called meres without visible inlet or outlet occur in hollows where the chalk comes very near the surface, whose influence on the life of the inhabitants must have been considerable, especially during the eleventh century, when vast numbers of sheep and horses were kept, and I do not think it is a mere coincidence that six parish boundaries meet at Ring Mere. Breckland is not just a land of rye and rabbits, but a picturesque district of small fertile valleys, sandy warrens, extensive heaths of bracken and ling, interesting meres, which give it a peculiar charm. Large fields protected from the winds by pine belts, which in times when grain fetches a good price are cultivated, only to be abandoned as the price falls, and left to revert to stony waste land. It is a land where interesting experiments have been carried out, such as the growing of tobacco and sugar-beet. The growing of tobacco has been almost entirely abandoned, but sugar-beet grown on soils that have been given a liberal supply of manure yields a high sugar content. Two other successful introductions must be mentioned, a well-established and successful production of black currants, and a very recent cultivation of asparagus for canning.

Until recently Breckland was almost entirely an area of huge estates, all of which were well stocked with game. Heavy taxation, and especially death duties, have been responsible for the sale of some of these estates, and the acquisition of large tracts of land by the Forestry Commission. Here then is a region which in neolithic [11] times had a greater rainfall and

[9] W. G. Clarke, *In Breckland Wilds* (1925).

[10] The figures are taken from *The Domesday Geography of Norfolk and Suffolk*, by H. C. Darby.

[11] W. G. Clarke, *In Breckland Wilds* (1925).

was covered with grass over which large herds of red deer roamed at a time when the landscape was beautified by beech, Scotch pine and stunted oaks growing here and there, but in Saxon times it was almost a treeless area. Towards the end of the eighteenth century the plantation of hedges of Scotch pine began on a small scale, followed by the planting of small woods in the nineteenth and early twentieth centuries, and to-day we have the beginning of what may probably be one of the largest forested areas in England.

The Good Sands Region.—Stretching northwards from Breckland as far as the salt marshes and from the hilly country of the Greensand region of the west to the Morainic Ridge is an interesting piece of upland country having an average altitude of 200 ft. Up to the end of the seventeenth century this region was a most desolate tract of heathland, consisting for the most part of heather-clad commons with some scanty grass, and relieved here and there by meadows in the narrow valleys of the Babingley, Burn, Glaven and affluents of the Wensum. Rabbits burrowed in the sandy soil and sheep grazed on the poor grass, but the number of cattle was small, and in a few places where crops were grown the yield was poor ; yet underneath the poor sandy soil there was a rich 'marl,' which paved the way for the improvements made by Townshend of Rainham and Coke of Holkham. When Arthur Young witnessed the success of Townsend's experiments he was so much impressed with the possibilities of utilising this land that he called it the Good Sands region (a term adopted by Prof. Roxby). The transformations brought about by the practice of marling the land, the introduction of new crops, the institution of the Norfolk four-course system coupled with the new ideas of improving stock made this land famous in the eighteenth and nineteenth centuries. To-day the region still retains its title as a land of experiment, for during the last decade two remarkable developments have attained success: (1) 'Prairie farming' methods for wheat cultivation by the Alley Bros. of Bluestone Farm, South Creake, and (2) the cultivation of about 2,000 acres of lucerne by Messrs. Parker and Proctor of the Castle Acre district. In connection with the wheat farming a subsidiary rural industry has developed, in which wheat is manufactured into 'Farmers' Glory,'[12] a prepared cured food ready for the breakfast table. The produce of the lucerne fields is taken to the 'dried fodder' factory at South Acre nearby, where it is dried within six hours from the time of cutting.

Broadland.—Alternate submergence and elevation as the results of earth movements during the period 3000–1600 B.C.[13] ended in the depression of the area now occupied by the marshlands of the lower Bure—Yare—Waveney, and formed a shallow bay or vast estuary. The formation of the sand spit from Caister to Gorleston, the deposits of alluvium, the embanking of the river of the twelfth century, and subsequent drainage operations have won back this land from the sea once more, and now this

[12] Since this article was written the Alley Bros. have concentrated on the manufacture of Farmers' Glory, and the farm has been taken over by a new company called the Bluestone Farm Ltd.

[13] W. G. Clarke, *Norfolk and Suffolk* ; also Clement Reid, *Submerged Forests.*

flat region consists of grazing marshes drained by a network of dykes, slow flowing tidal rivers with an average fall of 2 in. to the mile, and a number of reed-bordered sheets of water called Broads. The latter may be divided into three types: (1) those occupying the deeper hollows of the original estuary being separated from the rivers by reedy covered washlands, called ronds. Access between these broads and the rivers is only possible by digging connecting channels across the ronds. Among this class are included Wroxham and Ranworth near the Bure, and Surlingham and Rockland near the Yare; (2) a number directly connected with the rivers may be considered as 'broadenings'—e.g. the broads of the rivers Ant, Thurne and Much Fleet. It is interesting to note that H. B. Woodward[14] thought that Barton Broad was formed by the cutting of turf, and is therefore to a certain degree artificial; (3) Breydon Water, now almost silted up, is the last remains of the old estuarine channel.

The changing phases of Broadland from sea to grazing marsh have left their mark on the culture and development of the inhabitants of the surrounding regions, due in the main to the difficulties of communication by land and the ease of access by water. Large stretches of water provided an entrance for Danish pirates, and later the rivers played an important part as navigable highways, as indicated by a large number of staithes—wherries carried goods between North Walsham and Yarmouth, also between Aylsham and Yarmouth on the Bure, and its water connections; and between Norwich and Yarmouth on the Yare. The traffic on the Bure declined with the advent of railways and motor road transport, but small steamers and other craft still carry on an increasing trade of sea-borne goods, such as timber and coal, from Yarmouth to Norwich. The Broadland of to-day is best known as a pleasure resort, famous for its unique scenery and its wonderful skies—the source of inspiration of many famous paintings—its sport and yachting; while its reeds are used for thatching not only locally, but in many parts of the country over 150 miles away. During the past 200 years the isolation of Broadland has been considerably modified by the construction of railways and roads, nevertheless the region itself is but sparsely populated, although it is flanked by the two largest centres of population in Norfolk.

The Flegg Hundreds.—This sub-region cut off by sea and marsh, formerly an island, is remarkable for its Norse and Danish settlements. The very name Flegg is Norse, meaning 'flat,'[15] and Mr. W. Rye has made some interesting notes on the place-names and their possible significance on the history of the succession of Danish settlements. There seems to be little doubt that this island was the home of many Norwegians and Danes, ancestors of many of the present inhabitants. W. A. Dutt,[15] after remarking on the large number of village names ending in 'by' adds, 'that in these parishes tall, light-haired, blue-eyed men, closely resembling the Norwegians, are frequently met with.' Domesday records a large number of salt-pans along the inland fringe—e.g. at Filby; and indicates a large number of small holdings in these hundreds worked by freemen—a fact which may be interpreted as an outcome of the settlement of these inde-

[14] H. B. Woodward, *The Geology of the County around Norwich.*
[15] W. A. Dutt, 'Norfolk,' *Cambridge County Geographies.*

pendent Norsemen. Arthur Young was full of praise of the state of the agriculture here and the rich loamy soils with their associated sands and gravels. Nowadays it is one of the most productive agricultural districts of Norfolk, and has added to its wealth by the successful cultivation of soft fruits and sugar-beet. Its connections with Yarmouth are intimate, two being especially noteworthy: (1) the good roads connecting Yarmouth with Norwich, Wroxham and North Walsham, and (2) the provision of a good water supply for the town.

The Loam Lands of North-East Norfolk.—These lands have much in common with the Flegg Hundreds, the soils are similar, crag deposits are found between the chalk and glacial drifts, and the surface wells yield a good supply of water; on the other hand, the chalk does not yield its water as readily as in the more western sub-regions. The area includes Norwich and extends northwards to the Cromer ridge with two eastern extensions; the one in the north stretches as far as the coast from Cromer to Happisburgh; and the other may be described as a tongue of land extending to Acle and dividing the western part of Broadland into two arms. (The boundaries of this district, the Flegg Hundreds and the size of the Caister—Yarmouth sand spit are easily traceable on the 1-in. Land Utilisation Map, No. 67.) The good soils, a number of streams and rivers, a good supply of water from shallow wells, the proximity of the salt marshes, the wealth won from the sea by local fisheries and smuggling, the energy of the people descended from the Norse folk, and the knowledge brought by the Dutch and the Huguenots—all contributed to the prosperity and development of this region. Here the lands were occupied, agriculture and weaving went ahead of many parts of Great Britain. Villages are numerous, Worstead being noteworthy for its connection with the woollen industry. Of recent years great developments have taken place in the more intensive kinds of land culture. For example, many acres under glass produce large quantities of tomatoes, early flowers, early vegetables, etc. Fruit growing has made considerable progress, especially at Westwick, Wroxham and Burlingham. Poultry farms, nurseries, market gardens and small-holdings are to be found in many parishes, and five out of the seven silver fox farms in the country are situated either within or close to the borders of this sub-region. These activities combined with the varied and healthy industries centred around and within Norwich have attracted a large population amounting to over half the total for the whole county.

South Norfolk.—Between Broad and Breck the land of South Norfolk presents rather a flat appearance with an average altitude of about 150 ft., rising to over 200 ft. at Ashwellthorpe, and falling to under 50 ft. along the borders of Broadland and the valley of the Waveney. The Thet valley in the west, the Waveney trough in the south, the deep valley of the Yare in the north and the Broadland depression in the east receive the water from the radial drainage which has its source in a centre near Tivetshall station. The streams are much smaller and their valleys somewhat less pronounced in both steepness and width than those of the sub-region to the north. These boulder clay districts were covered with light undergrowth and forest in the days of the Iceni, and the vegetation tended to isolate the settlement of the Iceni of the east from the habitations of Breckland. The light woodlands of the boulder clay were probably left standing until the coming of the Romans, A.D. 50, who penetrated and partly cleared them. Dr. Darby's map of Domesday Woodland shows a fairly definite distribution of trees over the boulder clay lands here, although the process of clearing had made considerable headway by that time and at the present time South Norfolk is one of the least wooded of all the sub-regions of Norfolk. The heavy and tenacious soil covers about 70 per cent. of this area. Of the remainder the greater part is medium, although there are a number of patches of light soils. Where the soil is heavy, the fields are drained by ditches, 4 to 5 ft. deep, and the land is often piped as well. Little foot-bridges leading to the front gates of the cottages are a noticeable feature, while in the spring the banks of the ditches are yellow with primroses, and later in the year the meadows sparkle with cowslips. Cottages built of clay lump or stud and plaster are so common that they may be said to be a characteristic of this district. In Tacolnestone, Forncett, Bunwell, Carleton Rode, Aslacton, Tibenham, Tivetshall, Gissing and Old Buckenham,[16] cottages of this type with their thatched roofs and colour wash of pink, white and yellow, stand out in a pleasing contrast to the new council houses so rapidly springing up around them. Although many villages still possess their commons crossed by unfenced roads, quite a number of the old commons were divided up by the inhabitants about 100 years ago. The sites of these old commons are often indicated by the distance of the houses from the present position of the road with a regular line of the houses about 100 yds. or so back, with long gardens or meadows in front. Mixed farming is general; good crops of wheat, barley, beans, peas and sugar beet are produced. The inclusion of beans as part of the rotation of crops is more common here than in any other sub-region, winter sowing being the general practice. In Arthur Young's time it was an important hemp-growing district, the water of the Waveney being suitable for retting, and the local industry of making mats at Diss may be a survival of the old hemp spinning. A map showing the orchards of 1910 [17] records this area as the chief orchard district of Norfolk; the orchards appear to have been of long standing, and have given rise to the cider-making of Banham and Attleborough.

Mid-Norfolk.—Mid-Norfolk lies to the north-west of South Norfolk and is similar to it in many respects. Both sub-regions are boulder-clay districts covered with light forests in early times, but the woodland of the south was more pronounced, due to the smaller proportion of heavy soils in Mid-Norfolk. The elevation of Mid-Norfolk is somewhat higher, and although there are some flat areas the undulations are somewhat steeper, especially in the north-west boundary where the Morainic Ridge dominates the landscape. The rivers have a general east and west direction, carry more water, and on the whole have cut deeper and wider valleys. In each area the spread of the population is well distributed over the whole region, clusters of houses being interspersed between the valleys and the

[16] Claude J. W. Messent, *The Old Cottages and Farm Houses of Norfolk.*

[17] L. F. Newman, 'Soils and Agriculture of Norfolk,' *Trans. Norfolk and Norwich Naturalists' Society.*

towns. Good crops of wheat, barley, sugar beet, roots, peas and beans are raised, dairy farming is specially noteworthy, sheep and cattle thrive, and poultry farming is in a flourishing condition. The heavier land in the south accounts for the much larger acreage of beans, while on the balance it would seem that the milk production of Mid-Norfolk is the greater.

Taken as a whole Norfolk may be regarded as a fertile agricultural region where the climate with its light but adequate rainfall is eminently suitable for the growth of grass and grain. With the increase of production[17a] the need for markets arose and led to the establishment of market towns whose radius of influence increased more and more as the means of communication improved.

NORWICH.

Norwich, by reason of its general position, has outstripped the other market towns and become the capital of the whole region. In its neighbourhood the rivers Wensum and Yare have carved out valleys through the soft materials of the glacial drift and the Crag ; and to-day their flat flood plains are several feet below the surface level of the chalk. These rivers almost meet on the west side of Norwich, being less than three-quarters of a mile apart at a point[18] two and a half miles west-north-west of the Castle, where they are separated by a narrow strip of ground nearly a hundred feet above river level. From this point the Yare, on the south, takes a wide circular sweep southwards and then eastwards, eventually joining the Wensum at Trowse ; while, on the north, the Wensum flows eastwards for a mile and a half before it describes a graceful loop southwards, reaching a point a quarter of a mile north of the Castle. Thence for 600 yds. the course of the river is north-east before it twists abruptly first to the east and then to the south. The reach from Bishopsbridge to Foundry Bridge is almost due south and the course is nearly straight, with a flat flood plain on the right bank and a minor escarpment on the left. From Foundry Bridge the river curves slightly to the west where it is within 500 yds. of the Castle. Near this spot is the site of Conesford, ' the King's Ford,' where the King's men crossed the river on their way to the high ground on the east. From this spot the slow-moving waters flow southwards, but the low ground is now on the left bank, and a steep escarpment is on the right. Proceeding east the river leaves the high ground and is reinforced by the Yare at a point not many miles distant from the head of the old sea estuary. In addition to the river meanders, flat marshlands and minor escarpments mentioned above, there are a number of lesser topographical features traceable to the work done by old water courses, such as the cockeys shown in Hudson's maps of Norwich.[19]

The origin of Norwich is lost in obscurity, and it is quite outside the scope of this article to discuss the possibility of any settlements being established here in Roman times. Hence any references relating to the earlier settlements and the expansion in Norman times mentioned below

[17a] R. E. Dickinson, ' Town Plans of E. Anglia,' *Geography*, March, 1934.
[18] Marked A on Map II, p. 20.
[19] W. Hudson, *How the City of Norwich grew into shape* (1896).

are intended to show that the wide estuary attracted the Angles and the Danes and that the topographical features of the locality were significant factors in moulding the shape of the city. In Saxon times two river settlements, Conesford and Coselanye,[20] sprang up on the banks of the Wensum. Conesford, on the right bank of the river just above its junction with the Yare, was hemmed in between a steep escarpment and the river. Coselanye, some distance further up-stream, and on the left side of the river, was situated on an island having an expanse of marshland on its northern side. Some time later a third river settlement of Danish origin grew up on the right bank of the river opposite Coselanye. In course of time these villages grew and amalgamated with Tombland [21] as their common meeting ground, but up to the time of the Norman Conquest Norwich was a river town, consisting of three sections each retaining a certain amount of individuality, and the greater part of the ground occupied by their inhabitants was below the 50-ft. contour. When the Normans arrived in Norwich they used the northern end of the Ber Street Ridge as a vantage point for dominating the river settlements. On this spot they subsequently built their castle, 200 yds. from the 'Tomland,' and less than half a mile from Westwyk and Conesford. Around the castle the Norman part of the town grew up, particularly on the high ground to the west and south, where they set up a market place which was destined to supersede the 'Tomland'; [21] but it was on the low-lying flats, called Cow Holme,[22] or the Island of Cattle, that Herbert de Losinga built his cathedral church. In passing I mention these significant points in connection with the building of the cathedral: (1) its site adjoined the 'Tomland,' not the Norman market place; (2) the greater part of the stone for its construction came from Caen by water; (3) the moving of the See from Thetford was an important stage in the establishing Norwich as the capital of East Anglia.

The circumvallation of Norwich and the building of its walls during the thirteenth and fourteenth centuries determined the shape of mediæval Norwich. Lack of space forbids a detailed treatment of the period of great prosperity which followed the arrival of the Flemish weavers in the fourteenth century; the beneficial influence of the coming of the Friars; the building of the many beautiful flint churches, the development of trade between Norwich and European countries, and the trade between the city and the surrounding country districts, the establishment of its cattle market, reputed to be one of the largest in England. The decline of the woollen manufactures in the seventeenth and eighteenth centuries was due to the lack of adequate water power and distance of Norwich from the coal-fields, but other industries were established through the enterprise of the citizens. A description of the present-day industries is given elsewhere in this booklet.

Norfolk, by reason of its geographical position, is somewhat remote from the main lines of traffic of Great Britain, and in so far as this is true

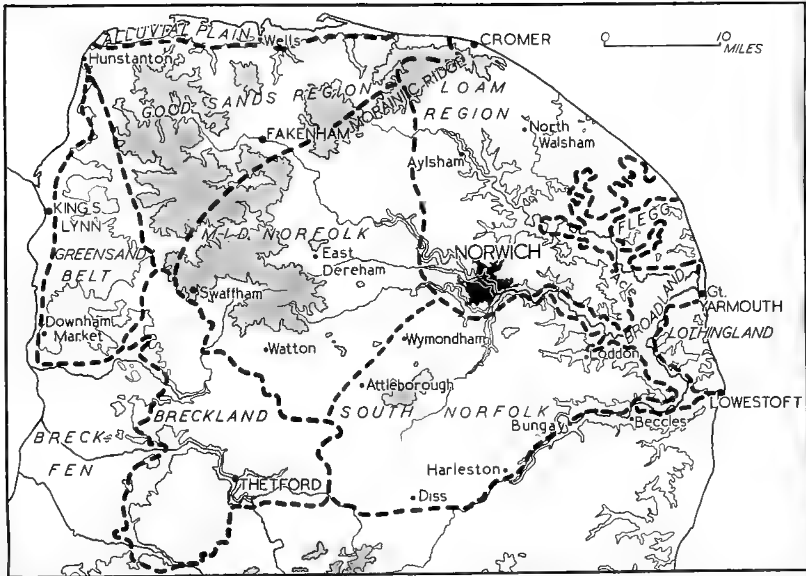
[20] I. C. Hannah, *The Heart of East Anglia.*

[21] Tombland, a corruption of Tomland, a vacant open space. I. C. Hannah, *The Heart of East Anglia.*

[22] *Ibid.*

MAP I.—ILLUSTRATING DIVISION OF NORFOLK INTO REGIONS.

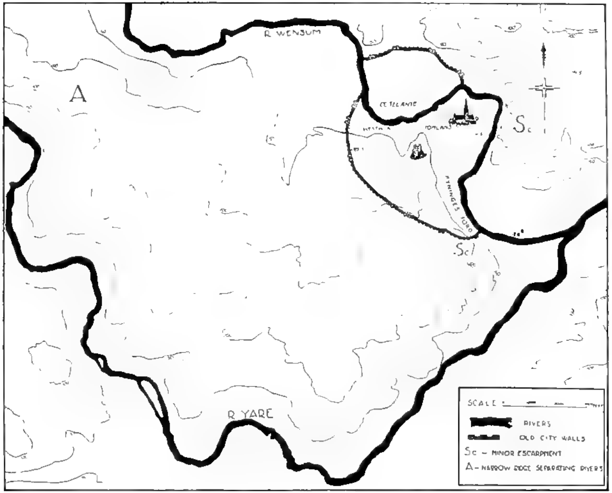
Map I.—Illustrating division of Norfolk into regions



[To face p. 20.

Map II.—Showing the site of Norwich.

MAP II.—SHOWING THE SITE OF NORWICH



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it still preserves to a certain degree an isolation which has enabled the countryside to retain the greater part of its charm and scenery. This very isolation, too, has enhanced the importance of Norwich as the county centre for administration, banking and commerce, as will appear in following chapters. Roads radiate from it in all directions like the spokes of a wheel, and around it villages are rapidly assuming the rôle of suburbs, while the rapid growth of new housing estates on the margin of the pre-war city marks another epoch in the expansion of the city itself.

III.

THE CLIMATE OF EAST ANGLIA

BY

JOHN H. WILLIS.

As the drive and energy of a people can now be shown largely dependent on their climate, the weather variations we experience become matters of vital concern. That none surpass from this standpoint, the variations experienced in the regions of the British Isles may be evidenced by the Ellsworth Huntington records in *Climate and Civilization.* Yet even among the variations prevailing in England, the climate of East Anglia may claim to rank high. As the changes swing from high summer to winter, its unusual position closely safeguards it from hurtful extremes. For as the drift of weather and cyclonic systems over England is mainly from the west, the moist free-roving winds from the Atlantic lose to the western hills much of their violence and rains. Hence not only is East Anglia's moisture relatively slight, amounting in the area of its capital to a depth of but little over 2 ft. to 26 in. of rain in a year, but its relatively clear skies yield East Anglia a high sunshine average, both in duration and intensity. The average, indeed, of 1,563 hours a year for its capital is among the highest for all inland cities in England; while thanks to the dryness of its air its intensity also ranks high, and the holiday sea and sun bather may feel on its coast, more consciously than elsewhere, the friendly kiss of the sun.

Yet thanks to its dryness, the warmth that sweeps over it in summer is stimulating rather than oppressive. Thanks also to the peculiar configuration of the region, a tendency to excessive and enervating heat is checked, almost as it were by thermostatic control. For at periods when the heat over England tends to rise to oppressive levels, the vast heated currents of air ascending above it draw over the crescent rim of East Anglia's low expanse a flood of cool air from the sea; even as far inland as its capital and beyond, one may feel, through periods of scorching and exceptional heat, the filtering stir of cool North Sea airs.

Just as the dryness of the air keeps the heat of the summer stimulating rather than oppressive, so also it keeps the cold of the winter bracing rather than raw; even though winter-time cold in England is keener in the east than the west. For contrary to what might be expected, the cold of the winter does not descend upon England from the north, but across it from the east. It is therefore against the western frontiers of the country, beside which the Gulf Stream ferries its constant cargo of warmth from the Caribbean, that the assaulting tides of winter form annually and break. And since it is by the east they ultimately withdraw, the East Anglian area is in January and February the coldest area in England.

Exactly how the tides of warmth and cold, of moisture and sunshine, eddy and ebb and flow through the year may be seen in the brief, tabled summary appended of the records of my station. But for those finding figures insufficiently informative, may be added a running commentary on the weather of the year as it passes the milestones of the months.

Through January sweeps by the coldest period of the year, with but 50 hours' sunshine to its 31 days; though only infrequently do its cold skies bring sprinklings of snow, and but rarely in winter is the ground mantled in depth. While the trough of the cold is past by the middle of the month, the rise in warmth through February is laggard enough. Its rise indeed is but a fraction of a single degree above January's, though as Fill-Dyke February in East Anglia is the driest month of the year, the month's bare boughs lack locally the beadings of raindrops they commonly carry elsewhere. Even in early March the air is still keen, though one is conscious now of the growing power of the sun each time the skies are swept clear. But by the close of the month winter is thawing from the air; and commonly with the first surge of spring enters proud-pied April, less showery in East Anglia than elsewhere, since April's rains locally are almost as slight as the rest of the spring's.

It is with May and June the year reaches its period of maximum sunshine. In May, in particular, the clouds so heighten and dissolve as to keep the sunshine recorder on overtime, at times up to 14 and 15 hours a day; while as June's sunshine averages but a few minutes a day less, the joint contribution of their prodigal skies to the year reaches 400 to 500 hours of sun. It is not till after this two months' flood of sunshine, which soaks so far into the ground as to lift soil temperatures a full dozen degrees, that the temperature of the year, in July, reaches its maximum. The actual crest is reached early in the month; but so sustained and prolonged is the surge of warmth through the whole of the summer, that to the close of August the mean temperature has not dropped by as much as a single degree. And even while rains in this latter part of the summer are somewhat increased, it is not that its rains are more frequent or lasting, but that summer's chance thunder spills heavier showers when they come.

If spring in East Anglia comes slowly, the warmth of its summer lingers late into autumn; indeed, the first month of its autumn might well in East Anglia rank as honorary summer. For September's mean temperature falls but 4·9 degrees below August's, and even October's mean temperature still remains above 50. For only towards its close does the warmth of the year begin to recede materially, and the subdued airs of summer give place at long last to the rising and rainier winds and cloudier skies of the autumn. It is not till November, however, that the year's main fall in temperature takes place. On its colder and moister airs float inland at times across the sea-level lands of the Broads, chill, invading white mists from the bordering North Sea; then in pale-sunned December the returning gleam of the gulls in the van of the cold against the cold blue of the sky, heralds the return of the winter.

The variations through the year, as will be seen, are not inconsiderable; they have indeed ranged from a dozen degrees below zero to 95·5 in the shade; from 0·12 in. of rain in a month to 6·49 in. in a day. But wide variations may well be accounted a factor of worth in a climate. For just as our vitalities are best served by alternations of activity and rest, so can our vigour be shown best furthered and enhanced by weather variations either side of the fittest mean—if we are called on to react only to unvarying conditions, our unexercised faculties tend to flag and decline. The dry cold of our winter, in short, may be regarded as the annual equivalent of our morning tub; the frequent changes of weather through the year the equivalent of our physical jerks. And while the changes in the East Anglian area of the temperate zone do not swing to hurtful excess, they are wide enough nevertheless for high fitness and vigour. The unbroken expanse of our skies exposes us alike to the sting of the sun and the passing cold shadow of cloud; our winds without hills to hinder run hard and free over level horizons. That longevity is in various East Anglian areas outstanding; that to the *Dictionary of National Biography* East Anglia contributes far above its quota of names, may evidence the worth of its conditions. May not indeed the appended figures of our climate, rightly translated, form the words, a splendid heritage?

	Temperature. Degrees F.	Rainfall. Inches	Sunshine. Hours
January	38·5	2·12	49·9
February	39·1	1·72	67·4
March	41·8	1·78	122·1
April	45·9	1·90	154·7
May	52·5	1·76	214·1
June	57·5	1·84	203·5
July	61·4	2·54	193·8
August	60·5	2·37	182·4
September	56·5	2·19	152·4
October	50·1	2·58	114·3
November	42·9	2·52	65·6
December	39·5	2·76	43·1
	Mean 48·8	Total 26·08	Total 1,563·3

IV.

THE BOTANY OF NORFOLK

BY
W. A. NICHOLSON AND E. A. ELLIS.

The general opinion of Norfolk is, that it is a flat county, with no outstanding features of great interest; but from a botanist's point of view it possesses a much more varied flora than would be expected. Perhaps its most striking characteristics are the large extent of water in the Broads district eastward and the sandy Breckland in the south-west, the latter with almost a special flora of its own. With an unstable coastline estimated at 80 to 90 miles, distant about 110 miles from the nearest point on the European mainland, its dunes and salt marshes are especially interesting from their geographical position and the frequent physiographical changes taking place. A low rainfall of 26 in., the prevalence of cold north-east winds in the springs of some years, and the occurrence of sea mists in coastal districts, exercise an important influence on vegetation.

In the following summary of what Norfolk has to offer to the botanist, the area is subdivided in accordance with special types of plant association: shingle-banks and dunes; the alga-producing zones of the sea; estuaries and salt marshes; rivers and broads; heaths (wet and dry); breckland; the chalk; wooded areas of various kinds; hedgerows and waste patches. The dominant or peculiarly interesting species are mentioned under each habitat. There follow a note on the conservation of the flora and a bibliography for the use of students.

Types of Norfolk Vegetation.

(1) *Dunes and Shingle-banks.*

The north coast, from Hunstanton to Weybourne, consists of outlying sand and shingle-ridges, broken by creeks connected with the sea, and there is a more uniform line of dunes stretching between Eccles and Great Yarmouth on the east. Blakeney Point, Scolt Head and Holme have been studied ecologically by botanists from London and Cambridge Universities, and numerous papers on the two former have been published in the *Transactions of the Norfolk and Norwich Naturalists' Society*.

Of the few shingle species, *Glaucium flavum* is found at Blakeney and Cley, having died out at Yarmouth during the past century. *Salsola kali* is widely distributed along the line of highest tides, and *Cakile maritima* frequently accompanies it; the sea pea, *Lathyrus maritimus*, is confined at a small patch at Holkham, and *Mertensia maritima* is at its southern limit of distribution in Britain at Blakeney Point. *Euphorbia paralias* rows in two places. The dunes are primarily established by *Agropyron* *junceum* and the marram, *Ammophila arenaria*, with *Festuca rubra* in many places; other grasses include *Desmazeria loliacea*, *Phleum arenarium*, *Poa bulbosa* (only in the neighbourhood of Yarmouth, where it is becoming rare through town development), *Corynephorus canescens* (especially on the east, where it is perhaps better established than in any other British station); and *Ammophila baltica* has been found in a few places. Sand sedge, *Carex arenaria*, is widespread and commonly nibbled short by rabbits.

The early-flowering annuals, *Erophila verna*, *Cerastium tetrandrum* and *C. semidecandrum*, appear ephemerally with the moss *Tortula ruraliformis* in sheltered sandy hollows between the marrams. *Arenaria peploides*, *Sedum acre*, *Vicia lathyroides*, *Lotus corniculatus* and *Galium verum* are widespread. *Teesdalia nudicaulis*, *Jasione montana* and *Ononis repens* exhibit a more heathy facies on Yarmouth Denes; the admixture of silt with the sand south of the town appears to be partly responsible for the richness of *Trifolium* species near the haven, where *T. striatum*, *T. scabrum* and the rare *T. suffocatum* grow in large patches. Sea bindweed, *Calystegia soldanella*, and sea-holly, *Eryngium maritimum*, are losing ground on the east, but are not in danger of extermination elsewhere.

The sandhills west of Wells have been colonised by *Lactuca virosa* and *Cynoglossum officinale*. *Juncus acutus* grows only on the mainland bordering Norton Creek, behind Scolt Head. *Thalictrum dunense* is threatened with extinction a little north of Yarmouth. The nearest approach to the 'slacks' of the west coast of England is found near Winterton, where hollows protected from the sea by high dunes have developed wet heath communities. The common polypody is the only fern well established in the sands, occupying mossy shelves and steep slopes in the older formations.

Some typical mosses of this region are *Polytrichum piliferum*, *P. juniperinum*, *Ceratodon purpureus*, *Dicranum scoparium* var. *orthophyllum*, *Tortula ruraliformis*, *Bryum pendulum*, *B. inclinatum*, *B. pallens*, *Brachythecium albicans*, *Hyphum cupressiforme*, *Hylocomium splendens*, *H. squarrosum* and *H. triquetrum*. Rare species confined to the coast are *Pleuridium axillare* at Yarmouth, *Rhacomitrium canescens*, *Trichostomum flavovirens* and *Bryum mamillatum* (found at Hunstanton and only one other station in Britain). Liverworts are poorly represented, e.g. by *Aneura pinguis* in a damp hollow at Scolt Head, *Lophocolea cuspidata* and *Cephaloziella starkei*.

While many of the sand lichens are common to both heaths and dunes, viz. *Cetraria aculeata*, *Cladonia furcata*, *C. foliacea*, *Peltigera canina*, the lateral shingle-spits at Scolt and Blakeney provide foothold for several *saxicolous* species, notably *Rhizocarpon confervoides*, *Lecanora atra*, *Placodium lobulatum*, *Buellia myriocarpa* and *Verrucaria maura*.

There are few of the larger fungi: of special interest are *Tricholoma bufonium*, *Astrosporina maritima*, *Tulostoma brumale*, *Gyromitra esculenta* (all on Scolt Head); *Psilocybe ammophila* and *Phallus impudicus* var. *iosmos* at Yarmouth and *Geoglossum difforme* at Burnham Overy. *Cordyceps militaris* has been found parasitising fox-moth caterpillars at Winterton. The rust *Puccinia schœleriana* is widespread on ragwort and sand-sedge, while *Elymus*, *Ammophila* and *Agropyron junceum* bear uredospores of their respective rusts throughout the year. The marram in decay is an excellent host for micro-fungi on this coast.

(2) *Marine Algæ.*

The meagre tide-range and paucity of fixed rocks on the Norfolk coast prevent extensive colonisation by seaweeds. At Sheringham and Mundesley large flints from the chalk are covered by the usual fucoids, down to the zone of *Chondrus* and *Laminaria*. Their small pools produce species of *Cladophora*, *Ectocarpus*, *Polysiphonia*, *Callithamnion* and *Ceramium*, numerous common epiphytes and tufts of *Phyllitis zosterifolia*, *Bryopsis plumosa*, *Dictyota dichotoma*, etc. The fairly extensive area of 'rough-bottom' worked by whelk- and crab-fishermen, off the north coast, doubtless provides most of the plants cast ashore after storms, as listed by the earlier recorders.

The creeks and salt marshes of the north coast, as shown by Cotton at Blakeney and Chapman at Scolt Head, afford conditions of special interest to algologists. *Lyngbya æstuarii* and *Microcoleus chthonoplastes* form felts and pans on the mud and sand surfaces; *Fucus spiralis*, *Pelvetia canaliculata* var. *libera*, and *Bostrychia scorpioides* being the noticeably peculiar species in the mass.

(3) *Estuaries and Salt Marshes.*

The great salt flats of the Wash have been largely reclaimed in recent years, and now present the somewhat uninteresting flora of meal-marshes used for grazing; the outer fringe retains its natural character, except in the neighbourhood of Heacham, where there is a curious mixture of littoral and terrestrial forms near the south beach. The north coast, on the other hand, is exceptionally rich in salt-marsh species. Much work has been done in elucidating the plant ecology of this region, the most recent being that of Chapman (3) who describes three main groups of marsh communities at Scolt Head, zoned in relation to tide levels. The lowest includes *Zostera nana*, *Salicornia perennis* and a little *Spartina stricta*; the middle group is formed of *Aster tripolium*, *Salicornia herbacea*, *Obione portulacoides*, *Suæda fruticosa*, *S. maritima* var. *flexilis*; and the uppermost of *Armeria maritima*, *Triglochin maritimum*, *Statice limonium*, *Spergularia media*, *Glyceria maritima*, *Plantago maritima*, *Artemisia maritima*, *Juncus maritimus*, *Statice reticulata* and *Obione portulacoides* var. *parvifolia*. *Frankenia lævis* and *Statice reticulata* (Mediterranean types) are at their northern limit for Britain in Norfolk.

The 'ronds' at the margin of Breydon and near the mouth of the Bure, produce quantities of *Cochlearia anglica*, which is largely replaced by *C. danica* on the north coast. *Obione pedunculata* seems now extinct near Yarmouth, and *Bupleurum tenuissimum* is rare on the marsh banks there. *Zostera marina* has so far escaped epidemic disease in Breydon, though it has decreased through the silting up of the mudflats in recent years. *Althæa officinalis* favours ditch-sides on the eastern grazing marshes where traces of estuarine salinity exist.

Many micro-fungi parasitic on the flowering plants withstand periodic immersion in salt water; these include several rusts, of which three rare British species are: *Puccinia extensicola* on *Aster tripolium* and *Carex extensa* at Wells, where Plowright first discovered it; *Uredo glyceriæ* on *Glyceria maritima* at Heacham; and *Uromyces sparsus* in all stages on *Spergularia media* at Scolt Head and Breydon (28).

(4) *Rivers and Broads.*

The shallow pools of east Norfolk, known as the Broads, almost certainly originated through the silting up of river mouths, the low-lying nature of the district and consequent slow movement of its waters, the southerly trend of tides and the shifting sand-banks of the coast. They evolved from a delta growing up by the incursion of floating reed 'hover,' the retention of silt in undisturbed backwaters, and the invasion of plants in the normal succession of alkaline fresh-waters. The circulation of water is greatest in the Yare valley, moderate in the Ant and Thurne, and least in the Bure broads; in addition, the Thurne is brackish, especially at its source (16).

Briefly, the plant communities are: (1. Submerged-leaf; 2. Floating-leaf;) → 3. Primary reed-swamp; → 4. Closed reed-swamp; → (5. Sallow-Alder carr or 6. Sub-acid fen).

The vegetation of the Broads is described in detail in references 16, 18, 5, and 9. Here a few plants only, in each community, can be mentioned.

In (1) and (2) the aquatic Ranunculi are well represented: *Castalia alba* is most abundant at Sutton Broad and *Myriophyllum verticillatum* at Barton. *Œnanthe fluviatilis* keeps mainly to the upper reaches of the rivers and *Œ. phellandrium* is common in the neighbourhood of Heigham Sound. *Utricularia vulgaris*, *U. minor* and *U. intermedia* occur in fen pools (10). *Hottonia palustris* is frequent in dykes; *Elodea canadensis*, *Ceratophyllum demersum*, all the British species of *Lemna* and eighteen *Potamogetons* flourish in the Broads; among the more interesting of these last are *P. zosterifolius*, *P. acutifolius*, *P. trichoides* and *P. interruptus*, with *P. freisi* rather common. *Naias marina*, in Britain, is confined to a few of those Norfolk Broads where the water is very slightly brackish on occasion.

Stratiotes aloides is plentiful in the Ant district and at Rockland Broad, occurring also in many of the larger dykes. It is interesting to remember that this species to-day produces only the female plants in our latitudes, both sexes being found midway between this and the extreme south of Europe, where only males occur; seeds found in the East Anglian Forest-beds show that both sexes lived here at one time (see A. M. Geldart, *Norf. Nat.*, vii, 181). *Azolla filiculoides* has spread in the Bure dykes since the flood winter of 1912 dispersed it from Woodbastwick (21). The floating liverwort, *Ricciocarpus natans*, is plentiful at Sutton.

The filamentous algæ of this region have been almost completely neglected, though Kitton (36) and others studied the diatoms to good effect. The *Charophyta* have received careful attention, and several of the rarer British species live in the broads and meres of this county, notably *Nitella* *flexilis*, *N. translucens*, *N. tenuissima*, *Tolypella prolifera*, *Chara canescens* and *C. connivens* (30, 31).

(3) *Ranunculus lingua*, in the forefront of the reed advance, is becoming scarcer. *Typha latifolia*, *T. angustifolia* and *Sparganium* spp. are often abundant, with odd clumps of *Rumex hydrolapathum*. *Scirpus lacustris* is, as Miss Pallis puts it, ' the most aquatic of the reed-swamp dominants ' in the broads of the Bure and its tributaries, but almost absent from extensive swamps in the Yare valley (5).

(4) The ' closed ' reed and reed-grass communities vary as to their dominant species in the separate river systems. In the Bure region *Phragmites communis* holds sway, while that of the Yare is to a great extent characterised by the presence of much *Glyceria aquatica*, in some places almost excluding *Phragmites*. *Thalictrum flavum* is common in the latter and almost completely absent from the former. The following are common to most well-established marshes of this kind, varying to some extent as the area is frequently or irregularly mown or burnt : *Lychnis flos-cuculi*, *Lotus uliginosus*, *Vicia cracca*, *Spiræa ulmaria*, *Lythrum salicaria*, *Epilobium hirsutum*, *Angelica sylvestris*, *Peucedanum palustre*, *Valeriana officinalis*, *Eupatorium cannabinum*, *Cirsium palustre*, *Lysimachia vulgaris*, *Iris pseudacorus*, *Cladium mariscus* (locally), *Carex riparia*, *C. acutiformis* and *C. paniculata*, *Phalaris arundinacea*, occasionally *Calamagrostis canescens*, *Poa trivialis*, *Festuca elatior* and *Equisetum palustre*. *Cicuta virosa* thrives at the edge of many tussock-swamps. *Lathyrus palustris* is becoming rarer, requiring as it does conditions which are transient in marsh development. *Œnanthe lachenalii* is present, usually near the lower reaches of the rivers, where also *Sium latifolium* is not uncommon. *Sonchus palustris* is well established among reeds beside the Bure and Waveney, in two stations ; and *Acorus calamus* grows beside several of the broads. *Butomus umbellatus* is not uncommon in dykes, especially in the Yare Valley.

(5) Thickets of alder or sallow and ash frequently encroach on the older reed-swamp, eventually dominating it ; the margins of these ' carrs,' as they are called, are often marked by trailing masses of *Calystegia sepium* and patches of *Solanum dulcamara*. Clumps of *Carex paniculata* line channels passing through them, and in some of the spaces *Osmunda regalis* grows, with *Dryopteris thelypteris*, *Peucedanum palustre*, and relics of the earlier marsh flora. The wilderness of fallen branches is comparatively rich in mosses and lichens. *Ribes nigrum*, *R. rubrum*, *Rhamnus catharticus*, *R. frangula*, and *Viburnum opulus*, are typical shrubs in this community ; ash becomes abundant, with oak and hazel coming in at the climax.

(6) In the ' growing-up ' process, certain pools and hollows in the marshes tend to become isolated and poorly drained, presently supporting the flora of a sub-acid fen (9) with *Sphagnum*, *Viola palustris*, much *Hydrocotyle vulgaris*, *Eriophorum* spp., *Juncus subnodulosus* and *Schœnus nigricans*, and may develop into wet heath (*q.v.*). The birch frequently encroaches on such areas.

Fungi typical of the sallow-carrs are *Trametes rubescens* and *Pholiota erinacea*, which are frequent on the dead boughs. The whole of the marsh area is remarkably interesting for its micro-fungi. A few of the rarer rusts may be mentioned : *Puccinia thalictri* on *Thalictrum flavum* at Wheatfen Broad ; *P. cicutæ* on *Cicuta virosa* at Surlingham ; *P. bullata* on *Peucedanum palustre* and *P. paludosa* on *Pedicularis palustris* and *Carex goodenowi* at Irstead. *Hypnum scorpioides, H. giganteum* and *H. cuspidatum* are three of the most important mosses carpeting the fens.

(5) *Heaths : Wet and Dry.*

Many of the more interesting heaths are to be found within a few miles of Norwich, including those of Felthorpe, Flordon, Hevingham, Horsford, Stratton Strawless and Swannington (4). 'Two distinct types of swamp occur in the area, one associated with Calluna heath, and the other related to fen. The former is restricted, with few exceptions, to the heads of valleys, the water of which reaches it percolating non-calcareous beds. As the main water supply of the county is calcareous, swamps associated with the principal streams and those on boulder clay, are of fen type. An interesting exception to this is the frequent occurrence of heath-swamp species in fen, attributable to two distinct sources of water, the swamp being inundated by a calcareous stream, while a more local drainage from gravel supports heath-swamp species at a level slightly above that of the marsh floor. Species common on acid peat but absent from fen are : *Drosera rotundifolia*, *D. longifolia*, *Erica tetralix*, *Gentiana pneumonanthe*, *Juncus squarrosus*, *Nardus stricta*, *Lycopodium inundatum*, *Sphagnum* sp., *Aulocomnium palustre* and *Gymnocolea inflata*. Plants common to both acid peat and fen are : *Parnassia palustris*, *Salix repens*, *Juncus effusus*, *J. subnodulosus*, *J. sylvaticus*, *Eriophorum angustifolium*, *Schœnus nigricans*, *Deschampsia cæspitosa*, *Hypnum scorpioides* and *H. cuspidatum*' (4).

Genista anglica is locally common on moist, peaty heaths ; *Ulex galii* and *U. minor* are both recorded here, the former in some abundance. *Scutellaria minor* is rare and known only from the eastern division of the county, Buxton Heath, Hevingham, being one of its few remaining stations. Of the orchids, *Liparis lœseli* and *Malaxis paludosa* are rare in spongy bogs, and *Goodyera repens* is established in fir woods and on open heathland in the north-east of Norfolk, where it is thought to have been accidentally introduced from Scotland. *Narthecium ossifragum* is rare and seems to have disappeared from several of its old habitats, now lingering only in the west ; there is no extensive moorland to encourage it. *Deyeuxia neglecta* has been identified from Hockham Mere (only).

The Bryophyta and Lichens of Norfolk heaths exhibit no special departures from what might be expected, considering the low rainfall.

Fungi of special interest are : *Bovistella paludosa* and *Entoloma bloxami* on Buxton Heath ; *Flammula decipiens* on furze-stumps at Ringland Hills ; *Collybia leucomyosotis*, *Naucoria myosotis*, *Omphalia posti* and *O. sphagnicola* in Sphagnum bogs ; *Russula claro-flava* in Sphagnum under birches at Calthorpe, Hoveton and Westwick ; *Paxillus giganteus*, sometimes in large groups on heaths ; *Xerotus degener* (once). Norfolk is very rich in *Boleti*. The rarer rusts include *Puccinia hydrocotyles*, *P. dioicæ* and *Phragmidium tormentillæ*.

(6) *Breckland.*

A considerable area of south-west Norfolk, forming part of the 'Breckland,' is covered by a pall of sand on which grow a number of plants almost confined to this district in Britain (4). The steppe element in the flora includes the following species, which are dealt with at some length by E. J. Salisbury (18): *Silene conica*, *S. otites*, *Holosteum umbellatum* (now extinct here?), *Medicago falcata*, *M. minima*, *Artemisia campestris*, *Veronica triphyllos*, *V. verna*, *V. spicata*, *Scleranthus perennis*, *Muscari racemosum* and *Phleum boehmeri*.

Medicago sylvestris, long known from East Anglia as a plant of somewhat variable and uncertain character, intermediate between *M. sativa* and *M. falcata*, is the hybrid of these two species, where they grow in the breckland and on the coast. It has been shown (8) that the effect of their hybridisation tends to eliminate the native *M. falcata*.

Other interesting plants are *Galium anglicum* and *Herniaria glabra* (South European types), *Carex ericetorum* (North Continental), *Malva moschata*, and *Tillæa muscosa*. *Viola lutea*, in East Anglia, grows only in the breck district.

The afforestation of Thetford Chase and much of the surrounding land has been carried out during the past few years, and the pines are obliterating the native plants on some thousands of acres. The State Forest is laid out in blocks of about thirty acres, bounded by rides and occasional public roads—the spaces forming 'fire-breaks.' These pathways are bordered mainly by oak and beech. About one-fifth of the blocks are of beech and larch, while most of the trees are Scots and Corsican pines (13).

(7) *The Chalk.*

The following notes are from a paper by the late W. G. Clarke (4). The Chalk Flora of Norfolk, unlike that of most other places, is mainly on the Lower and Middle Chalk. The beech and ash-wood associations, so typical of downland elsewhere, are quite absent. Ringstead Downs and Massingham probably form the best examples of chalk downland in the county. The most characteristic plants are *Reseda lutea*, *R. luteola*, *Orchis pyramidalis*, *Ophrys apifera*, *Helianthemum chamæcistus*, *Hippocrepis comosa*, *Astragalus danicus*, *Spiræa filipendula*, *Poterium sanguisorba*, *Asperula cynanchica*, *Scabiosa columbaria*, *Campanula glomerata*, *Plantago media* and *Origanum vulgare*.

The only moss actually confined to the chalk in Norfolk is *Seligeria calcarea*. *Thuidium abietinum* is found only on calcareous soil; *Camptothecium lutescens* is common in chalk-pits and on West Norfolk heaths, and *Barbula tophacea* where water stands occasionally in the pits. *Porotrichum alopecurum* and *Anomodon viticulosus* are lime-loving species common on chalky boulder-clay.

(8) *Woodlands.*

Norfolk has no great extent of wooded areas, and what there are have nearly all been planted. Perhaps the best district for pine and birch-scrub, outside the breckland, is that outlined by Norwich, Reepham, Holt, Cromer and North Walsham. The occasional small woods on boulder-clay are mainly of oak and ash. Specimen trees of sweet chestnut, beech and Atlantic cedar, are to be seen at Stratton Strawless, where there is also a good deal of hornbeam.

Few peculiarly East Anglian features may be noticed among the herbaceous plants in the woods. *Primula elatior* is present in the south-west, but occurs more abundantly in the clay lands of Suffolk ; *Hypericum hirsutum*, similarly, is much less frequent here than there. *Paris quadrifolia* exists in a few small woods. *Epilobium angustifolium* has spread rapidly to most woodland clearings in recent years.

Mr. G. J. Cooke has supplied a list of some of the more interesting fungi : *Geaster bryanti*, *G. triplex*, *Cyathus striatus*, *Amanitopsis nivalis* (West Runton and near Norwich), *A. strangulata*, *Pholiota grandis* (beech-stump, Bawburgh), *Cortinarius sanguineus* (Sprowston), *Hebeloma sinuosum* (Stratton Strawless), *Psilocybe sarcocephala* (Framingham), *Polyporus schweinitzi* (increasing north of Norwich, where it is damaging silver firs), *Sparassis crispa* (sparingly, on pine stumps), *Hymenochæte mougeoti* (on fir, Northrepps), *Clavaria fistulosa* (on birch twigs, Framingham and Stratton Strawless), and *Inocybe hystrix* (Sprowston). Most of the woods produce, typically, *Collybia butyracea* and *Clitocybe geotrupa* ; the pine woods, *Flammula sapinea*, *Inocybe rimosa* and *Clavaria rugosa*. Mossy glades and banks often yield *Cantharellus cibarius*, *Tricholoma sulphureum* and *Clitocybe odora*. *Tricholoma nudum* is exceedingly common in the county, whereas *T. personatum* and *T. gambosum* are local and uncertain in appearance. *Clavaria inequalis* is common, but *C. cristata* and *C. cinerea* are seldom met with. *Helvella crispa* is frequent in occurrence, while *H. lacunosa* appears to be distinctly local. About twenty specimens of *Verpa digitaliformis* appeared at Drayton, under hawthorns and elms, in May 1934. *Sarcoscypha coccinea*, uncommon in East Norfolk, has developed regularly in January for many years, on fallen hazel twigs at Earlham. *Cordyceps capitata* was recorded by Sowerby as having been sent to him from Holt ; it still occurs sparingly in woods of the Holt-Cromer ridge.

(9) *Hedgerows and Waste Patches.*

With modern agricultural methods in the fields, and the practice of severe hedge-trimming in these days of the motorist, several plants have become scarcer by the wayside, notably *Verbascum thapsus*. *Myosurus minimus* is of very uncertain occurrence at neglected field-margins.

Chelidonium majus is frequent near houses ; *Coronopus didymus* has spread on to waste ground at Yarmouth, with *Lepidium draba* and *Senecio squalidus* (both increasing their range in Norfolk). *Claytonia perfoliata* is established on many banks and forms large patches under pines, especially in breckland. *Geranium pyrenaicum* is almost confined to roadsides bordering the Waveney valley, while *G. rotundifolium* is abundant at Caister, near Yarmouth. *Smyrnium olusatrum* thrives all along the coast and inland beside the river-valleys. *Sambucus ebulus* and *Lonicera caprifolium* are rather rare, in hedges. *Matricaria suaveolens* is widespread on pathways now. *Verbascum pulverulentum* is still locally common in the Norwich district.

An interesting case of hybridisation between *Tragopogon porrifolius* and the small form of *T. pratensis* took place on a piece of derelict ground at Yarmouth recently, the F. 1 hybrids appearing first in 1929. Subsequent generations have produced sixteen distinct forms, most of them reappearing each year on the original plot, while others have been the subject of experiment (5).

Conservation of the Flora.

This county is fortunate in its protected areas, administered by the Norfolk Naturalists' Trust, such as Scolt Head, Blakeney Point and Alderfen Broad. Of necessity, much of the breckland will be altered through afforestation. Hockham Mere has been drained recently and its flora is changing already to a marked degree. Reclamation in the Wash has greatly reduced the area attractive to botanists there. Many of the smaller heaths have suffered from fire damage, especially in the dry summers of 1933 and 1934; this menace calls for more organised effort in combating it, as the effects on wild life are often irreparable.

The northward extension of Great Yarmouth imperils many of the peculiar species there, and already the main portion of the denes has been levelled and the endemic flora destroyed.

Fen development is so rapid that the preservation of its character becomes a matter for man's intervention in the interests of biology. The natural dominants of this type of community require periodic setbacks such as the removal of floating reed-bed where it tends to block channels, the clearing of patches in carrs, and the mowing of selected pieces of marsh. This is being done successfully by the owner of a large tract of fen and small broads at Surlingham.

It is more than ever necessary for an authoritative conclave of botanists to keep watch over the county's flora at vulnerable spots, and be recognised in its efforts to avert botanical calamities.

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V.

AFFORESTATION AT THETFORD CHASE

BY

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The Forestry Commissioners last year re-issued a pamphlet, *Forestry Commission Areas in Norfolk and Suffolk*, and most of the data in the following notes have been taken from that publication.

At Thetford Chase the Commissioners have planted 26,000 acres out of about 34,000 acres of plantable land acquired. Nearly all of this is too poor for agriculture, but is capable of producing forest crops of the less exacting species. In course of time this big tract of land should bear valuable timber, the soil will undoubtedly improve under forest occupation, and, meanwhile, tree-planting and tending operations are having a favourable effect on employment.

Most of the areas being afforested are on level or gently undulating land, consisting of sandy soil overlying chalk. The lack of natural shelter intensifies the effects of spells of east wind and frost in spring, and of drought in summer. Scots pine and Corsican pine suit the locality and produce a class of timber for which there is always a large and ready market. Beech may also be grown, and is particularly suitable for planting where the chalk comes near the surface; as is well known, however, it is very susceptible to damage from frost, especially in its early years, and to overcome this difficulty is one of the most serious problems engaging the attention of the Commission. Beech will probably continue to be difficult to establish until the time for re-stocking in the second rotation arrives, when shelter will be afforded by the older trees. Douglas fir and larch are capable of satisfactory growth if uninterfered with by frost, but apparently there is risk of heart-rot in the latter species. Considerations of amenity and fire protection have prompted the planting of hardwood belts along roadsides and elsewhere, prominent among the species used being English oak, American oak, Spanish chestnut, copper beech and black Italian poplar.

Before planting is commenced on any of the areas, wire-netting fences have to be erected and rabbits excluded. It might be thought that the extermination of rabbits inside the enclosures would be a difficult matter in such sandy soil and on areas which were practically rabbit warrens before afforestation. The local warreners, however, are experts at their work and their methods have been so effective that no considerable damage has been done since operations commenced. Previous to planting, surface vegetation has sometimes to be burnt off, but in places which have not been fenced, rabbits keep all growth except perhaps patches of gorse and bracken in check to such an extent that burning is not always necessary. In cultivating the ground shallow furrows are ploughed, 4 ft. 6 in. apart, and seedlings or small transplants are then 'notched in'—a vertical slit being made for the plant's reception. Direct sowing of pine seed has been tried, but although some plantations have been successfully established in this way, the method is on the whole less satisfactory than planting, and not much less expensive.

Most of the conifer plants have been raised locally, the Forestry Commission having nurseries at Weeting, Lynford, West Harling and Santon Downham. In these nurseries approximately 10,000 lb. of seed are sown annually, and several million seedlings and transplants are raised.

In common with pine plantations in other areas of low soil fertility, those at Thetford have suffered to some extent from insect pests, particularly from caterpillars of the pine shoot moth (*Tortrix* (*Evetria*) *buoliana*), and those of sawflies (*Lophyrus pini* and *L. rufus*). With regard to the tortrix, disbudding has been carried out without much success, but thinning operations should easily correct matters by gradually eliminating the deformed trees. As for the sawflies, their natural enemies soon gain the upper hand when the rate of increase becomes too great.

The risk of loss from fire in plantations so largely composed of resinous species causes much anxiety, but elaborate precautions, including the erection of a look-out tower, have been taken to ensure safety and the various protective measures are frequently revised and made more effective.

To increase the supply of local labour and to improve conditions for the workpeople, forest workers' holdings to the number of about 160 have been established. Each holder is allotted about 6 or 7 acres of land, and he is guaranteed a minimum of 150 days' employment per annum. The scheme has worked well and has proved an important means of arresting rural depopulation in the district. New bungalows for the holdings are erected at a cost of from £350 to £400, according to situation, and where old buildings have been converted the reconstruction has cost on an average from £150 to £250.

As to the final results of afforestation at Thetford Chase, only a rough forecast can be given, but as an indication it may be stated that the conifer plantations will be felled at about seventy years of age when fully-stocked areas may be expected to yield 3,000 to 4,000 cubic feet of timber per acre. This should assist in supplying the enormous demand for softwoods for building, railway sleepers, etc. Poles, pitprops and fencing material will also be obtained from the thinnings, which will be made at regular intervals until the crop attains maturity.

VI.

THE ZOOLOGY OF NORFOLK

BY

HENRY J. HOWARD, F.L.S., F.R.M.S.

NORFOLK is undoubtedly one of the finest counties in the kingdom for the zoologist. Possessing as it does a variety of physical features—sea-coast and salt marsh, large stretches of water known as the 'Broads' with river systems and innumerable dykes, and also large areas known as 'breckland'—it is not surprising that it has a varied and interesting fauna. On the other hand, there is no real forest, and consequently many forest denizens, particularly insects, are wanting; however, there are numbers of woodlands.

While there are several accounts of the fauna of Norfolk, the main sources are those contained in the *Victoria County History* (*Norfolk*), Mason's *History of Norfolk*, but especially the vast amount of material contained in the *Transactions of the Norfolk and Norwich Naturalists' Society*, which began to publish accounts of the fauna and flora of the county of Norfolk in 1871, and has continued so doing to the present time.

I am greatly indebted to various observers upon various groups, especially to Mr. A. H. Patterson upon Mammals and Fishes, Mr. H. E. Hurrell on *Polyzoa* and *Rotifera*, and Mr. E. A. Ellis on *Mollusca*.

MAMMALS.

Carnivora.—The otter (*Lutra vulgaris*) is not uncommon in the Broads and elsewhere; shallow broads like Rockland and Barton are favourite haunts.

The fox (*Vulpes canis*), unless protected, would not be tolerated in a game country; the few found in Norfolk possibly owe their origin to other parts of the country, or importation from abroad.

The marten (*Mustela martes*). In a paper read before the Zoological Society of London, in June 1879, Alston showed that there was no evidence whatever for the existence of the true *M. foina* at any time in Britain, and that those previously met with in the first two decades of the nineteenth century in the county, belonged to the above species; since then it has become extinct.

The stoat or ermine (*M. erminea*) is a fairly common animal, and is found both on the rabbit warrens of Breckland and on the marshlands.

The polecat is now a very rare animal in Norfolk and, like the previous species, is occasionally met with on rabbit warrens. I have not been able to obtain definite records within the last few years.

The badger (*Meles taxus*) is now almost extinct in the county; it is recorded from Holkham (1875), Kelling Heath (1877); from information received I believe there is one 'set' left.

Phocidæ.—The common seal (*Phoca vitulina*) occurs rather too plentifully in the Wash, lying between the Norfolk and Lincolnshire coasts, and several are sometimes seen upon the sandbanks off Blakeney Point.

The ringed or marbled seal (*P. hispida*) was killed on the coast in 1846.

The grey seal (*Holichærus gryphus*); a specimen killed on Breydon in 1882 is now in the Castle Museum.

Cetacea.—The Atlantic right whale (*Balæna biscayensis*). A small one is said to have been taken near Yarmouth in 1784.

Common rorqual (*Balænoptera musculus*). One entered Yarmouth Harbour some thirty years ago; Winterton 1857; Happisburgh 1875; and one was found floating dead in the Lynn Roads the same year.

Lesser rorqual (*B. rostrata*). One was recorded in 1891; a dead specimen was stranded at Gorleston in 1896.

Beaked or bottle-nose whale (*Hyperoodon rostratum*) has occurred several times.

Grampus or killer (*Orca gladiator*). Two very small ones were brought into Yarmouth, November 13 and 19, 1894.

White-beaked dolphin (*Delphinus*) is recorded from Yarmouth, Gorleston and Breydon.

Porpoise (*Phocæna communis*) is seen off the coast; has been known to enter the river; and found stranded upon the mud at Breydon.

Sperm whale (*Physeter macrocephalus*). Sir Thomas Browne records stranded specimens on the coast about 1626 and 1646; no modern instance is known.

Pilot whale (*Globicephalus melas*) was washed ashore at Mundesley 1879.

Rodentia.—The red squirrel (*Sciurus vulgaris*) is seen in many parts of the county, and as far as my knowledge goes the grey squirrel has not yet obtained a footing.

The dormouse (*Muscardinus avellanarius*). This rodent has been seldom met with, and only in the Waveney valley.

Harvest mouse (*Micromys minutus*). This species is sometimes met with during threshing operations; its distribution at the present time is local, largely as the result of modern harvesting methods.

Long-tailed field mouse (*Apodemus sylvaticus*). This is widespread, being encountered in sheds and dwellings in winter; it occurs in marshland as well as in drier situations.

The house mouse (*Mus musculus*) is only too common.

The black rat (*Epimys rattus*) is still to be found in cellars and malthouses bordering the river at Yarmouth, and doubtless shipping is responsible for its re-introduction; brown forms, determined by A. H. Patterson as *E. alexandrinus*, are occasionally met with.

The brown rat (*E. norvegicus*) is common everywhere.

The water vole (*Arvicola amphibius*) is a common resident of the Broads district, where banks of dykes are frequently tunnelled; it has been known to eat swan mussels, which it carries on to the dyke banks.

The common field vole (*Microtus agrestis*) with its variety *hirsutus*, a large form, is common on both marshlands and uplands. Marked fluctuations have been noted in its occurrence, and vole years have been correlated with an increase in nesting short-eared owls.

The bank or red field vole (*Evotomys glareolus*) is locally plentiful.

The common hare (*Lepus europæus*) is widely distributed.

The rabbit was once extremely abundant in Breckland; it has been severely discouraged during the planting of the new State forest.

Insectivora.—The mole (*Talpa europæa*) is abundant, especially in the marshlands; the cream-coloured form has occasionally been found in some numbers.

The common shrew or 'ranny' (*Sorex araneus*) is probably the commonest mammal, being found in both dry and marshland soils. The water shrew (*Neomys fodiens*) is not uncommon, although by reason of its unobtrusiveness it is not often seen.

The pigmy shrew (*Sorex minutus*) is usually found near water, and is of local distribution.

The hedgehog (*Erinaceus europæus*) is widespread throughout the woodland districts of the county.

Chiroptera.—The bats of Norfolk have not been investigated with any thoroughness; the commonest species are the pipistrelle (*Vespertilio pipistrellus*), long-eared (*Plecotus auritus*), barbastelle (*Barbastella barbastellus*), and noctule (*Nyctalus noctula*). The rare parti-coloured bat (*Vespertilio murinus*), regarded as British on the strength of two specimens, was taken at Yarmouth in the thirties of the last century; it may possibly have been carried by a ship. The red-grey, or Natterer's bat (*Myotis natteri*), which is not generally distributed, even in the South of England, has occurred in Norfolk.

Birds.

The county has long been noted for its ornithologists, notably the Gurneys and Henry Stevenson. Its geographical position on the main migration routes makes it peculiarly attractive in spring, when many waders drop into Breydon and the creeks of the north coast. A notable feature is the east to west passage of warblers, flycatchers, wheatears, common redstarts, and rarer insect-eating birds, such as the blue-throats and black redstart, in late August and September, when they rest among the sandhills along the shore. Winter visitors to the coast include shore larks, snow bunting, and Lapland bunting, which congregate occasionally in considerable flocks. The hen harrier wintering in the Broads is replaced in spring by marsh and Montagu harriers, which have become re-established as breeding species only within recent years. Other birds which have responded to protection are the bittern and bearded tit, which are extending their range into two other counties.

The avocet, spoonbill, black-tailed godwit and ruff at one time nested in the county; they are fairly regular visitors to the Broads and coast in small numbers to-day; the ruff has once again returned to nest (temporarily), and there is now a substantial hope that before long they may once again be re-established as nesting species.

Norfolk is particularly well favoured in possessing controlled areas such as Scolt Head, Blakeney Point and Cley marshes, where watchers are maintained by the Norfolk Naturalists' Trust. These sanctuaries are noted breeding places of the terns (five species in all are recorded), oyster catchers, ringed plovers, sheld duck and redshank.

The stone curlew or Norfolk plover is at home in the Breckland, where the probable effect of afforestation, now being carried out on an extensive scale, will be to compel them to concentrate on a few favoured open spaces.

The heron is a widely distributed resident in Broadland, and at one time there were many heronries in the county, but many of the older ones have disappeared, the largest and best known now in existence is at Reedham.

More birds have been recorded for Norfolk than for any other British county, and it is impossible to give even an adequate summary here. The writer would refer those interested to the many good books dealing with Norfolk ornithology.

Reptiles.

The grass snake (*Trepidonotus natrix*) cannot be called common although it is widespread, often frequenting marshy spots where frogs abound. The viper (*Vipera berus*) shows little variation in this county ; it is locally abundant on heathlands and sandhills. The common lizard (*Lacerta vivipara*) is found on heaths and hedge banks, while the slow-worm (*Anguis fragilis*), less common than in some of the southern counties, is not infrequently found in grassy spots.

Amphibians.

Of the three species of British newts, the smooth newt (*Molge vulgaris*) is by far the most common ; the great crested (*M. cristata*) is not uncommon in ponds, while the palmated newt (*M. palmata*) has seldom been identified.

The common frog (*Rana temporaria*) and toad (*Bufo vulgaris*) are ubiquitous, but the Natterjack or ' running toad ' (*B. calamita*) is confined to sandy ground near the coast, and is of very local distribution.

Fishes.

Each autumn finds the East Anglian herring fishery in full swing and its importance is too well known to need comment. The recent economic difficulties of the industry are referred to in a later chapter. The intensive research into the habits of the herring, carried out by the staff of the Fisheries Laboratory at Lowestoft, has had practical results, e.g. in the accurate forecast of yearly fluctuations in marketable fish, and the effect of plankton concentration on the movements of the herring. The mackerel fishery once carried on at Yarmouth has ceased to be practicable. To a minor degree the catching of smelts and of longshore herring takes place mainly near Yarmouth. Large shoals of whiting appear inshore every autumn, preceded by dogfish and followed by codling ; this phenomenon is well known to the sea-angling fraternity.

Mr. A. H. Patterson at Yarmouth has for many years kept close watch upon the catches brought in by shrimpers, longshoremen, as well by those fishing farther afield, and has increased the number of Norfolk species listed to 161, double that of a century ago. A few of the more interesting additions are given here: bergylt, Black Sea bream, boar fish, short-finned tunny, ribbon fish (young), gattorugine, power cod, pollack, four-bearded rockling, common and Eckstron's top knots, pearl-sides, and black-mouthed dogfish. The blue, basking, thresher, and porbeagle sharks have been encountered in the fishing grounds and dead specimens occasionally washed ashore have in most cases doubtless received rough treatment by fishermen.

Coming to the freshwater fishes: the eel's passage up and down streams is intercepted by numerous eel-setts often marked by the presence of an eel-catcher's hut or houseboat at the river side. The common bream thrives exceedingly in the shallow Broads as does also the pike, the latter not rarely attaining a weight of from 25 to 30 lb. The minnow is not known to occur below Norwich. Roach, perch and rudd are commonly fished for in the rivers and broads.

The Invertebrate Fauna.

The county offers ample facilities to the student of Invertebrate Fauna, possessing as it does a system of broads, five river systems with a network of dykes, innumerable ponds, as well as a sea coast and estuarine waters. It is, however, difficult in a small space to give even the briefest possible survey of the various groups included under the above title.

Protozoa.—Many well-known forms are widely distributed throughout the county. The various species of *Vorticellæ*, including *Carchesium* occur, and special mention may be made of *Zoothamnium geniculata*, first observed and described by Mr. Ayrton in the River Waveney at Beccles in Suffolk, and subsequently found by Mr. H. E. Hurrell at Brundall in the River Yare.

Coming to the *Rhizopoda* the only group which has been intensively studied is the *Mycetozoa* to which the author has devoted some twenty years' work in the county. In spite of the relatively dry climate, the average rainfall being about 26 in., the number of species recorded for Norfolk is remarkably high; 133 species and 22 varietal forms having been recorded to date. Among interesting and rare species met with may be mentioned the following: *Physarum carneum*; with the exception of a small gathering made near Lisbon, this species which occurred plentifully at Thorpe, Norwich, has only been found in Colorado, U.S.A. *P. javanicum* (first British record), *P. gyrosum* which has been repeatedly met with in cucumber houses at Eaton, Norwich, *P. lateritium*, only once previously recorded for this country, *Lamproderma atrosporum* var. *debile*, and var. *anglicum* found at Whitlingham on dead beech leaves were new to science, and *Cribraria piriformis* var. *fusco-atra* on a moss-covered pine log at Stratton Strawless, a varietal form which has so far only been discovered in the Jura Mountains of Switzerland.

Porifera.—The sponges are poorly represented; *Halichondria panicea* and *Chalina oculata* being the only two species which are at all plentiful.

The two fresh-water species, *Spongilla lacustris* and *S. fluviatilis*, are widespread in the rivers and broads; the latter also occurring in brackish water at Horsey.

Coelenterata. The Sea Anemones.—The coast of Norfolk is not congenial to the sea anemones which prefer solid rock and a greater tide range. However, piles and breakwaters, wrecks, and shore boulders with tide pools in chalk such as occur near Sheringham, give them a foothold. The commonest species here as elsewhere is *Actinia equina*, but it does not attain a large size. *Tealia felina*, the dahlia anemone, also occurs anchored to stones with its tentacles protruding from a covering of muddy sand. The most interesting species, however, is *Diadumene luciæ*, first found by Dr. Robert Gurney in the summer of 1921 in the brackish pools at Salthouse. This species is of rather exceptional interest by reason of its distribution both in this country, in Holland, and the United States. It has also been found on Ulva in Wells Harbour, and clinging to stones in Breydon. *Mitridium senile*, the plumose anemone, also occurs in its three varietal forms on the coast. *Alcyonium digitatum* occurs locally.

Among the Marine *Hydroids* several species of *Sertularia* are dredged up in the nets of shrimpers. *Tubularia indivisa*, *Campanularia verticillata*, *C. flexuosa*, *Halecium halecinum*, and *Antennularia antennina* are common on sandy bottoms; *A. ramosa* is seldom met with. *Obelia geniculata* is abundant on piles at Yarmouth.

Among the jelly fishes only two species are common, viz. *Aurelia aurita* and *Cyanea capillata*.

Of the *Ctenophora*, *Pleurobrachia pileus* swims inshore in summer months.

Cordylophora lacustris is found attached to reed stems growing in brackish water, especially in the Thurne and its associated broads.

Of the fresh-water species of *Hydrozoa*, *Hydra viridis*, *H. fusca*, and *H. vulgaris* are common and widely distributed.

Platyhelminthes.—This group has not been investigated in the county, but it is worthy of note that the effects of *Fasciola hepatica* (causing ' liver-rot ' in sheep is much less in evidence than formerly, due to scientific methods and the rearing of sheep on higher grounds.

Rotifera.—Mr. H. E. Hurrell, of Great Yarmouth, has devoted many years of study to this group resulting in a large number of species being added to those enumerated by the late Thomas Brightwell of Norwich in 1848. Many species that are to be found in the brackish waters of ditches surrounding Yarmouth are not to be found in fresh water more inland. From the fact that the Rev. R. Freeman was able during six days' work at the Sutton Broad Laboratory in 1904 to collect about 120 species shows that the Rotiferan fauna of the Broads must be a very rich one. Although it is impossible to give the distribution of the numerous species, mention may be made of the rare *Pedalion mirum*; a single specimen being discovered in a tow-net collection of Rotifers including *Polyarthra paltyptera*, *Asplanchia*, and *Triarthra* in the River Ant near Ludham Bridge, in August 1906. It was found in abundance also by Dr. Robert Gurney in Langmere and Ringmere in September 1919, and also by Mr. Hurrell in a pond in his garden at Yarmouth.

Annelida.—Practically all our knowledge of the earthworms of Norfolk is due to the work done upon the group by Mr. A. Mayfield. The study was further taken up by the Rev. Hilderic Friend, whose paper in *Trans. N. N. Nat. Soc.*, vol. ix, part 3, pp. 394–405, upon 'Some Norfolk Annelids' (with special reference to Sutton Broad) should be consulted; he records some 38 species. Among other *Polychæta* may be mentioned *Nereis diversicolor*, abundant in Breydon and other estuarine habitats; *Aphrodite aculeata*, the sea mouse, is not uncommon on the coast; *Arenicola marina* (lugworm) is dug for bait in a few places, e.g. Blakeney; *Lanice conchilega* builds its tubes in the sand at Yarmouth, Sheringham, etc.; *Pectinaria korenii* is occasionally washed ashore in large quantities.

Hirudinea.—Among the leeches *Hæmopis sanguisuga*, *Herpobdella atomaria*, *Glossosiphonia companulata*, and doubtless others occur commonly in Norfolk waters.

ARTHROPODA.

Crustacea.—With the exception of records due to a German exploration of the North Sea carried out about three-quarters of a century ago on the ss. *Pommerania*, and scattered references in works on British *Entomostraca*, little fresh material had been published on the *Crustacea* of Norfolk prior to 1904. For Marine *Crustacea* conditions are not very favourable; although the county has a lengthy coastline there is an absence of sheltering inlets which foster many aquatic invertebrates; the temperature of the water too is subject to considerable fluctuation.

Crab and lobster fisheries are carried on at Cromer, Sheringham, Runton, and Weybourne, where large flint boulders upon a bed of marl with a vast forest of seaweed form a splendid feeding place for the edible crab. They are taken in pots set out to sea from the foreshore to a distance of two miles; the fishing grounds cover an area of about sixteen square miles.

The most recent work upon the Marine *Crustacea* was carried out in the region around Blakeney Point by T. J. Hart, and the following brief notes are taken from his paper 'Notes on the *Crustacea Malacostrata*' in the area mentioned (*Trans. N. N. Nat. Soc.*, 1929–1930).

Decapoda.—Cancer pagurus (edible crab) chiefly frequents inshore during ecdysis. *Carcinas mænas*: these shore crabs or 'ghillies' to give them their local name, are present in enormous numbers in the salt marsh creeks, and although they are useful scavengers, they are a nusiance to line fishers as they take the bait meant for their betters. *Portunus depurator*: the cast shells of this commonest British swimming crab are frequently cast up on the beach. *Eupagurus bernhardus* (hermit crab) is fairly common. *Homarus vulgaris* (lobster) occasionally shelters in holes and corners in wrecks. *Leander serratus* (common prawn) is found in tide pools, but *L. squilla*, the 'white prawn' is not so common. *Hippolyte varians* is widely distributed in tidal pools and *Crangon vulgaris* (common shrimp) is abundant upon the sandy bottoms of tidal creeks. Among the *Amphipoda* are listed: *Gammarus locusta*, common under stones; *Orchestia littorea* among stones and piles at Morston; *Calliopius* *læevisculus* in great numbers on brown alga (*Palleila*); *Ampelisca spinipes* is rare in the vicinity of the Point; *Bathyporeia Robertsonii*, a burrowing form in the surf-beaten sand; *Haustorius arenarius* in similar situations; *Corophium volvulator* is a mud-burrower forming food for fish and waders.

Isopoda.—*Ligia oceanica* crawling over rotten timber; *Idotea linearis* abound in inshore waters and form food for flocks of immature terns; *I. pelagica* common under stones and algæ on the open beach; *I. granulosa*, a single specimen, hitherto not previously recorded south of Northumberland; *Eurydice pulchra*, a very common pelagic form; *Cyathura carinata*, first recorded in Britain by Dr. Robert Gurney under stones and behind bark of old piles near Acle bridge, was found at Stiffkey burrowing freely in the mud; *Sphæroma rugicauda* in Stiffkey freshes.

Mysidacea.—Mysids are very common in summer in wreck pools and appear to be a favourite food for fish.

The fresh-water *Crustacea* have been intensively studied by Dr. R. Gurney, and his valuable papers mentioned below not only afford information as to the distribution of the various groups in the Broads, and for the county outside that area, but also on the physical features of the Broads, and their effect upon the fauna. It is quite impossible even to summarise the results of his work, and the writer would refer those interested to *Trans. N. N. Nat. Soc.*, vii, 637; 'The Fresh and Brackish-water Crustacea of East Norfolk (1904),' viii, 410; 'The Crustacea of the East Norfolk Rivers,' xii, 550; *The Fresh-water Crustacea of Norfolk* (1928). 'The Phytoplankton of some Norfolk Broads,' by M. B. Griffiths, *Jour. Linn. Soc. Bot.*, xlvii, 595, is also a useful paper for consultation with reference to the subject.

One interesting crustacean deserving special mention as apparently confined in Britain to our Norfolk rivers, is the new British prawn (*Leander longirostris*), first found by Dr. Gurney, in Breydon, in large numbers; it also occurs in Oulton Broad, in the Waveney, and in the Bure as far up as Acle bridge. It is a species which has been found in the Mediterranean, in certain estuaries of the west coast of France, and is common in estuarine regions in Holland; the fact that it is confined to Britain in our Norfolk rivers leads the discoverer to make the interesting speculation that it is a relic of the time when our rivers were tributaries of the Rhine and that the larvæ have the migrating instinct causing them to return to those rivers.

The distribution of the crayfish (*Potamobius Pallipes*) in the county has not been fully worked out; it occurs in streams flowing into the Bure, in the Yare at Keswick; at Taverham Mill (river Wensum) it is abundant, and probably inhabits all the upper waters of the Wensum.

Myriapoda.

The systematic collecting of *Myriapoda* has never been carried on in Norfolk; the species given below were casually picked up by Mr. F. Pickard-Cambridge and Mr. O. Thomas on or near the Broads, and by the former at West Runton. They are all of wide distribution in the southern counties.

Centipedes.—*Lithobius forficatus, L. calcaratus.*

Millipedes.—*Polydesmus complanatus*, *Brachydesmus superus*, *Attractosoma polydesmoides*, and all occur in the Broads district. *Julus subulosus*, *J. niger* at West Runton, and *J. punctatus* (Broads).

Arachnida.

The *Arachnida* of the county have not been worked to a very large extent, but the *Victoria County History* mentions the fact that 193 species have been placed to its credit. As the county possesses tracts of wild heathlands, some cultivated woodland districts, rich broadlands, and sea coast there are abundant opportunities for increasing the number of species recorded.

Of the 188 species of spiders those deserving special mention on account of their rarity are: *Attus caricis*, *Lycosa spinipalpis*, *Pardosa farenii*, *Pholcus phlangioides*, *Steatoda sticta*, *Asagena phalerata*, *Hiclaira uncata*, *Mengea scopiger*, *Araneus patagiatus* and *Clubiona neglecta*.

Among the Chelifers, out of 24 species of False Scorpions regarded as indigenous to Great Britain, *Chthonius rayi*, *Chelifer latreillii* and *C. cancroides* have been taken in the county.

Phalangida (Harvestmen).—*Phalangium opilio* has been recorded from Scratby sand cliffs; *Liobunum rotundum*, *Oligolophus agrestis*, *Nemastoma lugubre* and *N. chrysomelas*, all from Ormesby; *Megabunus insignis* (West Runton).

Hydracarina (Water mites).—These are much at home in the Norfolk broads and dykes where they have been studied by C. D. Soar who with W. Williamson prepared the three-volume *Ray Society Monograph* (q.v.). He recorded 92 species for the county, some being new to science, as well as many new facts about their economy and life history.

Insecta.

Norfolk is noteworthy for the number of enthusiastic entomologists which have specialised upon the various orders of insects to be found in the county, and for a detailed account reference must be made to the large amount of data available in the *Transactions of the Norfolk and Norwich Naturalists' Society*.

Thysanura.—The 'Fire brat,' *Thermobia domestica* occurs commonly in bakehouses at Yarmouth, Norwich, and elsewhere.

Collembola.—Among the Springtails may be mentioned *Anurida maritima* which is found on debris along the tide marks.

Orthoptera (Cockroaches, Crickets and Grasshoppers).—*Ectobius panzeri*, a very small cockroach, lives in sandy places on heathland, often near the sea. *Blatella germanica* has been found in houses in Norwich, *Blatta orientalis* frequently occurs in farmhouses and bakehouses, *Periplaneta americana* has occurred several times, probably introduced from ships and in imported fruit.

Gryllotalpa gryllotalpa, the mole cricket has not been reported within recent years, *Gryllus campestris*, the field cricket is rare, but *G. domesticus* is very common in bakehouses.

With regard to the grasshoppers, *Phasgonura viridissima* has appeared in many parts of the county from time to time but irregularly. *Conocephalus dorsalis, Tetrix subulatus* and *T. bipunctatus* are found in wet places in the Broads district. *Mecostethus grossus* appears on *Myrica*, etc., in the Broadland fens. The commonest grasshopper in fields and on dunes is *Stenobothrus bicolor*.

Dermaptera (Earwigs).—*Forficula auricularia* and its variety with long pincers, *forcipata*, are all too common. *Labia minor* is rare; *Apterygida albipennis* was recorded in autumn 1889, and as far as in known, Norfolk is the northern limit of its distribution.

Odonata (Dragonflies).—Rather more than half the British species are present in Norfolk; *Agrion armatum* being known only from this county.

Hemiptera.—This order of insects has been extensively studied in the county by J. Edwards, and H. J. Thouless and complete lists are to be found in the *Transactions* previously mentioned. The extremely rare *Cimex pipistrelli* was found in Norwich by Mr. Thouless in September 1903, from the hollow of an old tree which had been inhabited by bats; it may be rarely found owing to the fact that few entomologists ever have the opportunity to search for it under such successful conditions. *Corizus hyalinus*, only previously recorded from Essex, was found upon the Cemetery wall at Norwich in 1903 by Mr. Thouless.

Mallophaga (Bird lice).—It is interesting to notice that this order was first studied intensively in this country by Henry Denny of Norwich who published *Monographia Anopleurorum Britanniæ* in 1842.

Neuroptera (Stone-flies, May-flies, and Alder-flies).—Owing to the absence of swiftly-flowing streams, and waterfalls, the *Perlidæ* or Stone-flies are represented by very few species. Large numbers of *Ephemeridæ* or May-flies may sometimes be seen rising from the water, but neither these nor the *Sialidæ* or Alder-flies have been systematically worked in the county.

Trichoptera (Caddis-flies).—These occur abundantly in some of the streams; the commonest species are *Phryganea*, *Limnophilus* and *Rhyacophila*. The *Victoria County History* gives a list of some 50 species recorded for the county.

Mecoptera (Scorpion-flies).—Besides the common scorpion fly, *Panorpa communis*, the first recorded British example of *Boreus hyæmalis* was taken at Costessey near Norwich by Leech.

Lepidoptera (Moths and Butterflies).—The skill and industry of Norfolk entomologists such as Lord Walsingham, C. G. Barrett, F. D. Wheeler, E. A. Atmore, H. J. Thouless, F. C. Hinde, and a large number of others has led to the *Lepidoptera* of the county being well worked; resulting not only in the discovery of many rare species but also in the enumeration of a large number of localities for those recorded. Norfolk *Lepidoptera* recorded to the present year comprise 1,562 species, some 72 per cent. of the 2,150 recorded for the British Isles.

The peculiar nature of the geological features and the various physical aspects has the effect of causing many species to be confined to exceedingly restricted localities. One fact which is of interest in connection with recent work which has been done upon insect immigration is the geographical position of the county and the great probability of its serving as a refuge for insects driven by migratory impulse from countries on the other side of the North Sea.

Another point worthy of note is the occurrence in the fens of the Yare and Bure of the Swallow-tail butterfly (*Papilio machaon*) in considerable numbers ; the food plant of its larva (*Peucedanum palustre*) grows plentifully and the only other locality for this insect is Wicken Fen near Cambridge. Melanistic forms have been met with on very rare occasions. *Vanessa antiopa*, the Camberwell Beauty, has been recorded several times between 1834 and 1905. The exceedingly rare Queen of Spain fritillary (*Argynnis lathonia*), was noted at Harleston 1846, Plumstead near Norwich 1865, others at Beechamwell, Halvergate, Caistor and Booton. The Large Copper (*Chrysophanus dispar*) once lived in the fens of the county, its larva feeding upon the leaves of the great water dock ; this insect has been extinct in Britain since 1847. Mention might be made of the attempt to introduce the Continental form *C. rutilus* into some of the Norfolk marshes by the late G. H. Gurney. Some 550 butterflies were liberated in Woodbastwick during July 1926 ; however, weather conditions were unfavourable and although its larvæ and pupæ were found the next year, very few imagines were seen ; as far as I am aware no further attempts at re-introduction were made and the species disappeared. Several rare and local species of moths have occurred in the Broads district and in Breckland where conditions favour their life history ; reference must be made to the Norfolk *Lepidoptera* in the *Victoria County History*, and the many references in *Trans. N. N. Nat. Soc.* One interesting moth may be mentioned, *Xylophasia zollikoferi* which was taken by Mr. Plunkett on September 4, 1905, on an electric light at Carrow, Norwich ; this is not only one of the most uncommon of British, but is actually one of the rarest of European moths ; it was the fourth British record. Excellent collections of Norfolk *Lepidoptera* may be consulted at the Castle Museum.

Coleoptera.—The beetles of the county have been carefully worked out by James Edwards, H. J. Thouless, and E. Atmore. The Yarmouth district alone has yielded over 800 species. Among the rare records made at various times may be noted the first indigenous specimen of *Carabus clathratus* taken by Mr. Haworth at Halvergate in 1809, *Calosoma sycophanta*, a rare occasional visitant, *Pterostichus aterimus* discovered by Joseph Hooker of Norwich, *Pogonus luridipennis* first discovered in Britain by Rev. J. Burrell at Salthouse in 1806, *Ilybius subæneus*, *Œdemera virescens* and *Hesperia alveus*. In 1920 H. J. Thouless discovered specimens of the rare weevil *Tapinotus sellatus* at Horning, previous to this only three other British records were known, two of them being also from Horning. *Leptura rubra*, a fine Longicorn, not previously recorded as British, was found during three successive years in rotten stumps of Scots Pine at Horsford by the same worker, and he also discovered specimens of *Anthicus humilis*, new to the county at Scolt Head in 1923. F. Balfour-Browne, working in the Sutton Broad Laboratory made a study of the Aquatic *Coleoptera* and their surroundings in the Norfolk Broads district ; his very interesting results may be found in *Trans. N. N. Nat. Soc.*, vol. viii, pp. 58 and 290. *Dytiscus marginalis* is common in most dykes, but *Hydrophilus piceus* is much more local in its distribution ; on the floating leaves of water lilies, species of the Genus *Donacia* are frequently seen, e.g. Sutton Broad. Some 2,100 species of beetles have been recorded for the county.

Hymenoptera (Ants, Bees, Wasps, etc.).—Norfolk has been very fortunate in having a number of very enthusiastic workers upon the various groups of *Hymenoptera* over a large number of years, resulting of the enumeration of an extensive list of species being recorded.

Phytophagus *Hymenoptera* (Saw-flies).—Mr. J. B. Bridgman chiefly working in the neighbourhood of Norwich, with the assistance of his co-workers, Rev. E. N. Bloomfield and Mr. E. A. Atmore in other parts of the county, recorded a list of 211 species, including many of rare occurrence (*Trans. N. N. Nat. Soc.* 1908–1909) ; 17 further species were subsequently added.

Aculeate *Hymenoptera* (Wasps, Bees and Ants).—Bridgman was also responsible for the listing of a very large proportion of this group and also for the *Chrysididæ* of the county ; his extensive collection may be consulted in the Castle Museum.

The Parasitic *Hymenoptera* (Ichneumons, etc.).—These also came under the notice of Bridgman who published a list of no fewer than 616 British species. Mr. Claude Morley, the authority upon the British *Ichneumonidæ*, made further additions with the result that in *Trans. N. N. Nat. Soc.* 1912–1913, he states that the total number now known in Norfolk is 675, a number at present exceeded by no published county list ; the number of kinds indigenous to Britain is 1,517. Other parasitic Hymenoptera (*Braconidæ*, *Chalicidæ*, etc.) have received practically no attention in the county.

Diptera.—The Rev. E. N. Blomfield made a great study of the Norfolk and Suffolk Diptera during a long life of eighty-six years, and only a few days before his death handed over his notes and MSS. to Mr. Claude Morley and Mr. E. A. Atmore with a request that they should be published in the *Transactions of the Norfolk and Norwich Naturalists' Society.* The account occupies 180 pages to the Supplement to vol. x, Part 1, and it is a tribute to his energy that some 1,828 species were recorded for Norfolk out of about 3,000 given for Britain.

Culicidæ (Mosquitoes).—In connection with the close relationship known to exist between many blood-sucking insects and the transference of certain diseases to man and animals, Dr. Sidney Long commenced to make a list of the mosquitoes occurring in the county and recorded some 8 species with their distribution ; in time he hopes to make additions to the list.

Mollusca.

Marine Mollusca.—Comparatively few marine species are represented immediately off the Norfolk coasts owing to the shifting and disturbed sandy floor. At the mouths of rivers where mud is deposited, one finds beds of *Mactra stultorum*, *Tapes pullastra*, *Nucula nucleus*, and where similar contributions of silt obtain in localities like Holkham Bay, the Razors (*Solen ensis* and *S. siliqua*), *Spisula solida*, *Lucina borealis*, *Pecten* *varius* and *P. opercularis* are abundant. *Macoma balthica* is common to these habitats and the estuaries but does not attain the robust forms of more sheltered stations. Other estuarine Lamellibranchs include *Scrobicularia plana* (shells of which have been dug from the alluvium within a few miles of Norwich), and *Mya truncata*. The mussel (*Mytilus edulis*) and the cockle (*Cardium edule*) are cultivated on the north coast in specially chosen beds known as ' lays ' ; the immature molluscs being collected in the Wash. The rearing of these shellfish is of considerable economic importance. Whelks (*Buccinum undatum*) are obtained in baited basket-like traps on the weedy grounds between Cromer and Hunstanton; winkles (*Littorina littorea*) are collected in the Wash and to a lesser extent on the ' winkle stones ' on the chalky foreshore. Mud-littoral species are *Littorina saxatilis* which shows considerable variation on this coast, *Peringia ulvæ* which teems on Breydon (the typical form), and in the Wash region (mainly var. *subumbilicata*), *Phytia myosotis*, and *Assiminea grayana*.

Freshwater Molluscs.—*Paludestrina Jenkinsii* is widely distributed in the east, and is the only species living in estuarine and fresh water ; it has been found in Breydon and as far up the Yare as Norwich, and in the Bure at Coltishall. The extensive system of dykes is very favourable to freshwater molluscs, though the Broads themselves for the most part produce few species. The stagnant waters abound in *Limnæa* and *Planorbis* spp., which show interesting modifications as they come within reach of estuarine influence, *e.g.* between Acle and Yarmouth. *Neritina fluviatilus* occurs in Horsey Mere which is somewhat saline, but otherwise lives only in the upper reaches of our rivers. Of the freshwater Mussels, *Anodonta cygnea* is small in the rivers, thin shelled (but not eroded) in the shallower broads and reaches its greatest size in ponds ; *Unio pictorum* accompanies it where there is flowing water. Extensive deposits of recent freshwater shells are present between Surlingham and Rockland in channels connecting some of the smaller broads.

Land Molluscs.—The mossy hummocks in sallow carrs of the river valleys yield many small terrestrial molluscs including *Vertigo substriata*. *Arianta arbustorum*, and *Fruticicola striolata* abound in nettle beds near the rivers. The dunes are colonised primarily by *Pupilla muscorum*, *Vitrina pellucida*, and *Candidula caperata* which can live under conditions too stringent for other species ; they are followed by *Cepæa nemoralis*, *Cernuella virgata*, *Xerophila itala*, *Theba cantiana* and others. *C. nemoralis* is also widespread in hedgerows and sometimes attains a large size in fenny localities ; *C. hortensis* is rather local in this county. *Pomatias elegans* is confined to chalky districts and has been found near Hunstanton and inland at Whitlingham.

Among the slugs, *Arion ater* keeps mainly to the river valleys ; *Agriolimax agrestis* is ubiquitous occurring on the marshes, on dunes, as well as throughout the agricultural districts.

Polyzoa.—The marine species have received scant attention. *Pedicellina cernua* and *Bowerbankia* have occurred on *Tubularia* colonies at Yarmouth haven. *Flustra foliacea* is perhaps the most abundant species washed ashore. The brackish ditches near Yarmouth contain *Membranipora monostachys* var. *fusaria* encrusting various debris.

The rivers and broads of Norfolk are pre-eminently rich in Freshwater Polyzoa, as is well known through the intensive study the group has received from Mr. H. E. Hurrell, F.R.M.S. *Plumatella fungosa* occurs in large masses among the submerged roots of alders and willows at South Walsham Broad. *Cristatella mucedo* and *Lophopus crystallinus* are sometimes abundant upon *Elodea canadensis* and water lily leaves at Brundall, particularly in the dyke leading into Surlingham Broad ; *Fredericella sultana* forms tangled masses upon submerged reed stems ; *Plumatella repens* and *Paludicella Ehrenbergii* also occur in the Broads.

Chætognatha.—The arrow-worms (*Sagitta* spp.) are sometimes plentiful in plankton.

Echinodermata.—Asterias rubens is very plentiful off the coast and large numbers are often washed ashore after winter storms ; with them occur the sunstar (*Solaster papposa*) and *Ophiura* churned up from the sand. Here and there inshore shoals produce numbers of heart urchin (*Echinocardium cordatum*), and the purple-tipped urchin (*Echinus miliaris*) is frequent among the seaweed-covered stones off the coast.

Tunicata are poorly represented, and apart from *Botryllus* spp. on flint boulders they have been scarcely noticed.

The information given in these notes on the fauna of Norfolk is necessarily incomplete, and it may be mentioned that the extensive collections made by the various workers in the different groups are housed in the Castle Museum, and members of the British Association are cordially invited to consult the members of the staff with regard to them. One special feature of the Museum is the new Norfolk Room, where fine panoramic displays are to be seen illustrating the main physical units of the county. In the gallery above it is intended to make as complete a collection as possible of not only the fauna but the flora of the county, and the services of local specialists have been secured to co-operate in making this material available as befits a county unique in its faunistic and floristic advantages.

VII.

GEOLOGY OF THE NORWICH DISTRICT

BY

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I. PHYSIOGRAPHY.

As indicated in the chapter on Norwich in its Regional Setting, Norwich lies near the centre of an area of plateau country which is trenched by the valleys of the Upper Bure, Wensum, Yare and Tas. Of a general level of approximately 120 to 150 ft. above O.D., this plateau declines in height towards the east, where it gives place to the low-lying flat district of the Norfolk Broads, 20 to 30 ft. above O.D. Between Norwich and the north Norfolk coast, and nearer the latter, there intervenes the Cromer Ridge (or, more accurately, a series of gravelly and clayey ridges) of morainic origin, reaching to a height of 300 ft. and alined from east-north-east to west-south-west. The elevation of the surface of the country determines to some extent the character of the coast-line: between Lowestoft and Yarmouth the plateau of Glacial Drift and Pliocene deposits meets the sea in the cliffs of Corton and Hopton, but north of Yarmouth the plateau almost disappears, and the flat area of the Broads is continued as a low marshy coastal belt. At the north-western limit of this stretch of coast-line lies Eccles, long famous since Lyell's observation in 1839 of the inland advance of the sand-dunes and overwhelming of the church, the destruction of which was completed by the sea in 1895. From Happisburgh, a few miles farther westwards along the shore, the sea cuts obliquely across the Cromer moraine, disclosing cliff-sections of Glacial Drift which display the tectonics of ice-action in such a manner and on such a scale that the locality has become known all over the world. The cliffs continue from Paston westwards as far as Weybourne, a distance of 16 miles.

II. The Chalk.

The bed-rock of the district is formed by the Upper Chalk, but it is exposed only in the deeper valleys, such as those of the rivers Yare, Wensum and Bure, and on the sea-coast. When the contours of its surface are plotted from the data provided by exposures and boreholes, that surface is found to be a plane dipping gently eastwards at about 9 ft. to the mile, until it is covered by Eocene deposits (see p. 51), when the gradient increases to 50 ft. to the mile. As the dip of the various sub-divisions, or zones, of the Chalk is about 18 to 35 ft. to the mile, the zones crop out on the surface as belts of approximately north-north-west to south-south-east trend, the lowest appearing farthest towards the west. The Middle and Lower Chalk appear only in the westward-facing escarpment overlooking the Wash, but the zones of the Upper Chalk (in ascending order, those of the *Holaster planus*, *Micraster cor-testudinarium*, *M. coranguinum*, *Marsupites*, *Actinocamax quadratus*, *Belemnitella mucronata* and *Ostrea lunata*) crop out on the eastern slopes of the cuesta. Around Norwich and near the coast at Blakeney, the zone of *Belemnitella mucronata* (120 to 150 ft. in thickness) is well exposed, and the sections have long been famous as the best collecting-grounds in England for fossils from this horizon. Many collections contain specimens from the 'Norwich Chalk,' and it is possibly on this account that T. H. Huxley, at the last meeting of the British Association at Norwich (in 1868), chose for the subject of his famous address to working-men 'A Piece of Chalk.' To geologists there is the added interest that in Norfolk is to be found the highest portion of the zone exposed in England; at Thorpe and Whitlingham, east of Norwich, the characteristic high-zonal sea-urchins, '*Epiaster*,' *Micraster* (of an advanced *coranguinum* type), and the very large domed variety of

Echinocorys scutatus Leske can be collected, as well as an interesting assemblage of gasteropods. Other fossils, typical of the main mass of the zone, which can be found in chalk-pits on the southern and western limits of Norwich and at Coltishall, include *Belemnitella mucronata* (Schlotheim), *Ostrea vesicularis* Lamarck, *Rhynchonella limbata* (Schlotheim) var. *lentiformis* S. Woodward, *R. plicatilis* (J. Sowerby), *Carneithyris carnea* (J. Sowerby), *Terebratulina striata* Wahlenberg, *Chatwinothyris symphitica* Sahni, *Crania costata* G. B. Sowerby, *Typocidaris subvesiculosa* (d'Orbigny), and *Bostrychoceras polyplocum* (Roemer).

Scattered about the district, and also on the shore west of Cromer, are the curiously shaped 'paramoudras,' which consist of masses of flint of roughly cylindrical form, often a foot or two in diameter and up to 4 ft. in height, with a hollow centre. The tubular cavity is vertical as they lie in the Chalk. Their mode of origin is not fully understood, but it is probably concretionary, although Lyell compared their shape with that of giant sponges. Variations in shape, however, pass through all gradations down to the well-known irregular nodules.

The Chalk of Trimingham, on the Norfolk coast, has now almost disappeared as a result of marine erosion. It belongs to a still higher division of the Chalk, namely, the zone of *Ostrea lunata*, and constitutes the only occurrence of this zone in England. The Chalk occurs in bluffs in the cliffs and on the foreshore, and is often yellow-stained and disturbed, presumably by glacial action. Much controversy has raged over the question as to whether these chalk-masses are transported blocks or are *in situ*. If transported, they are likely to have come from an outcrop close at hand, for they occur at just about the position which might be expected in relation to the outcrops of the other zones in Norfolk. The thickness of the *lunata*-Chalk is estimated at about 70 to 80 ft. Flints are abundant and often of curious form. Fossils occur in bands of the Chalk, and include *Ostrea lunata* Nilsson, *O. vesicularis* Lamarck (true form), *Terebratulina gracilis* Schlotheim and *T. gisei* Hagenow, *Belemnitella mucronata* (Schlotheim), *Echinocorys scutatus* Leske, *Chatwinothyris subcardinalis* Sahni, bryozoa, etc.

III. Tertiary.

After the great period of steady marine transgression which accompanied the deposition of the Chalk, a general upheaval brought the British area above sea-level, and a process of planing down ensued. The Chalk was tilted until its general dip was eastwards, and the south-east of England was once more submerged beneath the waters of the Eocene sea of the Anglo-Belgian basin. This sea encroached only on eastern Norfolk, and some of the deposits then formed, the Reading Beds and London Clay, were preserved, as has been demonstrated by deep boreholes like that at Yarmouth. But the Chalk of our area, being at the north-eastern limit of the London Basin of deposition, remained for the greater part bare until, in Pliocene times, the ancestor of the North Sea came into being. From those times to the present day, the geological story is one of gradual refrigeration of climate and of restriction of the marine area, which had originally extended as far as Kent and northern France. The southern shores of this sea lay eventually in the position of what is now the north Norfolk Coast and the Zuyder Zee. Meanwhile, the ingress from the south of warm-water mollusca had been gradually barred, and the southern migration of cold or even arctic species of mollusca from the north was facilitated.

The Pliocene Deposits.—East Anglia is the home of the Pliocene deposits of Britain, and Norwich has appropriately given its name to one of the major divisions of the shelly sands and gravels generally known as the 'Crags.' The late F. W. Harmer, of Norwich, whose contributions to knowledge of European Pliocene and Pleistocene geology earned for him an international reputation, proposed the appropriate term 'Icenian' for the later Crag beds, including the Norwich Crag, the Chillesford Clay and Crag and the Weybourne Crag.

These deposits are exposed in the valleys and sea-cliffs of eastern Norfolk and Suffolk. They display considerable variation in lithology, the lowermost or Norwich Crag consisting of yellowish or reddish brown sands and gravels, occasionally very fossiliferous, as at Bramerton and Whitlingham, near Norwich. The fauna is dominantly molluscan and is indicative of colder conditions than the more ancient Red Crag found in Suffolk. As would be expected, also, it includes a greater number of recent (living) species than the Red Crag, the latter being composed of about 70 per cent. living species, while the Norfolk Crag contains 89 per cent. Instead of being deposited like the Red Crag in the form of low shell-banks (up to 30 ft. in thickness) in land-locked bays, the Norwich Crag seems to have been laid down in an estuary of a large northward-flowing river, the course of which has been traced from Aldeburgh in Suffolk to beyond Norwich. This estuary, belonging perhaps to a forerunner of the river Rhine, which reached the restricted North Sea of that time near where Cromer stands to-day, sank under the load of sandy and gravelly deposits until a thickness of about 170 ft. had been accumulated. F. W. Harmer detected sufficient change in the fauna as the deposits are followed northwards to divide the Crag into two sub-zones, that of *Mactra subtruncata* below, and that of *Astarte borealis* above. In consequence of the northward recession of the Icenian sea, only the upper sub-zone is found in Norfolk. Among the most characteristic forms of the Norwich Crag are the following: *Astarte borealis* Chemnitz, *Cardium edule* Linné, *Cardium grœnlandicum* Chemnitz, *Corbicula fluminalis* Müller, *Corbula gibba* Olivi, *Cyprina islandica* Linné, *Leda oblongoides* S. Wood, *Lucina borealis* Linné, *Mactra subtruncata* da Costa, *Mactra truncata* Montagu, *Mya arenaria* Linné, *Mytilus edulis* Linné, *Nucula cobboldiæ* J. Sowerby, *Pecten opercularis* Linné, *Scrobicularia plana* da Costa, *Solen siliqua* Linné, *Tapes virgineus* Linné, *Tellina lata* Gmelin, *T. obliqua* J. Sowerby, *T. prætenuis* Leathes, *Buccinim undatum* Linné, *Cerithium tricinctum* Brocci, *Hydrobia ulvæ* Pennant, *Littorina littorea* Linné, *Melampus pyramidalis* J. Sowerby, *Natica catena* da Costa, *Paludina media* Woodward, *Purpura lapillus* Linné, *Scalaria grœnlandica* Chemnitz, *Trophon antiquus* Linné, *Turritella terebra* Linné. (It will be noted that the majority of these shells are living species, and northern in character. The old names are retained to facilitate comparison with lists long published.)

The detrital minerals found in the Norwich Crag differ but little from those of the earlier deposit, the Red Crag, and appear to indicate a southernly origin for each of the sediments. Beds of highly micaceous sands and clays occasionally occur, like those in the Chillesford Beds of Suffolk; these suggest that the parent rocks were of mica-schist type.

At the base of the Norwich Crag, where it is seen to rest on the Chalk, is a bed of brown-coated flints, among which are found the famous 'rostro-carinates' and other types of implements, described by Mr. J. E. Sainty in Chapter VIII. These implements afford evidence of the earliest appearance of man in Norfolk, but for many years the flaking was the subject of vigorous controversy. On the question as to whether the implements prove the existence of Pliocene man depends in turn the question as to whether the Norwich Crag is to be regarded as Pliocene—the long-established practice—or placed in the Lower Pleistocene, as E. Ray Lankester advocated so long ago as 1912.

Whilst in Suffolk the Chillesford Beds are marked by a well-defined fauna and lithology, indicating their deposition under quiet estuarine conditions, in the district here described the homotaxially equivalent deposits are irregular and impersistent. The presence of comparatively thin seams ('jambs') of highly micaceous clay in sands and pebbly gravels has, despite their impersistence, led to correlation with the micaceous Chillesford Beds of Chillesford in Suffolk. F. W. Harmer has linked up the various occurrences of these beds and traced the ancient course of an estuary winding through Norfolk from Beccles to Rockland, Wroxham, and Burgh. H. B. Woodward preferred to map these variable beds with the Norwich Crag. Although in Suffolk the beds contain a molluscan fauna more recent and boreal than the Norwich Crag, the fauna in Norfolk is not well defined.

The Weybourne Crag is of marine facies and is marked by the first appearance in Britain of the northern shell *Tellina* (*Macoma*) *balthica* Linné. The molluscan fauna is not rich, only about 50 species having been recorded, but *T. balthica* itself often constitutes the bulk of the shells present. The deposit is well exposed in the Norfolk cliffs, and sands in which the same shell and its associates have been found occur in the Bure Valley and as far south as Norwich, but no farther. F. W. Harmer opined that the beds indicate a renewed incursion of the sea into Norfolk, following the opening-up of communication with the northern and Baltic areas.

In recent years there has been a growing tendency to group together these ill-defined Crag divisions—that is, to revert to the practice adopted by the Geological Survey during the original mapping of Norfolk. Certainly, the separate divisions cannot be delineated on a map with any satisfaction to the surveyor. The officers of the Geological Survey were inclined, for example, to correlate the Weybourne Crag of northern Norfolk with the Chillesford Clay inland. Dr. J. D. Solomon sees in the Weybourne Crag, however, the marine equivalent of the (estuarine) Cromer Forest-beds Series next to be considered.

In the neighbourhood of Cromer, Mundesley and Lowestoft, the series of deposits known collectively as the Cromer Forest-beds appears at the base of the cliffs and on the foreshore. The succession includes two freshwater beds separated by an estuarine deposit, the 'Forest-beds' proper. The Lower Freshwater-bed is composed of peat and peaty clays, but it is often missing, or may be replaced by a bed of large flints in which have been found flakes and hand-axes of early human types. As Clement Reid (who did so much admirable work on the Pliocene deposits of Britain) pointed out in 1890, the relation of the Lower Fresh-water-beds to the estuarine division of the Forest-beds seems to be somewhat similar to that of the recent submerged forests in estuaries to the deposits now being formed in the same localities, in part from the destruction of them. The upper surface of the Estuarine-bed, which contains many bones and teeth of large mammals, is in places weathered into a soil and penetrated by roots. The Upper Freshwater-bed consists of peaty loams containing freshwater shells and many bones and teeth, and lies in erosion-hollows of the Estuarine-bed. The general characters of the life of Cromerian times may be summarised in the statement that the land fauna, which may be largely derivative from the south, is dominantly of warm type, and the marine fauna, which seems to be indigenous, is of a well-marked arctic type. The mammalian fauna indicates the survival from earlier Crag times of warm temperate species such as *Elephas meridionalis*, *E. antiquus*, *Hyæna striata*, *Rhinoceros etruscus*, *Equus stenonis* and *Machærodus*, and the first appearance of *Hippopotamus*. There is also a rich rodent and deer fauna, but together with the southern forest types, the arrival of tundra and northern forest types, such as *E. trogontherii*, *Ovibos moschatus*, and *Alces latifrons*, is to be noted. The vegetable remains from the Forest-beds include stools of trees swept down by the rivers, together with the twigs, leaves and pollen, all indicative of plant life not very different from that of the area to-day.

Next in the stratigraphical succession, according to the views of the earlier workers, comes the *Leda myalis* bed. Its molluscan fauna is similar to that of the Weybourne Crag, with the addition of *Leda* (*Yoldia*) *myalis* Couthouy, and its lithological characters are not notably different.

IV. Quaternary.

A deposit but rarely exposed in the Norfolk cliff-sections is the Arctic Freshwater-bed, which consists of laminated peaty loams of lenticular character, apparently occupying channels and only sporadic in occurrence. It lies immediately beneath the Cromer Till, referred to hereafter, and seems to be separated from the Forest-beds by the *Leda myalis* bed, but exposures showing the stratigraphical relations have not been visible for many years. According to C. Reid, its plants include mosses, arctic birch and arctic willow, and the freshwater shells include *Succinea putris* (Linné), *S. oblonga* Draparnaud, *Valvata piscinalis* (Müller), and

Pisidium henslowianum (Shepard). A rodent, *Spermophilus*, has also been found.

The wonderful series of glacial deposits of Norfolk—probably the most complete in Britain—has been the subject of much re-investigation in recent years. Considerations of space forbid the recapitulation of the views and classifications propounded by the many distinguished geologists who have investigated the glaciology, but passing mention should be made of the work of Lyell, Joshua Trimmer, John Gunn, S. V. Wood, F. W. Harmer, Clement Reid and H. B. Woodward. Latterly, the work of Dr. G. Slater and Dr. J. D. Solomon has added much to our knowledge, and the discovery of flint implements *in situ* in various deposits of the coastal area by Mr. Reid Moir, Mr. J. E. Sainty, Mr. A. C. Savin and others has stimulated discussion and given rise to tentative correlation. It is difficult in a short article to summarise and reconcile the different views, for details must necessarily be omitted.

Excluding the locally occurring Arctic Freshwater-bed, the opening phase of the Pleistocene epoch in East Anglia appears to have been an invasion of this low-lying country by a sea which spread sands and gravels, usually of shingly character (the Westleton Beds of J. Prestwich), over Norfolk, Suffolk and Essex. The age of these deposits is uncertain, for they contain no traces of life (unless the *Leda myalis* beds and the Bure Valley beds in part are regarded as their equivalents), but they are seen to overlie the Norwich Crag and to underlie the Norwich Brickearth, a boulder clay which constitutes the earliest glacial deposit of Norfolk. Dr. Solomon has recently come to the conclusion that the sands and gravels of the Westleton Beds interdigitate with the Norwich Brick-earth and represent its marine facies, lying in front of the advancing ice-sheet, thus facilitating the drift of icebergs.

The Norwich Brickearth is distributed over eastern Norfolk, and reaches as far south as Beccles and Sotterley near the Suffolk boundary. It consists of a yellowish brown or greyish sandy loam and includes occasional erratics. The erratics are dominantly of Chalk, chalk flint, and crystalline rocks, and the last named include types such as the well-known rhomb-porphyry, which could have been derived only from Scandinavia. The manner of their occurrence and the composition of the Brickearth are, however, suggestive of the possibility that the deposit was produced by the transport action and subsequent melting of icebergs rather than land-ice.

Resting on the Norwich Brickearth and forming the striking sand-plain of north-eastern Norfolk (as well as of eastern Suffolk) are the sands and gravels formerly known as Mid-Glacial, but now considered by Dr. Solomon to be in large part Westleton Beds in which the Norwich Brick-earth occurs as lenses. In part these deposits indicated the recession of the North Sea ice and a consequent amelioration of the climate. Well-wooded estates, rhododendron avenues and beautiful open heaths, like those which inspired George Borrow, mark the outcrop of this sandy facies. At a few localities, as for example in the Flegg Hundred, near Yarmouth, the sands have yielded a marine fauna, the indigenous shells of which prove that the sea was rather colder than the southern part of the North Sea at the present day. About 100 species of mollusca and ostracoda have been found, the best collection of them being preserved in the Norwich Castle Museum.

Next in order of formation was the Great Chalky Boulder Clay, with its accompanying outwash sands, gravels and brickearths. Such were the characteristic features of its matrix and erratics that F. W. Harmer considered that it originated with the advance of the Great Eastern Glacier. Essentially, the boulder clay is composed of 'home-grown' material—of rocks derived by glacial advance over the outcrops of the rock-formations of the east of England (or their extension on the bed of the North Sea) from the Fen district to Lincolnshire, Yorkshire, or even the north of England. The matrix, like the erratics, varies in different parts of Norfolk. In the central and western parts of the county, the fine material is buff or whitish and largely composed of chalk, the erratics including hard chalk, grey chalk, tabular Lincolnshire flint, red chalk, Spilsby sandstone, phosphatic Neocomian sandstone with *Terebratula rex*, etc. This is the Chalky-Neocomian Boulder Clay. In north-eastern and southern Norfolk and in most of the area of Suffolk, the boulder clay has a dark bluish-grey matrix derived from the Jurassic Clays, and its erratics include rocks from the Chalk, Jurassic deposits, Trias, Carboniferous and older systems. This Chalky-Jurassic Boulder Clay in the main lies side by side with the Neocomian type. The contact between the two types is well seen in the cliffs at Scratby, five miles north of Yarmouth.

The succession of glacial deposits in the neighbourhood of Cromer must now be considered. Correlation with the sequence of beds found farther south and described above is not easy. The lowermost deposit seen in the coastal sections is the Cromer Till, a dark grey clay containing erratics which are more numerous, on the whole, than those of the Norwich Brickearth. The erratics include Scandinavian types, but British rocks predominate. The presence of the former has led to the correlation of the deposit with the Norwich Brickearth, the two boulder clays being included in the general term North Sea Drift. From Happisburgh to Mundesley two beds of Cromer Till have been described, the Upper Till and the Lower Till (of Dr. J. D. Solomon), separated by very fine sandy beds known as the Mundesley Sands. Resting on these is a series of laminated clays with wisps of sand, the 'Intermediate Beds' of C. Reid. In turn, the laminated clays are succeeded by a white or buff boulder clay, containing little else but debris from the chalk—the 'Marly Drift' of older writers. The stratigraphical position of this deposit has been the subject of much discussion, F. W. Harmer regarding it as the western equivalent of the Cromer Till, and H. B. Woodward (and, more recently, Dr. J. D. Solomon) as a variant of the Great Chalky Boulder Clay. It also forms part of C. Reid's Contorted Drift. The succeeding deposits consist of sands and gravels, often containing outwash material from the Marly Drift.

All the deposits from the Cromer Till to the Marly Drift have been involved, together with the various Pliocene divisions and the Chalk, in a striking series of contortions, to which the general term 'Contorted Drift' has been applied. Dr. G. Slater has traced out, from Happisburgh to Weybourne, a succession of built-up mounds of Chalk, Pliocene deposits and Till, of drumlin-like form, separated by basins of deposition containing mainly sandy deposits. The ice which gave rise to the phenomena and formed the Cromer Ridge appears to be that which produced the Great Chalky Boulder Clay. Following a period of recession, there was a fresh ice-advance which Dr. Solomon has termed the Little Eastern Glacier. Its outwash gravels include those banked upon the Cromer Ridge, like the ferruginous cannon-shot gravels of Holt. Inland it produced the Upper Chalky Drift.

At Hoxne, a short distance south of the boundary between Norfolk and Suffolk, the beds overlying the Chalky Jurassic Boulder Clay and underlying the Chalky Drift have long been famous for the evidence they furnish of mild interglacial conditions and the occupancy of the area by Acheulian and 'early Mousterian' man. The plant and animal remains are indicative of climatic oscillations, but dominantly of a temperature at least as mild as that of the present day.

Resting against the western end of the Cromer Ridge at Morston, is a raised beach at a height of about 25 ft. above O.D. This beach, which was first recognised by Dr. Solomon, marks a submergence of the area after the retreat of the Little Eastern Ice. The beach is capped by brown boulder clay like that found at Holkham and Hunstanton, its easily recognisable characters being altogether different from those of any of the earlier boulder clays, but similar to those of the Hessle Clay of Yorkshire and Lincolnshire. It is not found south of Hunstanton, nor are its characteristic erratics (dolerites, porphyrites, and dark blue greywacke grits) and minerals (especially pyroxenes) detectable in quantity on the Cromer Ridge or in outwash gravels. The ice appears to have been 'dead' by the time it reached Norfolk. At Hunstanton, Mr. J. Reid Moir has found in the Brown Boulder Clay implements which appear to be Middle Aurignacian, and one may assume from this that the glacial phase would correspond to that of the cold Magdalenian phase, of which evidence is found elsewhere in Europe.

The chief river systems of Norfolk, like those of the Yare and Waveney, have been excavated through the Norwich Brickearth and the overlying sands and gravels, but are earlier than the Chalky Boulder Clay which rests on their valley slopes. They were thus carved out in a period of great erosion between the first and second glaciations of the area. But the river Bure, river Glaven and others rise in the Cromer Moraine, hence these smaller streams and valleys must have developed during or after the retreat of the Little Eastern Glacier. The Norfolk Broads, many of which are connected with the river Bure, are of still more recent formation. The mode of origin of the Broads was explained by the late Prof. J. W. Gregory as follows. The area of north-eastern Norfolk as a whole was a drowned estuary in post-glacial times. The once continuous sheet of water was gradually silted up with detritus brought down by rivers, the process being aided by the accumulation of shingle and sand drifted southwards by tidal currents, with consequent ponding up of lake-like areas. Thus the main streams were induced to build up levees of mud on their flanks and, by damming up their tributaries, to form the Broads which are laterally placed with respect to the main streams.

Mr. R. C. S. Walters has kindly contributed to this chapter the following note on underground water levels, with map.

THE UNDERGROUND WATER SUPPLY OF NORFOLK

BY

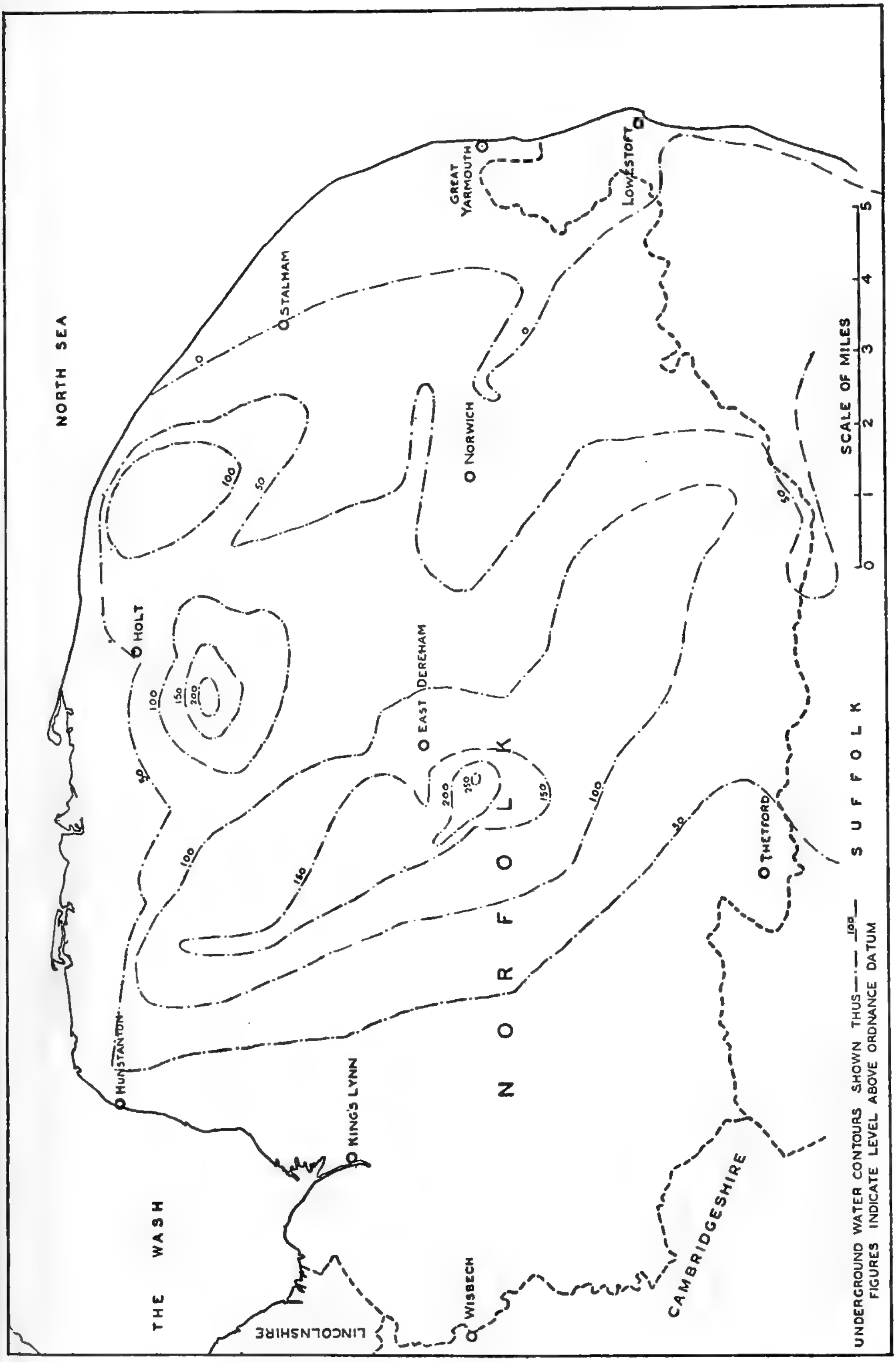
R. C. S. WALTERS

THE underground sources of water supply of Norfolk are derived from the Chalk overlain by other strata for the most part permeable, such as beaches, alluvial and glacial sands and gravels, together with the 'Crag' series in the east. In parts of the county there are considerable thicknesses of Boulder Clay under which water is often obtained.

From the work of Baldwin Latham, who published a report to the British Association in 1887, and from the *Norfolk Water Supply Memoir of H.M. Geological Survey*, by William Whitaker, it is possible to show diagrammatically the underground water levels throughout the county by means of contours. The diagram shows the author's interpretation of these records.

The underground water level is governed largely by the surface configuration of the chalk, part of the flow being in a westerly direction towards the valley of the Ouse, and part being in a northerly and easterly direction to the sea.

The highest underground water levels met with are in the high ground to the south of East Dereham and Holt, where they are about 200 ft. above Ordnance Datum. From these high points the underground water flows in all directions, giving rise to numerous rivers which generally flow in the same direction. Just as most of the country between Hunstanton and Thetford on the west, and between Stalham, Norwich, and Lowestoft on the east, is low-lying, so also are the underground water levels generally less than 50 ft. above sea-level.


NORTH SEA
THE WASH
NORFOLK
SUFFOLK
CAMBRIDGESHIRE
LINCOLNSHIRE
GREAT YARMOUTH
LOWESTOFT
STALHAM
NORWICH
HOLT
EAST DEREHAM
THETFORD
HUNSTANTON
KING'S LYNN
WISBECH
SCALE OF MILES
0 1 2 3 4 5
UNDERGROUND WATER CONTOURS SHOWN THUS — 100 —
FIGURES INDICATE LEVEL ABOVE ORDNANCE DATUM

VIII.

NORFOLK PREHISTORY

BY

J. E. SAINTY, B.Sc.

East Anglia has been so closely associated with English prehistory from the first recognition of palæoliths at Hoxne by Frere in 1797 to 'the most remarkable advance in English prehistoric studies achieved in recent years'[1]—the discovery of pre-Crag artifacts—that it was fitting that Norwich should witness the foundation of the Prehistoric Society (of East Anglia) by W. G. Clarke in 1908.

The chief reason for early man's activity in this area is the fine quality and abundant quantity of the flint, derived mainly from the Upper Chalk and easily obtainable in the exposures on the valley slopes or loose in the huge masses of gravels. The preservation of the deposits variously classified as Late Pliocene or Early Pleistocene has given opportunities for the study of the activities of pre-Palæolithic man which are unequalled elsewhere. In post-Palæolithic times the early agriculturists found the light, permeable, and loamy soils suitable for their needs, whilst the absence of heavy clay areas with their accompanying dense forests allowed of easy penetration. The earlier invaders could obtain access by land, the North Sea basin reaching its present level by a depression occurring probably as late as Neolithic times. The county of course forms part of Fox's 'lowland' area, upon which successive waves of invaders imposed their cultures, and its relations have been ever with the east and south-east, with the Rhine mouth rather than with France and Spain.

The Stone Bed.[2]

The earliest implementiferous deposit in the area is the 'stone bed,' which represents the spreading of the unfloatable debris of the Tertiary land surface by the advancing Crag Sea. It forms a deposit about 1 ft. thick, heavily cemented by ferruginous matter, and resting immediately on the surface of the chalk, extending from the south of Norwich as far west as Guist and north to Weybourne. It consists almost entirely of flint, with occasional quartz or quartzite, seldom any igneous material, sporadic fossil bones, and, in patches, typical Crag shells. In the Norwich area it is usually sealed in by up to 20 ft. of the marine deposits of the Crag; on the north coast the boulder clay occasionally cuts down through it into the chalk. The flint itself is mainly the fine quality, thin crusted grey-black flint of the Upper Chalk,

[1] Kendrick and Hawkes, *Archaeology in England and Wales*, 1914–1931, p. 7.
[2] *Proceedings of the Prehistoric Society of East Anglia*, Vol. VI, Pt. ii, pp. 57–71.

though occasionally specimens occur with unusually thick cortex. The characteristic staining, usually underlain by a definitely thick layer of pure white, renders recognition easy, even in the case of surface finds. The main tints are black-lead or purple black, passing through purple to pale lavender, or through deep mahogany to orange-brown or yellowish, and these contrast strongly on freshly fractured surfaces with the white patinated layer and the unchanged flint beneath. The intense patination suggests prolonged exposure on a former land surface, but the final tint of the staining seems to depend to some extent on the conditions of oxidation or reduction of the local portion of the deposit itself. At Harford Bridges the flints were of a lavender tint, at Thorpe mostly black, though a given patch might show all the contained flints brown or purple ; on the West Runton foreshore browns prevail below and blacks above.

The first stone bed artifacts were found by the late W. G. Clarke in 1905,[3] but the establishment of the fact of human industries is entirely the result of twenty years' unremitting research by Reid Moir. The bitter controversies have now died down ; the arguments formerly advanced against the human workmanship of the specimens—the appeal to 'natural causes,' pressure of the superincumbent strata, earth creep, the flaking effects of moving ice, wave action, and 'chip-and-slide'—are no longer met with, and the time is ripe for the further investigation based on design, technique and condition of surface, towards differentiating between the pre-Crag industries ; for in the formation of the stone bed all specimens, of whatever age, were swept into one deposit. This task has already been begun by Reid Moir.

Whilst the Suffolk 'bone bed' contains a fairly high proportion of rostro-carinate types, these are by no means so well represented in the Norfolk Stone Bed, and are outnumbered by flake implements, some of which are of surprisingly advanced type. The great mass of the specimens are certainly pre-Chellian, but the occasional hand-axes, particularly the boldly flaked and skilfully designed specimen from Whitlingham (Norwich Castle Museum),[4] suggest that Early Chellian is at hand. The chief sites now available are Eaton, Whitlingham, the cliff section from Weybourne to Sheringham, and beach exposures at Beeston and West Runton. Amongst the specimens which call for special notice are 'The Norwich Test Specimen' rostro-carinate (British Museum),[5] described by Sir Ray Lankester, and the huge flake, 6 lb. 6 oz. (British Museum),[6] both from Whitlingham ; the fine scraper (Norwich Castle Museum) from Thorpe ; the 'giant hand-axe' from Beeston,[7] and a series from the coast sections which will be exhibited at the meetings. The conditions of formation of the stone bed have militated against the preservation of human skeletal remains. The striæ and chattermarks present on many of the flaked specimens appear to be due to moving ice, but no information is at present available concerning any tertiary glaciations.

[3] *P.P.S.E.A.*, I, i, p. 40. [4] *P.P.S.E.A.*, VI, iii, pp. 222–225.
[5] *Royal Anthropological Institute Occasional Papers*, No. 4 (1914).
[6] *P.P.S.E.A.*, VI, ii, p. 67. [7] *P.P.S.E.A.*, VI, iii, pp. 222–225.

Later in type than the stone-bed industries, and differing from them in their vivid orange colouring, in the size of the implements, the inferior quality of the flint utilised, and in the bolder and heavier technique, are the 'great flint implements of Cromer,' [8] discovered by Reid Moir in a flint-strewn patch of foreshore west of Cromer pier, specimens occurring in diminishing numbers as far west as Sheringham. This is essentially a flake industry, though it includes some huge roughly-flaked hand-axes and massive tabular choppers. Their great size has led to the suggestion that the makers were men of exceptional strength and size of hands. The actual level in which they occur is not yet decisively settled, though the upper and lower limits—the stone bed and the base of the Till—are quite clear. They belong apparently to an old land surface above the Crag or Cromer Forest-beds and are recognised as Early Chellian.

With them are found occasional specimens of purple-black or 'black-lead' staining, which appear to represent a rather later development, belonging to the Cromer Forest deposits. The flint of which these are made is intensely hard, either by nature or by the changes it has undergone, resisting fracture to a much greater degree than the orange or ordinary stone bed specimens.

Cromer Forest-beds.

The faunal associations of the Cromer Forest-beds, *Elephas meridionalis*, *E. antiquus*, *hippopotamus*, etc., are those of Chellian (Abbeville) man, but the intensive researches have so far failed to produce any human skeletal remains, and very little evidence of his implements, perhaps to be accounted for by the estuarine and fresh-water nature of the deposits. The 'much-discussed hand-axe' [9] (Ipswich Museum) found *in situ* in Till at Sidestrand was obviously derived from a pre-Till deposit. It is a shapely and clearly flaked specimen of evolved Chellian type. A second cruder example and a well-shaped flake were later obtained from the same exposure. The available evidence suggests that 'a fixed point in geology may be found for the Chelles period in the Cromer Forest Bed.'[10] 'In fact, we have the complete Chelles industry of this country, from its earliest stages to its latest, represented among the implements found along the 14 miles of Norfolk coast between Bacton and Sheringham.' [10]

Early Palæolithic Industries.

The gravels of south-west Norfolk have yielded numbers of Chellian hand-axes, but these are associated with late St. Acheul types and are usually rolled and obviously derived, as was the case at Whitlingham. The Chellian-Cromerian industries are clearly earlier than the Scandinavian drift of the North Sea glaciation, whilst St. Acheul-Clactonian are later than the Chalky Boulder Clay of the Great Eastern. Of the interglacial period between these, during which the local rivers cut down their beds through glacial deposits and crag beds to the chalk, no evidence of human

[8] *J.R.A.I.*, 1921, p. 385, and *Great Flint Implements of Cromer*, Ipswich, 1921.
[9] *Antiquaries Journal*, 1923, p. 135.
[10] Kendrick and Hawkes, *Archæology in England and Wales*, 1914–1931, p. 14.

industry is at present available.[10a] The Palling hand-axe (Savin Collection) is probably late Chellian.

St. Acheul-Clactonian.

The gravels of the Thet and Little Ouse valleys have in the past produced enormous numbers of specimens, the high proportion of ovates being particularly striking. Hand-axes have been recorded from the Yare valley at Cringleford and at Eaton, whilst other single specimens have come from Markshall and Great Melton. Isolated finds of importance are those from West Runton, Overstrand, Eccles and Gresham in the north.

In 1926 Whitlingham [11] yielded what Prof. Boswell described as 'a wonderful series of implements, certainly unique for Britain and possibly for Western Europe.' The 500 artifacts obtained in the excavation occurred in gravel which, underlying 8–10 ft. of sandy and stony clay, belongs to the terrace deposits laid down by the stream, swollen by the melting ice during the glacial retreat. The fresh and unrolled condition of most of the implements shows that they cannot have been moved to any appreciable extent from the place where they were manufactured. The complete find is available for examination in Norwich Castle Museum. Of the hand-axes the proportion of flake implements to core implements is 68 : 56; some 50 per cent. show resolved flaking; whilst faceting of the butt is very scarce, most of the flakes showing the flat striking platform and prominent bulb of the Clactonian technique. No animal remains were obtained.

A year later H. H. Halls discovered at Carrow [12] a similar industry, possibly of slightly later date, associated with tusk and teeth of mammoth, the implementiferous gravel lying at a somewhat lower level than that at Whitlingham, whilst the proportion of flake implements to hand-axes was distinctly higher.

Further to the west, the hand-axes from Massingham and Syderstone, like the earlier finds at Tottenhill, South Wootton and Swaffham, are derived from the gravels of the Little Eastern glaciation.[13] On the whole the Norfolk evidence agrees well with that from Hoxne and Foxhall in Suffolk in fixing the St. Acheul-Clactonian industries to the post-Chalky Boulder Clay interglacial.

Middle Palæolithic.

Evolved Clactonian industries are represented in and above the gravels at Whitlingham, a lustrous grey hand-axe, unstained scraper and some of the 'points' (Norwich Castle Museum) being very similar to specimens from the High Lodge Brickearth, whilst the decreasing size and resolved flaking of many of the hand-axes suggest a post-Acheul date. A hand-axe of La Micoque type from Salhouse and the 'basket-work' specimen from

[10a] Reid Moir is obtaining specimens of primitive High Lodge type, which may prove to be early Acheulean.

[11] *P.P.S.E.A.*, V, ii, pp. 176–210.

[12] *P.P.S.E.A.*, VII, ii, pp. 171–174.

[13] *P.P.S.E.A.*, VII, ii, pp. 175–177.

Gresham resemble some of the later work at Whitlingham. Faceting of the butt is not prevalent, but enough occurs to suggest some Levallois influence. The industries are met with in the Little Eastern gravels in general. Recently Coombe-Capelle hand-axes have been obtained at Great Melton and Mousehold Heath.

Later Palæolithic.

Later Palæolithic industries in Norfolk are clearly more recent than the deposits of the Little Eastern glaciation, and appear to occupy the interval between it and the ice advance which deposited the 'purple' (Hessle) boulder clay at Hunstanton. Here, in and beneath the boulder clay Reid Moir found specimens of Aurignacian type.[14] In south Norfolk many of the surface finds would, from technique and condition, be classified as of late cave date; but stratigraphic confirmation is usually lacking. Dr. Sturge claimed a cave date for a floor, characterised by burins, at Wangford,[15] and Marr for one at Wretham,[16] whilst finds from Heacham may well be of this age.

Solutrean specimens, in contrast to the numerous and beautiful laurel leaves of Suffolk, are poorly represented by two found at Heacham [17] and possible specimens from Gorleston and Gresham. Solomon claims that a series of coarse choppers and scrapers from Morston [18] are also of cave date; whilst a scraper-core from Brancaster seems certainly of Les Eyzies type.[19]

Mesolithic.

The ice advance which deposited the purple boulder clay seems to mark the end of the Palæolithic in Norfolk, and the retreat of the ice was followed by the introduction of Mesolithic industries. These, widespread and prolific, fall mainly into Dr. J. G. D. Clark's Province B, characterised by 'non-geometric microliths-cum tranchet axe,' [20] though the Wangford-Lakenheath specimens belong to the 'evolved geometric' of Province A.[21] The most productive site is on the heathy plateau at Kelling,[22] on the edge of the Cromer-Holt ridge, characteristically Maglemosian in type, with grand-tranchet and spoon-shaped scrapers, though a series of 'haches-burins' connect with industries of Tardenoisian type. Micro-burins are almost lacking, though true burins are reminiscent of cave industries; axes and picks with tranchet technique are common, as are finely worked saws and the innumerable 'beaten-back' points—some over 3 in. in length. The discovery of the beautiful harpoon (Norwich Castle Museum) [23] near the Leman Sands provides a connecting link with

[14] *Antiquaries Journal*, X, Oct. 1930, No. 4, pp. 359–371.
[15] *P.P.S.E.A.*, I, iii, p. 378, and I, ii, p. 227.
[16] *P.P.S.E.A.*, I, iii, p. 374.
[17] *Antiquaries Journal*, XI, 1931, p. 56.
[18] *Man*, XXXI, Dec. 1931, p. 267.
[19] *P.P.S.E.A.*, VI, iv, p. 308.
[20] J. G. D. Clark, *The Mesolithic Age in Britain*, pp. 54–58.
[21] *Ibid.*, pp. 32–35.
[22] *Ibid.*, pp. 54–56.
[23] *P.P.S.E.A.*, VII, i, pp. 130–132.

the Danish industries, and the peat association shows that the southern North Sea basin was then above sea level, confirming the discoveries of the Fenland Research Committee, whose borings showed what appeared to be the Mesolithic level now 26 ft. below O.D.

Hellesdon,[24] Sparham,[24] Lyng,[24] and Two Mile Bottom, Thetford,[25] are valley sites, as is also the yet unpublished site at Bowthorpe ; odd specimens from Costessey, Salhouse and Great Melton also occur in the river valleys ; Hockham has produced a petit tranchet, and further west Northwold has yielded Mesolithic material.

Kelling, Sparham, Hellesdon, Bowthorpe and Costessey have all produced polished axes, whilst the crude barbed arrow head and rubbed knife from Kelling suggest survival of the industry on this site to early Bronze times. At Morston the fresh unpatinated condition of the Mesolithic specimens, whether found *in situ* in the section above the purple boulder clay or scattered on the arable, strengthens Solomon's contention that the heavily patinated, iron-stained, chopper-scraper industry is pre-Mesolithic, but among these patinated specimens occurred a fragment of a polished axe of late type ; it is clear that here also dating by patination and staining must be applied with caution. On the whole the Norfolk evidence suggests the late survival of Mesolithic industries and the correspondingly limited duration of the Neolithic. The eastern and south-eastern connections of the Norfolk cultures continue until historic times.

Neolithic.

Norfolk possesses no long barrows (the nearest being at Royston and in south Lincolnshire), no ' interrupted ' earthworks, and only scanty records of Neolithic pottery, though until a thorough re-investigation has been made little importance can be attached to the ceramic evidence available. The absence of suitable stone might in itself be sufficient to account for the lack of megaliths (though Stukeley refers to a stone circle at Gorleston)—the few great erratic boulders usually marking trackway junctions give no indications of date—but in any case the advance of Neolithic man from the south-west could not long have preceded the arrival of ' beaker ' man from the lower Rhine area, since in the Fens there is distinct overlap of beaker and Peterborough ware. Leaf-shaped arrow heads occur in roughly equal numbers with barbed, whilst the extraordinary wealth of flaked or polished specimens for which the county is so justly famous cannot be restricted to the Neolithic period, but may well range in date from Mesolithic to Iron Age. Hoards of axes are recorded from Whitlingham,[26] Wells[27] (Norwich Castle Museum), and Egmere (Norwich Castle Museum) ; flint sickles occurred at Wreningham [28] (British Museum), Roydon (Norwich Castle Museum),[28] South Runcton (Norwich Castle Museum), and recently a fragment was found at Swannington ; these again emphasise the eastern relationships of the Norfolk cultures. Remains of lake dwellings were discovered

[24] *P.P.S.E.A.*, II, ii, pp. 194–203.
[25] *P.P.S.E.A.*, I, iv, pp. 461–467.
[26] *P.P.S.E.A.*, I, i, Plate XVI.
[27] *P.P.S.E.A.*, VI, i, p. 56.
[28] *P.P.S.E.A.*, VII, i, p. 73.

when the Wretham meres were drained, and also at Barton Mere, whilst possible hut circles have been noted at Litcham, Wellingham and Weasenham, but these await excavation. The hollows on the Cromer-Holt ridge appear to be of later date.

Flint Mines.

It is now generally accepted that the flint mining characterises the Late Neolithic and Early Bronze Ages, being practically abandoned by the Early Iron Age, but Armstrong's claim for an earlier beginning at Grime's Graves requires consideration. Here mining was certainly carried out on a comparatively enormous scale, suggesting either a prolonged duration, or, less probably, a comparatively short spell of intense productivity. Of the 34 acres, 16½ are occupied by nearly 400 saucer-shaped hollows, from 12–70 ft. in diameter, each indicating a filled-in shaft. Over the remaining 17½ acres no surface indications are visible, but excavations show that the area is closely crowded with mine shafts of small diameter. Recently, fresh shafts have been exposed at Lyndford. Armstrong [29] has stated the problem of Grime's Graves under six heads :

(1) The presence in the pits and on the chipping floors of numerous artifacts of Palæolithic type.
(2) That these artifacts have been manufactured on the site and in the traditional Palæolithic technique.
(3) The presence of Levallois flakes and tortoise cores.
(4) That these artifacts have been found associated with an advanced method of mining, in which polished axes appear to have been used.
(5) That celt-like forms occur on some chipping floors, but no polished implements have been found.
(6) That the fauna, though including Pleistocene animals, includes none which are exclusively Pleistocene, red deer and short-horn ox predominating.

It has been the aim of the post-war work to elucidate these points. The pits previously excavated had been sunk to a depth of 30 ft. through successive layers of sand, boulder clay, chalk, flint (top stone), chalk, flint (upper crust), chalk, flint (wall stone), and chalk, to the level of the ‘ floor stone,’ the wonderful flaking quality of which rendered it so desirable a raw material. Armstrong found that contortions due to glacial action had caused outcrops of the floor stone, making it possible to obtain it by shallow open workings. This discovery led to the finding in 1923 of the group of ‘ primitive pits.’ [30] ‘ These pits and the tools used in sinking them are of a type not previously recorded and undoubtedly mark an early phase in the evolution of mining. They are bell-shaped at the base, entirely devoid of galleries, and entered by wide steps cut in the chalk walls. The picks used were not the familiar deer antler picks, but merely long bones of animals, artificially hollowed at the distal

[29] *P.P.S.E.A.*, V, ii, pp. 91–127.

[30] *P.P.S.E.A.*, IV, i, p. 113.

end to prevent the shaft splitting as a result of accumulation of chalk debris within.' 'The antiquity of the pits is emphasised (1) by the complete absence of any surface indications of their presence; (2) by the solidity of the filling and the sealing in of the shaft by a stratum of blown yellow sand; (3) the primitive tools employed. Two of the shafts examined were partly overspread by chipping floors which antedate the sandy layer but were clearly more recent than the shafts.' The few tools resemble Campigny and tranchet types, the flints bear a greenish and highly lustrous patina, giving a varnished appearance suggesting a prolonged period of flooding or the presence of a considerable flow of water subsequent to the sinking of these early shafts.

The 'intermediate pits' and the recently described Pit 12,[31] which produced Peterborough ware, connect up with the deep pits originally excavated. The huge communal workshop and cooking site of early Iron Age date, termed the 'Black Hole,'[32] provides fresh-looking unpatinated flint implements as well as derived and patinated specimens of the older industries. It was obviously subsequent to the cessation of the mining.

Whilst the engravings[33] seem to bear relationship to the rude scratchings of the Baltic cultures, the extraordinary mixture of drift hand-axe types with a magnificent Levallois flake industry and with pottery presents a picture of which the details are far from clear as yet. The evidence for a Neolithic date is certainly strong, but it seems that in view of the late survival of the Mesolithic industries in the county and the admittedly short duration of the Neolithic, Armstrong may well be right in putting the early stages of the mining industry in the (local) Mesolithic.

Other Norfolk Cissbury sites are recorded at Massingham,[34] Buckenham Tofts, and Ringland,[35] where an open quarry was investigated by W. G. Clarke. Antler picks are recorded from Whitlingham and Eaton, whilst typical implements occur at Easton, Markshall and Great Melton.[36] At the latter sites are hollows which appear to be filled-in pits, though this awaits confirmation by excavation. Beechamwell, Cranwich, Drayton, Heacham, Weeting, Northwold, Keswick, Quidenham and Costessey have all produced implements of Cissbury type.

Wood Circle.

Though no stone circles are known in the county, air photography has revealed what appears to be a wooden circle of apparently 'Woodhenge' type at Arminghall.[37] It is hoped that the Norfolk Research Committee may have excavated this in time for the results to be available for the British Association meeting.

[31] *P.P.S.E.A.*, VII, iii, pp. 382–394.
[32] *P.P.S.E.A.*, IV, ii, p. 182.
[33] *P.P.S.E.A.*, III, iii, p. 434, and III, iv, pp. 548–558.
[34] *Transactions of the Norfolk and Norwich Naturalists' Society*, 1901.
[35] *P.P.S.E.A.*, II, i, pp. 148–151.
[36] *P.P.S.E.A.*, II, iii, p. 374.
[37] *Antiquity*, VII, No. 27, Sept. 1933; III, No. 11, Sept. 1929.

Bronze Age.

Bands of armed invaders from the east and south east, 'Beaker men' of the A complex, with flint daggers, stone axe hammers, V-bored buttons and riveted bronze knife-daggers, entered by way of the Wash [38] and spread over the adjoining area, where they seem to have developed the handled beakers and polished discoidal knives, of which this district appears to be the primary centre. Almost at the same time Bronze Age B invaders moved northwards from the Suffolk coast, with archers' wrist guards and tanged metal daggers.

A fine handled beaker (Norwich Castle Museum) [39] associated with a skull comes from Smuggler's Road, Bodney, whilst a fragment of a polished axe has recently been found near the site. Flint daggers are recorded from Rushford (Norwich Castle Museum), Weeting and—yet unpublished—from Bowthorpe. Numerous records of polished knives come from the Brecks, whilst the area around Castle Acre has produced several recent finds. Flat bronze axes of early type come from Heacham, Methwold Hythe and West Runton.

Over 200 round barrows are recorded for the county, and many of these appear to belong to the early part of the Bronze Age, whilst the cooking sites investigated by Apling in the Thetford valley [39a] and at Hoe, and others recorded on the slopes of the Cromer-Holt Ridge, may belong to this period.

Among the B beakers is a curious horizontally hooped specimen from East Tuddenham (Norwich Castle Museum).[40]

Of the numerous hoards of later Bronze Age date the great find at Carlton Rode in 1845 (Norwich Castle Museum) is outstanding, comprising gouges, punches, palstaves, hammer, chisels and celts; whilst that at Stibbard near Fakenham with its 80 implements fresh and unused—70 palstaves, each made in a separate mould, and 10 spear heads—is equally important. Two hoards at Eaton and others at Stoke Ferry and Reepham may be mentioned. Sword blades from Thetford and Methwold, a dagger from Cromer, and another, with amber beads and thin gold plates, associated with a contracted male skeleton at Little Cressingham, belong to the late Bronze period. Bronze sickles are recorded from Corton beach (over the border in Suffolk), Dereham (Norwich Castle Museum), and 'Norfolk' (exhibited at the Archæological Institute in 1881), whilst a gorgeous specimen, recently found in Norwich by a schoolboy (Norwich Castle Museum), will be the subject of a forthcoming monograph. Gold is recorded from Ashill, Downham and Foulsham—two torques and an armilla. A fine circular shield was recovered from Sutton,[41] and a bronze torque from Stoke Ferry.[42]

Among the pottery A-C beakers are common and varied, whilst B, penetrating from the south-east, are scarcer. A good deal of the material from the round barrows awaits examination. Deveril Rimbury fragments at Cambridge are labelled Sheringham.

[38] *P.P.S.E.A.*, VI, iv, p. 357.
[39] *P.P.S.E.A.*, VII, i, pp. 107–110.
[39a] *P.P.S.E.A.*, VI, iv, pp. 365–370.
[40] *P.P.S.E.A.*, VII, iii, Plate XIX.
[41] *P.P.S.E.A.*, III, ii, Plate XVIII.
[42] *P.P.S.E.A.*, III, ii, p. 319.

Sir Cyril Fox's distribution maps show that in late Bronze Age times there developed a steady drift of wealth and population south-westwards, more mixed soils being taken into cultivation and the lighter areas abandoned.

Iron Age.

The Iron Age A witnesses a sporadic infiltration of nomadic bands from the Lower Rhine tumulus area between 500 and 400 B.C., entering Norfolk by the Wash. The earliest phase is represented in Apling's discovery at West Harling, where the Hallstatt pottery shows characteristic Bronze Age influence, and by Armstrong's find at Grime's Graves. The tumulus at Warborough Hill, Stiffkey, recently excavated by R. R. Clarke suggests an independent coast landing, and represents the unusual phenomenon of having been utilised in late Romano-British times as a refuse pit. The early settlement at Runcton Holme[43] was slightly later than these.

Iron Age B is best represented by the peasant settlement at Runcton Holme,[44] where occupation continued till the first century A.D. Whilst the many Norfolk earthworks await excavation, it appears that some, at any rate, may be allocated to this period. The most perfect and impressive, the double circular chalk-rubble ramparts at Warham, yielded fragments of pottery similar in type to that at Runcton Holme and also some 'decorated sherds recalling genuine La Tene of Glastonbury.' Other similar earthworks at Hunstanton, Hunworth, Tasburgh, South Creake and Castle Acre are also probably pre-Roman. The enclosures adjoining Narborough and Caistor probably belong to this period.

The chariot burials of the Fen border show that the Parisii penetrated to Norfolk and suggest the origin of the historical Iceni.

The northward-pressing Belgic invaders of Iron Age C obviously met with desperate resistance and failed to extend their influence over Norfolk, coin distribution maps showing clearly a bare 'no man's land' along the border. Like the other non-Belgic tribes the Iceni were pro-Roman and became allies of the invaders.

The retarded Romanisation of Runcton Holme shows that Norfolk remained a 'backward area'—a tendency emphasised by the terrible vengeance following Boudicca's rising.

The work of the Fenland Research Committee, however, shows that, in contrast to the rest of the country, in early Romano-British times the Fens (which then occupied a higher level) were well populated and fully tilled. The air photographs are showing the settlements, and Fowler's recognition of the 'roddens' as the former stream beds is helping to direct archæological investigation. Hawkes remarks, 'In what we can perceive from air photographs of the nucleation of fields around various settlements and such differential characters as may exist among the fields so nucleated, we have economic and sociological evidence at hand such as has never been available before.'[45]

[43] *P.P.S.E.A.*, VII, ii, p. 199. [44] *P.P.S.E.A.*, VII, ii, p. 233.
[45] *Geographical Journal*, LXXXIII, No. 1.

ROMAN.

The early alliance of the Iceni with the Roman power was broken by Boudicca's rising and the devastation of the area which followed. Prof. Donald Atkinson's excavations at Gayton Thorpe[46]—a winged corridor building—show that it was occupied between A.D. 150 and 300, and both here and at Caistor the backwardness of the Romanisation is obvious. The results of the investigations at Caistor, the county town of the Iceni, set afoot by the wonderful air photographs, will be available for the meeting.

Brancaster and Burgh Castle were important Saxon Shore forts, the buildings at Caister-by-Yarmouth may be related to Burgh Castle on the opposite shore, whilst R. R. Clarke's find at Stiffkey suggests a possible signal station, which may also be the explanation of isolated pottery finds at Muckleburgh and Beeston. Remains of buildings at Ashill, Baconsthorpe, Brundall, Dunham, Fring, Grimston, Howe, Methwold, Reedham and Weeting; coin hoards at Beechamwell, Carleton St. Peter, Caston, Elmham, Great Melton and Wilney; a silver dish at Mileham and pigs of lead from Saham Toney, do not much relieve the impression of the general poverty of the remains.

Whilst the Icknield Way has every appearance of being pre-Roman, the direct course of Peddar's Way and its lack of settlement sites have suggested Roman influence, and recent excavations show that certain sections at any rate belong to the first century. Phillip's discovery of Lincolnshire roads[47] leading to a ferry across the Wash to some extent links up with the Norfolk evidence. A road southward from Brancaster, one along the line of the Ipswich Road from Norwich, and a short stretch of E.-W. road in Mid-Norfolk are all that can be definitely recognised as Roman.

ANGLO-SAXON.

Documentary evidence of the Anglian conquest is entirely lacking, but the geographical position of the country gives it great importance for the study of the earliest invaders. Unfortunately among the Angles cremation was the rule, and the numerous discovered burials are in general lacking in the information that attends inhumation. The occasional occurrence of inhumation prompted Reginald Smith to suggest an intrusive non-Anglian element. In any case the great cemeteries at Walsingham, Castle Acre, Elmham, Shropham, Hargham and Markshall were excavated so long ago that the recorded finds need expert re-investigation. Much is expected of Mann's recent work near Caistor. Inhumation burials of the pre-Christian period (anterior to A.D. 700) are known from Hockham, Sporle, Northwold, Walton, Bacton and Santon; the forthcoming Ordnance Survey map of Britain in the Dark Ages should be of much help in collating the isolated discoveries. The position of the burials at Hunstanton, Castle Acre, Thraxton and Brettenham along Peddar's Way suggests invasion by way of the Roman

[46] *Norfolk and Norwich Arch. Soc.*, XXIII (1928), pp. 166–209.
[47] *Antiquity*, VI, No. 23, Sept. 1932, p. 343.

roads as well as by the river valleys. The linear earthworks, particularly on the chalk ridge to the south-west, have not yet been excavated, but judging by the evidence of similar dykes in Cambridgeshire they derive from this period—the Bran dyke overlies 50 Anglian skeletons and appears to belong to the struggle for supremacy between East Anglia and Mercia.

Whilst the extent of the Anglian Kingdom was similar to that of the Iceni, there seems reason to assume the late survival in the Fen area of Romano-British peasantry.

The discovery of the Anglian cremation urns at Walsingham enriched English literature by Sir Thomas Browne's *Hydriotaphia*, and marked the beginning of the study of Norfolk Archæology.

IX.

THE AGRICULTURE OF NORFOLK

BY

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NORFOLK is probably the most important arable county in England. The total area of the county, excluding water, is 1,308,156 acres; 989,034 acres are under crops and grass, and two-thirds of the cultivated land is under the plough. During the past decade, when much land in the British Isles has been lost to the plough and the country in consequence has become even more pastoral, Norfolk farmers have continued to cultivate by far the greatest proportion of their land under the plough, and have maintained the very high standard of arable cultivation established by their forefathers. The size of the holdings varies in different parts of the county; the largest are found in the west, where there has been a marked tendency for a number of holdings to be taken by one man, and worked as a large-scale enterprise. In the north-west of the county, in particular, holdings of 800 to 1,000 acres are quite common, and there are several farmers with more than 1,000 acres in their hands. The remainder of the county, however, is composed of smaller farms; County Council small-holdings are up to 50 acres in extent, and the farms of other tenant farmers may be any size up to about 400 to 500 acres, the smaller farms predominating. The statistics show that there are 13,203 holdings above 1 acre, 4,443 above 50 acres, 2,724 above 100 acres, 1,873 above 150 acres, and 8,760 below 50 acres. In some places in the county the area of permanent grassland has increased, but the increase has not materially affected the agricultural practices of the county, which are still predominantly arable.

It is difficult to visualise Norfolk as anything but an arable county, for its soils are light and its climate is dry and sunny. Harvest weather is usually good, and the after-harvest cleaning of the stubbles is made easy by the continued fine weather. Thus the conditions are more favourable to arable than to pastoral farming.

The county possesses no minerals or other natural resources ; the land is its only asset. In this respect it is not unlike Denmark and other near continental countries, whose agricultural produce is the only possible export. Thus Norfolk exports meat, milk, grain, vegetables and fruit, and fish, and manufactures nothing of importance, except silks, shoes and tonic wine in Norwich, that is not directly concerned with agriculture. Colman's Mustard, Waverley Oats, Farmers' Glory Breakfast Food, agricultural implements at North Walsham, Great Ryburgh, Diss and other small towns, and fertilisers at King's Lynn, are all products of the land or are required by the land, and thus Norfolk depends upon agriculture for its welfare, probably more than any other English county. The whole atmosphere is agricultural ; small-holdings are numerous and highly developed ; there is an active Agricultural Education Sub-Committee of the Norfolk County Council ; most of the County Councillors are either directly or indirectly interested in agriculture ; the large landowner is an important person in rural sociology and continues to lead his tenants by the example of his own practice. Most Norfolk landowners are farmers.

There need be no surprise, then, in recalling that Norfolk has produced so many outstanding men in the history of agriculture. Coke of Holkham, Townshend of Rainham, noted landowners, whose enterprise and teachings have influenced the agriculture of the world ; Joseph Arch, George Edwards (the first farm labourer to be knighted), who between them did so much to champion the cause of the agricultural worker ; T. B. Wood, Professor of Agriculture at Cambridge, and now John Hammond, also of Cambridge, are men of agricultural science whose influence is national.

From the time of Kett, and perhaps earlier, Norfolk men have been politically minded. There was a Farmers' Federation before the days of the National Farmers' Union, and recently a new party—the Agricultural Party—was formed in Norfolk and seriously considered contesting a number of important constituencies at the last General Election.

Over fifty years ago the Norfolk Chamber of Agriculture appealed for funds to initiate the series of agricultural experiments that culminated in the establishment of the present Norfolk Agricultural Station in 1908. The Stalham Farmers' Club was founded in 1838, and with occasional periods of inactivity has met regularly since that date. Its influence on the farming of East Norfolk and on the public work of its members has been profound. Many other instances could be quoted of the interest in every walk of life of the Norfolk countryman in the famous agriculture of his county and of his determination in good times or bad to do, as A. G. Street puts it, ' his duty by the land.'

The geological and geographical aspects of the county of Norfolk are described at other places in this publication. The course of geological events, however, has not unduly favoured the agriculture of the county of Norfolk, except in the extreme east and west ; otherwise with the exception of a few isolated acres in Mid- and South Norfolk the soil is light, sometimes too light to farm, and much of it is derelict, especially in the south-west. There will be found vast expanses of desert-like land, broken by belts of conifers, and left to the rabbit to colonise. In better times much of it was farmed, but when agricultural conditions are bad it cannot be profitably cultivated. At all times it is hovering on the border of dereliction. Much of this Breckland area, however, appears never to have been cultivated.

The county is almost entirely covered by glacial drift, with chalk at varying depths below the surface. The following rough divisions of the county are very familiar to Norfolk residents and will serve as a useful basis of descriptions in this article. The divisions are : East Norfolk ; South Norfolk ; Mid-Norfolk ; North Norfolk ; and the Marshlands and Fens.

Generally the best soils are the medium loams of the extreme east and west of the county, the lighter soils are in the south-west and north-west ; those of Mid-Norfolk are rather inclined to be heavy, while those in the south are clays of the boulder clay formation.

East Norfolk.

It is difficult exactly to define the limits of the areas under description, but East Norfolk may be taken as the area enclosed by the sea and lines drawn through Cromer, Aylsham, Norwich to Beccles on the Norfolk and Suffolk borders. East Norfolk is a typical winter bullock fattening area, where magnificent crops of mangolds and swedes are still grown, although the area of stock-feeding roots has been considerably reduced since the introduction of the sugar-beet crop, for East Norfolk grows sugar-beet better than any other part of Norfolk, except the Marshlands. The soil is an easy-working medium loam of considerable depth, which permits the deepest cultivation. It is in the area of the most recent geological formations in England, and the agricultural possibilities of the soil are wide and varied, although it is not extremely rich chemically. Its great agricultural value is largely determined by the excellent physical condition of the soil, for East Norfolk can withstand drought, yet drains freely enough to withstand the ill-effects of excessive rainfall. Chemically the soils are often deficient in lime, and sometimes also in phosphates ; in fact, striking results have been obtained from phosphatic manuring on the beet crop at some East Norfolk centres in the county agricultural demonstrations.

Few sheep are kept in this area, the land being rather too sticky to carry them with ease during the winter. Thus the produce of the root shift is entirely consumed by yard-fed fattening cattle, and it is not uncommon practice for as many as three bullocks per acre of roots to be fattened during the winter-feeding season, and, incidentally, there has been no diminution in that number since the beet crop has been so largely grown.

Norfolk generally breeds few cattle, and there are probably less bred in

East Norfolk than at any other place in the county. Large numbers of store cattle are offered for sale on Norwich Hill every Saturday; from 3,000 to 4,000 are commonly to be seen awaiting sale by private treaty, between the Irishmen who bring them over and Norfolk farmers. A number of store cattle are also brought in from the north and west of England, but Irish stores largely predominate. They are dehorned, therefore polled and less troublesome in the yards than the horned cattle supplied from other districts in England.

The four-course rotation is no longer practised in East Norfolk, for great difficulty is experienced in growing first quality samples of malting barley, as the land is usually in too high condition for the best barleys to be grown. In consequence many farmers turn their rotation into five or six courses, taking barley or oats after the wheat and sometimes two barley crops after sugar-beet, mangolds or swedes. A one-year ley cut for hay and broken up for wheat completes the rotation. Black currants are an important crop in East Norfolk and there are a number of well-managed fruit farms mainly growing apples, black currants, strawberries, and at Westwick cherries have been most successfully established.

East Norfolk includes the famous Broadlands, and as the rivers contributing to the Broads pass towards the sea, they reach a flat alluvial area of reclaimed land, which is farmed entirely as permanent pasture. These are the Acle and Yarmouth marshes, and start as rather inferior grassland around Horsey on the sea-coast, but improve so much towards Yarmouth that they have every right to be classed amongst the best permanent grassland in England. They are entirely devoted to the summer fattening of mature bullocks, and in this respect are similar to the better-known Midland pastures. The Norfolk marshes, however, carry no sheep and the management of the grassland is not of the same high order as that of, say, the Market Harborough district of Leicestershire. It is possible, however, that an improvement in the grazing methods of the Norfolk marshes would make them capable of as heavy stocking as the Midland pastures, and there is plenty of experience to show that the beef produced is just as good, although the cattle do not fatten quite so quickly. It may seem rather paradoxical to write of first-class grazing in a county where it is supposed to be impossible to establish good permanent grassland. This last mentioned is a fallacy, but on the upland pastures drought is a serious factor in the permanent grassland management of the county. In the Norfolk marshes drought is rarely a serious factor, for the land is situated below sea-level and is drained by means of dykes, the water being moved towards the sea by means of a very well-organised system of drains and pumps worked by windmills. Thus the Norfolk marshland grazier can and does control the water table and appreciably reduces the ill-effects of continued drought. The system of management adopted on the marshes is peculiar and interesting. There are no farmhouses on the Norfolk marshlands; a few isolated cottages, situated in apparent desolation, mark the place where the Norfolk marshman lives. The marshmen are responsible persons, who undertake to 'look' the cattle for a number of different owners on the marshes. The owners of the cattle usually farm some of the adjoining upland and care of their grazing cattle is entrusted entirely to the marshmen, many of whom employ additional labour to assist them ; they are responsible for the cutting of the reeds and the ' bottomfying ' of the dykes during winter, when there are no cattle on the grass.

Many of the marshes are let by public auction each year, a system that is not conducive to improvement schemes. Some, however, have been bought, and are farmed by the owners. Rents vary according to the prospects of the beef trade. The marshes have been let at a somewhat higher rate this year, due possibly to the fact that Canadian cattle are not coming into the country and the graziers, in consequence, hope for a better winter trade.

Each occupier of the land pays a drainage rate, and the marshmen are left to control the grazing and to consult with owners of the cattle, perhaps weekly or later in the year when they meet to draw cattle out for the market. There are cattle markets at Yarmouth and Acle, which are situated on opposite sides of the marshes, where some very fine specimens of grass-fed beef animals are sold each year. Shorthorns, Aberdeen Angus, and crosses between the two breeds, are the most common cattle, but in recent years the North Devon has become quite popular.

West Norfolk.

West Norfolk is usually regarded as the country west of an imaginary line drawn from Wells-next-the-Sea, Fakenham, Swaffham, to Downham Market. Thus defined, it includes the rich area west of King's Lynn and the river Ouse, known as the Marshlands, including the Fen country on Isle of Ely borders. The Marshlands are arable and are not to be confused with the grassland stretch of country some sixty miles away known as the Acle Marshes mentioned above. For the purposes of agricultural description, however, West Norfolk must be divided into two, and the Marshlands with their entirely different agricultural character separated from the land immediately east of King's Lynn. It is to the last named that the remainder of this section applies.

The soils in the area are rather variable, but the majority of them are light. In the south-west they become so light that they may truly be described as blowing sands, especially from Swaffham to Thetford in the direction of Brandon in the neighbouring county of Suffolk. Those areas are in the Norfolk Brecklands, which despite its many other attractions, is the worst soil in Norfolk, and one of the least fertile in England. The soils of North-West Norfolk are much better, except the coastal ridge near Sheringham and Cromer, but they are still light gravels overlying the chalk, which in a few places is near enough to the surface to influence the character of the soil.

At Denver, and from West Bilney and East Winch a band of Greensand runs through to Snettisham, producing a soil superficially different from anything else in the county of Norfolk. It is, however, still light soil and is farmed almost precisely as the remainder of North-West Norfolk.

Along the North Norfolk coast are mud flats and grazing lands of variable value devoted to the grazing of livestock. Holkham Marshes, on Lord Leicester's estate, are in this area and are, of course, well known.

There is also a narrow strip of this alluvial arable land along the coast which grows excellent crops, especially in the neighbourhood of Heacham and Brancaster. It is, however, a very narrow strip, and might easily pass unnoticed by the cursory observer.

Irrespective of the derelict land in the Breckland area, there are a number of uncultivated heaths in West Norfolk. It is a district of typical sheep and barley farms where in the right season, the best of England's malting barleys are grown, and where four-course rotational farming was first practised on a large scale. The arable flock of Suffolk ewes is still an inseparable part of the farming. It is also, unfortunately, the part of Norfolk to suffer most in the present agricultural depression, and many financial failures, sometimes in families that have occupied the same farms for a century or more, have been experienced. It is not surprising, therefore, that a number of changes have taken place in the farming of this district during the past ten years. The wheat, roots, barley, hay sequence of the four-course rotation, however, is still adopted on many farms, the sheep being largely responsible for maintaining the condition of the arable land. They consume the greater part of the root crop, some of the clover and ryegrass, and often special catch-crops of rye or oats and tares are grown specially for them.

Early fat lamb production is usually attempted ; otherwise the sheep are sold at the many lamb sales held in the county, that at Swaffham being perhaps the most important in West Norfolk. Barley is the chief cereal, the land being rather too light for the best wheat crops, although the variety 'Little Joss' does quite well on the lighter soils. Towards the coast the country becomes pleasantly undulating and it is there, notably in the Burnhams, where the finest malting barleys are grown. The winter fattening of cattle is important, but sheep compete for the roots and reduce the number of yard-fed bullocks it is possible to feed. Compared with East Norfolk straw yields are not high, and there is not the same necessity for the heavy head of winter cattle to 'jam' the straw. It is a common practice in Norfolk to cross the Suffolk ewes with Cotswold rams, and possibly, but for this practice, one of the breeds, the Cotswolds, might easily become extinct, since there is a good trade for Cotswold rams in Norfolk. The cross, however, is a big hardy sheep that withstands the East Coast winds and will consume large quantities of roots and can be fattened to heavier weights without becoming too fat.

Almost frantic efforts, however, have been made in the past ten years to escape the almost inevitable losses of farming the West Norfolk gravels on the traditional four-course system. They have taken three forms—two extensive and one intensive. First the ranch methods of the grassland sheep farmer, and later the power methods of the continuous corn grower were adopted to oppose the incompatability of fixed wages and falling corn and stock prices. Others have tried the more intensive methods of beet and vegetable cultivation, combined with milk production, and arable sheep, fed on beet and vegetable by-products.

There are a number of mechanised farms in the district using Combine harvesters, driers, and in general imitating the methods of the prairie farmer. At Southacre in this district also is situated the only Lucerne

Meal organisation in England. The 14,000 acre collection of farms of Messrs. Parker & Proctor, the King's Estate, and the flax-growing enterprise centring around His Majesty's farms, are also in West Norfolk. The south-west of the district adjoins the Fens and towards them, for a few miles, the soils become stiffer ; in fact, a wide range of soils can be seen around Stoke Ferry.

MID-NORFOLK.

The soils of Mid-Norfolk are, perhaps, best described as heavy loams ; they are largely arable, growing excellent wheat, sugar beet and barley in dry seasons. The farming is not unlike that of East Norfolk, but the soils are different, being under-drained and the fields separated by deep ditches. Along the banks of the Wensum is a wide stretch of permanent grassland upon which dairy cattle in Norfolk were first developed on a large scale. Mid-Norfolk has become, in recent years, the chief milk-producing area of the county, and presumably because the new dairying interest coincided with a period of great Friesian popularity, that breed of dairy cow predominates, although there are some excellent herds of Red Polls in the area. In consequence of the dairying development there is less interest in the fattening of cattle, and a number of bullock yards have been turned into cowsheds. Recently, there has been a considerable development in the growing of vegetable crops in the Fakenham district on the borders of Mid- and West Norfolk. Carrots, brussels sprouts, cauliflowers, broccoli, and asparagus are all cultivated, not on market gardens but on farms often one thousand acres in size. On these farms the vegetable crop and sugar-beet have taken the place of the older sheep-feeding root crops, and it is usual on these farms to run a ewe flock throughout the year. This, however, would be impossible on some of the heavier soils of Mid-Norfolk, and these last remarks perhaps apply more particularly to a radius of about ten miles around Fakenham, which is the chief market town in that part of the county.

SOUTH NORFOLK.

South Norfolk, approximately bounded say by lines drawn from Norwich to Bungay, and along the south border to Diss, East Harling, Attleborough, Wymondham back to Norwich, is composed of heavy soils ; some, notably those immediately south of Norwich, on the way to the Suffolk border, are stiff clays, and a considerable acreage of arable land has recently been put down to permanent pasture.

The soils are similar, geologically, to the heavy clays of the Halesworth and Saxmundham district of the adjoining East Suffolk. They are often ploughed on ' ten-furrow work,' and lie in consequence in high ridges for drainage purposes. Many of these soils are inadequately drained and ditches and fences have, to some extent, been neglected during the recent difficult times. The land is now mainly devoted to store raising, dairy farming and grassland sheep. Further west, in the direction of Wymondham and Diss, the soils are better but are still heavy, and mixed arable farming and dairying is carried out. Well-treated, the land in South Norfolk grows good wheat and beans. Excellent beet crops are grown around Diss. Clover and other small seeds grow well in Mid- and South Norfolk. They are usually harvested in excellent condition and are in demand by North Country and Scottish farmers.

The Marshlands and Fens.

The Marshlands and Fens extend in Norfolk from King's Lynn to Wisbech and the Holland borders at Walpole Cross Keys near to Sutton Bridge. The Marshlands are silty soils and the Fens black and peaty.

Two types, at least, of fen are recognised, viz. overlying sand and clay respectively. The former is the least fertile. The Fens are shrinking rapidly when cultivated and are reduced as much as 4 ft. in sixty years. This may be seen on the Southery-Feltwell road. Eventually the Fens will either become heavy clay or sandy soils, as the large stores of humic material are exhausted.

The silty soil of the Marshlands may be divided into heavy and light, the extreme form of the latter being river silt formed in old creek and river beds. Skirt land is the term given to land which is a mixture of silt and loam on the margins of the Fens. Raised bands of silt sometimes run across black fen; these are probably the remains of the beds of old creeks. Patches of white marl are found and probably mark the site of former meres, the white earth being composed of shells.

Silt soils present no cultural problems except those associated with heavy land on the heavy silts. Occasionally patches are found with a lime requirement, due to drainage troubles. The light black fen is occasionally sour and 'pans' are often troublesome.

In the case of both fens and silts there is never any fear of drought, for there is a perfect control of the water table by the system of drainage (by pumps in the case of fens).

Modern pumping plants have reduced the danger of flooding to a minimum in the Fens, but the serious effects of floods in the past have left their mark, for farm buildings are crude in the extreme and the houses are also small and mean. On the other hand, the silt land is characterised by excellent buildings of a substantial nature and large, mansion-like houses.

In the past, livestock, especially sheep, was an important industry on the silt land when this was under grass, and Cobbett refers with evident satisfaction to the hog-like sheep he noted there. Livestock have never been important on black fen. The only classes of stock kept to-day on both fens and silts to any extent, are bullocks and pigs. A great increase in the latter has occurred, partly due to the uneconomic nature of the cattle trade, and latterly owing to the Pigs Marketing Scheme.

Pig manure proves as good or better than cattle dung and is less costly o produce. Pigs also are regarded as more efficient consumers of potatoes than bullocks.

In the evolution of the silt lands, corn-growing followed the grazing of last century, when the grass was broken up and this was followed by potatoes. On the silts potatoes are grown more widely than beet and are really the chief crop of the area. Yields of 15 tons per acre of 'King Edward' potatoes of high quality are quite usual. Cereals and clover are a secondary consideration, but many farmers specialise in seed crops of mustard, mangolds, beet, turnips and swedes. Spring cabbage and early flowers—daffodils and tulips—are also grown. Thus the district is quite unlike any other part of Norfolk. Its agriculture, like its soil, belongs more to that of the adjoining Holland division of Lincolnshire.

On the fen soils, beet is now the chief crop, especially with the smaller farmer. Next come potatoes and cereals, while celery is a speciality with many men on the lighter fens.

The farming of the silts is very high, and large quantities of artificial fertilisers are used. In cases where farmyard manure is scarce, it is a common practice to plough in mustard or clover as a green manure.

Labourers in the Marshlands and Fens are very hard-working and intelligent men and often possess a little land of their own. They work in an intensively farmed area and are comparatively well paid as they receive much piece work.

The deep soil and absence of hedges with even contours of the land makes it possible to employ cable cultivators and Gyro tillers, and to plough very deeply, up to 18 in. being not unusual. The Marshlands are the Norfolk land of Goshen.

Small Holdings.

This county also maintains its reputation as the premier agricultural county by leading in the provision of statutory small holdings under the various Acts of 1908–1931, the County Council controlling 29,510 acres (of which 26,580 acres were purchased), occupied by 2,074 tenants at a rent roll of £67,270.

The density of the holdings naturally follows the quality of the soil, and concentrates in two main areas, east on good loams and west in the Marshlands and Fens, although there are also some very successful schemes in the Dereham-Fakenham district. The southern part of the county—principally boulder clay—contains a large number of naturally small farms with a consequent reduced demand on the Council.

The holdings, as may be expected, are mainly arable, the average proportion of grass being one-sixth. There are considerable variations in size, from 4 acres in the fruit district near Wisbech to the maximum 50 acres in the north-east. A number of fully-equipped minor holdings of about 10 acres have recently been created at the request of the Ministry of Agriculture, but, possibly owing to the distance from suitable markets, the major holdings of 45–50 acres, family farms, are in great demand, in fact, the average acreage has increased from 9 in 1909 to 15 last year, with a consequent drop in the number of tenants.

The depression has, of course, seriously affected small-holders as well as the larger farmers, and a considerable number of 'bare-land' holdings have been given up during the past five years. To counteract this, the energetic County Land Agent, Mr. T. G. Ellis, has not only modernised the existing equipment, but arranged the provision of new houses and buildings wherever necessary, and the county can rightly claim to have some of the most up-to-date estates in the country. Dairying has naturally increased, with the consequent improvement of cowsheds, dairies and water supplies. A pleasing standard dwelling-house of Peterborough rustic bricks and pantiles, with bath, and a compact set of buildings—concrete dwarf walls, weather-boarded and tiled—has been evolved, as well as a standard pair of cottages for minor holdings.

The principal arable crop is now sugar beet, 5,682 acres, a meteoric rise from 880 acres in 1925; barley has fallen to 4,074 acres, with wheat third at 3,938 acres. The root acreage has fallen considerably from 2,700 to 1,900 acres in the past ten years, the loss of home-produced feeding stuffs being replaced by sugar beet pulp. Potatoes and fruit are important crops in the Fens occupying 2,095 acres and 1,050 acres respectively.

Bullocks are fattened by smallholders, often from home-bred calves. A large head of poultry is also kept on up-to-date methods.

The largest estate is at Burlingham—midway between Norwich and Yarmouth—consisting of 3,995 acres with 163 tenants. The woods on this estate, 50 acres, are systematically felled and replanted, being very suitable for larch, oak, ash and chestnut.

The average rental is £2 per acre and 85 per cent. of the tenants pay promptly, 13½ per cent. are not such ready payers, but the actual failures are only about 1½ per cent.

On an average, one-fifteenth of the holdings change hands annually, and even during the recent trying times approximately twenty tenants yearly left to take larger farms. Some very striking examples of success by agricultural labourers and ex-service men from very small beginnings have been obtained.

Even during the past two years the Small Holdings' Committee has been optimistically buying land—often at bargain prices—their policy being to provide the type of holding found by experience to be most suitable to the district.

At Michaelmas last, tenants were found for 162 holdings, comprising 2,737 acres, and at present only five holdings, totalling 44 acres, are in hand, pending equipment, besides a few odd marshes.

Considerable assistance is rendered to the small holders by the staffs of the Agricultural and Horticultural Stations and by the Council in liming where necessary.

Horticulture.

Horticulture has developed rapidly in Norfolk. It was during the war years, when efforts were being made to cultivate all the available land, that farmers turned their eyes to new developments, and from a small beginning an important industry in horticulture has arisen in Norfolk.

In Norfolk the production of horticultural crops has been rapid in recent years, and with the continued depression in agriculture, farmers have turned to sidelines, developing horticulture as one endeavour to improve their prospects.

From King's Lynn to Wisbech in the Marshlands of West Norfolk, will be found the largest block of top fruit trees and strawberry plantations in the British Isles, together with a large acreage of pears, plums, cherries and gooseberries. In this district the glasshouse industry has developed considerably, and now that there is a prospect of an improved water supply it is possible that the district might even become the most important area in England for glasshouse crop production. Consequently glasshouses are still in the course of erection. Another important glasshouse area is near Norwich, where a large number of houses may be found.

The black currant crop is mainly in East Norfolk and the produce is known in all English markets, the East Norfolk Fruit Growers' Association having done much to increase the consumption of this fruit. In East Norfolk there are large acreages of apples, pears, plums, cherries, gooseberries, raspberries, loganberries, blackberries, vegetables and flowers. A notable feature in recent years has been the increase in the production of the Cox's Orange Pippin dessert apple in the cultivation of which Mr. H. Goude, the Horticultural Superintendent of the County, has made a special study. The following figures are given in the Ministry of Agriculture's recent return for the acreage of the main horticultural crops grown in Norfolk :

June, 1934.

Orchards	10,059 acres.
Strawberries	4,371 ,,
Currants, gooseberries, etc. . .	5,057 ,,
Carrots	1,868 ,,
Cabbages, broccoli, etc. . . .	3,106 ,,
Peas, beans, etc.	2,258 ,,
Brussels sprouts	1,523 ,,

There are no reliable figures relating to the area under glasshouses in Norfolk, but it is probably not less than 100 acres, entailing a capital outlay of not less than £400,000. The intensive production of vegetable and salad crops is also developing.

Poultry Keeping.

Norfolk possesses over 2,000,000 head of poultry and has nearly doubled (181 per cent. increase) its poultry population during the past ten years—a rate of increase greater than that of any other county in the British Isles.

Commercial egg production is the main feature of the poultry industry in the county. Most of the eggs produced are marketed in the London area. The main marketing channels are through large wholesale distributing firms and the National Mark packing stations, a number of which are operating in every part of the country. In addition, every market town has its egg and chicken auctions.

The main concentration of poultry in the county lies eastwards of the middle line, north to south of the county, from Wells, Fakenham, Dereham to Thetford. The chief commercial egg breed used in the county is the Rhode Island Red Single Comb, which also enters largely into most of the crossbred flocks.

The table poultry industry is being developed in Norfolk. The Light

Sussex, crossed with the Rhode Island Reds of commercial egg flocks, is producing a good class 'country chicken.'

Ducks.—Around Attleborough and Diss and on the borders of Suffolk and Norfolk, a very large and long-established duck-raising and -fattening industry is operated. The ducks used are of the Aylesbury type, although they are not pure. Large-scale operations are carried on, some fatteners dealing with a throughput of 50,000 ducks per year. The ducks are all prepared for the London market. Many cottagers in the district keep a flock of ducks and sell the resulting young ducklings to the large-scale fatteners.

Norfolk is the premier English county for turkey production. Approximately 60,000 per annum are produced. These consist almost entirely of the American Mammoth Bronze variety and although production is widely scattered through the general farms, the heaviest production is in the district of the duck fatteners. In the centre of this area as many as 7,000 to 10,000 turkeys change hands each year at the Attleborough Michaelmas Auction Sales.

As far as can be ascertained the small black turkey was the original turkey imported into Great Britain. A few specimens of the variety still exist in Norfolk under the name of the Norfolk Black. The breed was in danger of extinction, but a club has now been formed to preserve and develop it. The Norfolk Black Turkey, owing to its high table value and small size, is eminently suited to the present requirements of the market.

Agricultural Statistics for Norfolk.

The total area of the county has already been given ; of the 989,034 acres that are under crops and grass, 697,922 acres are ploughed. The statistics for the last ten years, however, show a decline of nearly 67,000 acres in arable land. This is entirely due to the uneconomic conditions that have prevailed during the past few years and the decline would undoubtedly have been much greater had not the introduction of the sugar beet crop most fortunately coincided with the most intense agricultural depression, so far experienced perhaps in the history of Norfolk farming.

Decline in Arable Land.

Year.	Acreage.	Year.	Acreage.
1924	764,661	1929	730,992
1925	758,315	1930	727,688
1926	751,706	1931	719,035
1927	746,397	1932	707,479
1928	741,118	1933	697,922

In the last ten years there has been a reduction of 33,000 acres in the area of the county cultivated. Some of the decline in the arable acreage and in the total area under crops and grasses reappears in the figures for rough grazings, which have increased by over 21,000 acres in the last decade. The permanent grass of the county has increased by 31,000 acres. There has obviously been less incentive to be committed to the heavy labour and other charges of arable land and an effort has been made to reduce them by turning less suitable arable soils into permanent grazings. This tendency has been largely confined to the heavy intractible clays and the lighter sands and gravels, the first named being too difficult and expensive to cultivate under the existing conditions of fixed wages and low prices of farm produce, and the latter too uncertain in its cropping to withstand the same combination of economic forces.

Actually, there are now 249,782 acres of permanent grass not for hay, and 78,927 acres of rough grazings in the county. The reduction in the acreage of the arable land of any district is to be deplored, for it has grave effects upon the social structure of an agricultural county, each section of which is dependent upon the others for its living. Arable land employs very appreciably more labour than the rough grazings produced by the light lands of Norfolk or the pastures established on the heavy clays; in consequence not only is the food output of the land reduced, but the agricultural labourer finds less employment. Some of the light West Norfolk farms have been grassed down and now, unfortunately, carry about one sheep to the acre, employing one or two shepherds and their dogs on 1,000 acres, whereas in former times there were between thirty to forty labourers on the same land.

On adjoining land in the hands of farmers with greater capital resources, hopefully carrying in until the depression has passed, are to be seen as many as thirty to forty workmen on a field of carrots or sugar beet. Such enterprise is only possible with considerable capital, but the contrast directs attention to incongruity of a nation that permits its suitable arable districts to be turned into inferior pasture land, and at the same time maintain its unemployed industrial workers on State resources.

Normally, the Norfolk four-course farm employs 3·5 to 4 men per 100 acres of arable land. One of the alternatives to the four-course shift, namely, continuous corn growing by power methods, substitutes one man per 200-acre farm for the seven to eight that used to work the same land on the traditional system; farmers on the last-named system, however, have often gone out of business or been forced to seek fresh and smaller fields to conquer; the power farmer continuously growing corn, however, safeguards his own interests by the comparative safety of his machines and comparatively negligent wages bill.

Crops and Grass.—To lose 33,318 acres of cropped land during ten years is a serious encroachment upon the capital reserves of the county. Nearly half (14,085 acres) have been lost since 1929, and 10,000 acres of the lost land appears as rough grazings and 4,000 as permanent pasture.

There has, however, been greater agricultural confidence during the last three years and it is hoped that the deplorable losses of arable land have now been checked. Much, however, will depend upon the agricultural policy of the Government.

Root Crops.—The statistics for the root crops since 1924 make interesting reading. They show the gradual reduction in the acreages of turnips, swedes and mangolds, and a very large increase in the acreage of sugar beet.

	Turnips and Swedes.	Mangolds.	Sugar Beet.
1924 . . .	83,698	54,336	7,207
1925 . . .	82,573	52,207	15,515
1926 . . .	76,565	50,816	32,384
1927 . . .	71,287	47,819	51,444
1928 . . .	72,608	47,738	41,063
1929 . . .	66,431	47,554	53,438
1930 . . .	60,023	46,117	74,627
1931 . . .	57,762	44,448	41,980
1932 . . .	47,233	37,228	66,135
1933 . . .	39,093	35,659	99,834

The turnip and swede acreage has been reduced approximately to half the acreage shown in the 1924 statistical return, and the mangold crop by nearly one-fifth. The combined turnip, swede and mangold acreages in 1933 were less than the acreages in 1924 by some 63,000 acres. In 1924 7,207 acres of sugar beet were grown in the county; last year there were nearly 100,000 acres. At least 63,000 acres, therefore, of the increased 90,000 acres of beet had been grown at the expense of the older root crops. As the reduction in arable acreage of the county would account on a four-course rotation for the disappearance of about 16,000 acres of mangolds and swedes, it is obvious that the beet crop has to a great extent taken the place of the other root crops and has been fitted into the rotation farming of the county. An exception is the experience of the small-holders who have grown much beet instead of barley. There are beet factories at Cantley, King's Lynn and Wissington in the county, and at Bury St. Edmunds, a few miles over the Suffolk border. Beet is extensively grown at all places in Norfolk except on the heaviest soils and some is even exported by sea to Selby in Yorkshire from the old port of Wells.

Around the beet crop have arisen new methods of stock feeding. Just as Townshend's turnips revolutionised the farming of Norfolk, and in particular the maintenance of livestock during the winter, so the sugar beet crop has become the pivot around which the whole system of Norfolk farming now turns, and the feeding of the beet bye-products—the leaves and crowns, and the pulp is now an essential part of the agriculture of the county. Sugar beet farming is highly developed in Norfolk and about one quarter of the British crop is grown in the county.

Cereals.—Barley and wheat are the chief cereals of the county. In 1933, their acreages were approximately equal, but in 1930 there were 100,000 more acres of barley than wheat. This increase was due to the introduction of the wheat quota and the comparative uncertainty and lower prices for malting barley. In 1927 the acreage of barley in Norfolk was lower and the wheat acreage higher than at any other time in the previous ten years. Oats are an unimportant crop in Norfolk, for the climate is not ideally suited to them. Despite this disadvantage, however, magnificent crops of oats are grown on the best soils in Norfolk, particularly when the rainfall is rather above the normal.

	Wheat.	Barley.
1924	98,988	196,693
1925	102,744	199,107
1926	100,031	192,036
1927	106,854	182,617
1928	86,644	204,576
1929	77,661	196,927
1930	82,623	184,026
1931	86,237	194,050
1932	91,189	174,429
1933	132,475	129,223

Sheep.—There have been fluctuations in the number of sheep kept in Norfolk during recent years, but the present tendency is for the numbers to increase rather than decrease. A good trade for mutton has been experienced in the last two years, and although wool prices have been unsatisfactory, the products of the sheep have promised to be less costly to produce than beef. In consequence, there is more confidence in sheep farming, at the moment, than in any other branch of animal husbandry in the county of Norfolk.

The type of sheep, however, has varied very appreciably during the last ten years. In quite recent times there were no sheep in the county except those accustomed to arable-land folding. Suffolks and their crosses and an occasional Southdown flock were the usual sheep on the farms. With the decline in the price of arable produce, the fixed labour charges, and the tendency to reduce the arable acreage, the grassland sheep was introduced in large numbers; the Scotch half-bred, the Yorkshire Masham, and other breeds accustomed to live the whole of the year on grassland, were brought in in large numbers and are still to be found on many farms. Their numbers, however, are now tending to decrease, and there is some indication that the arable flocks are regaining some of their lost popularity. To a great extent this is due to the cheap sheep feed that is available from the beet tops and the residues of vegetable crops in which there is now great interest in Norfolk.

	Sheep.
1924	277,537
1925	289,231
1926	311,148
1927	297,114
1928	285,681
1929	274,949
1930	258,659
1931	289,792
1932	297,745
1933	285,303

Total Cattle and Cows in Milk.—During the last ten years the number of cattle has increased by 30,000 head to a total of 154,883 in 1933. During the same time there has been a very large increase in the number of cows in milk, for there are now 41,000 cows in Norfolk. Before the War Norfolk farmers took little serious interest in milk production, but Norfolk is now an important milk-producing county. Practically the whole of the milk is sold wholesale to London, and many farmers have adopted modern methods for producing milk of higher quality. The Milkers' Competitions held by the County Council have been amongst the largest held in England, the entries this year being over two hundred. The Norfolk Milk Recording Society has done much valuable work in fostering the development of dairy farming in Norfolk, and Norfolk dairy farmers are usually to be found in leading places in the National Milk Competitions.

	Total Cattle.	Cows in Milk.
1924 . . .	124,285	33,637
1925 . . .	140,857	34,582
1926 . . .	141,971	36,480
1927 . . .	147,006	37,551
1928 . . .	134,014	36,670
1929 . . .	140,923	36,701
1930 . . .	139,127	37,278
1931 . . .	135,065	37,151
1932 . . .	143,656	39,110
1933 . . .	154,883	40,861

Pigs.—The pig to a very great extent is found in large numbers where there are waste products to be consumed. In milk-manufacturing areas, potato and corn-growing districts, there is frequently quite wholesome produce that cannot be marketed through the usual channels. In Norfolk the very large pig population is due to the large quantities of 'tail' barley and potatoes in the marshland district that are available for feeding purposes. The number of pigs in the county has been maintained at a high figure during the past three years, due to the operation of the Pigs Marketing Board, and the pig population is now one of the largest in the country. The most popular breed is the Large Black, which is usually crossed with a Large White boar, of which two breeds there are a number of excellent pedigree herds in the county. Great interest has recently been taken in bacon production, and, as is usual when the Norfolk farmer undertakes a new enterprise and has the necessary capital, the undertaking is being well done. New houses of the Danish type are not infrequently erected and the science of pig-keeping is being studiously followed. There are no bacon factories in Norfolk and the pigs are mostly sent to the Bury and Ipswich factories in the adjoining county.

	Pigs.
1924	196,493
1925	168,570
1926	123,039

	Pigs.
1927	119,735
1928	166,133
1929	142,010
1930	128,068
1931	146,205
1932	176,380
1933	185,271

Horses.—As would be expected with the arable land declining and increased interest being taken in the use of power on the land, the number of agricultural horses is decreasing ; in fact, the number has been reduced by about one-fifth in the last ten years. Despite this fact, however, there have been signs recently that horse-breeding is still a profitable undertaking, and excellent prices have been realised at recent sales of Suffolk horses. Agricultural horses in Norfolk are either Suffolks or Shires, and a number of good horses of both breeds are bred in the county each year. The Suffolk horse in particular is well suited to the agricultural conditions of Norfolk, and is deservedly popular, while the Shire has still no equal for town purposes.

	Horses.
1924	58,809
1925	56,580
1926	55,470
1927	54,797
1928	53,061
1929	51,843
1930	49,330
1931	47,444
1932	45,691
1933	44,584

Agricultural Workers.—The total number of permanent agricultural workers in Norfolk was reduced in the disastrous years of 1931 and 1932, due to unprofitable farming conditions, but it is gratifying to note the recovery, in 1933, to the more normal number, exemplified by the 1924 returns. Then it was not impossible to farm on traditional methods without serious loss of money. The increased employment of permanent workmen in 1933 is indicative of the increased confidence in agriculture, brought about at that time by the operation of the various Marketing Schemes.

That the reduction in the numbers of workmen was not more than is shown below is to a very great extent due to the sugar-beet crop. Nevertheless, there has been much seasonal agricultural unemployment in Norfolk in recent years, for farmers could not afford to find work for the men during the less busy periods of the year and, in consequence, there has been as many as 3,000 men on relief work after beet lifting has finished in December and before the hoeing of the next crop has started in May.

	Total Workers.
1924	41,159
1925	42,616
1926	42,238
1927	41,908
1928	41,280
1929	42,239
1930	41,329
1931	37,358
1932	37,729
1933	41,271

Agricultural Education.

Agricultural education has been considerably developed in Norfolk during the last ten years ; there are separate agricultural and horticultural departments established by the County Council. There is an experimental and demonstration farm, the Norfolk Agricultural Station at Sprowston and horticultural stations at Burlingham in the east of the county, and Emneth in the west. The Norfolk Agricultural Station is not controlled by the County Council, although the Director of the Station acts also as the Director of Agricultural Education for the county, and co-ordinates the work of the two agricultural staffs. The Station started in 1908 as an offshoot of the old agricultural experiments of the Norfolk Chamber of Agriculture, and was originally and still is capitalised by Norfolk farmers, of whom about 700 are members, paying an annual subscription. Its work is controlled by an executive committee, upon which the Norfolk County Council is strongly represented. There is a staff of four scientific workers at the Station, and there are six other advisers dealing with problems of agricultural and poultry husbandry in the county.

Horticultural education has developed rapidly under the direction of Mr. H. Goude, the Horticultural Superintendent, whose staff consists of five instructors who, like the agricultural advisers, are in constant demand all over the county. A notable feature of the work of the Horticultural Education Department has been the introduction, at the instigation of the County Council of orders made by the Ministry of Agriculture, to control the spread of destructive insects and pests. The existence of these orders has had a salutary effect, and there has been much improvement in consequence in the health of the trees and the quality of the crops. The inspection days at Burlingham and Emneth are the Mecca of all Norfolk horticulturists, and the attendances at the gatherings are truly astonishing.

In compiling this article I have been materially assisted by my colleagues : Mr. T. G. Ellis, the County Land Agent ; Mr. Goude, the County Horticultural Superintendent ; Mr. T. D. Bell, the County Poultry Instructor ; Dr. G. H. Bates and Mr. A. R. Trory, of the County Agricultural Education Staff.

X.

NORWICH AND DISTRICT INDUSTRIES

BY

HERBERT P. GOWEN, F.S.A.A., J.P.,

CHAIRMAN OF THE NORWICH CHAMBER OF COMMERCE

(*a*) MESSRS. J. & J. COLMAN, LTD.

THROUGHOUT the world, the name of Colman is synonymous with mustard. The chief creators of the present firm were Jeremiah James Colman (1830–98), of Carrow House, Norwich, and Jeremiah Colman, his relative, of Gatton Park. But the family partnership was much older, and goes back to the beginning of the nineteenth century. The ancestors of the two directors mentioned above had been milling flour and making mustard at Stoke since 1814 at least. Starch milling was undertaken in the early thirties. The mustard seed came from the Wisbech district, in bags which were, so one of the old clerks said, ' of material called duck or drill, which was bleached and made beautiful summer suits.' In 1834 James Colman (1804–54) did all the mixing of the various siftings of the crushed mustard seed for the four qualities of mustard, ' which were stored in a chamber over the chaise house on the east side of the Mill House garden.'

' Lazarus Horne,' it is related, ' did all the packing into casks in that chamber. He had only one arm. . . . In busy times . . . (Mrs. James Colman) . . . used to help nail the labels on the casks.' Until 1845 there was no railway in Norfolk, and the transport was effected by three- or four-horse waggons. But like all patriarchal business men of the period, the Colmans and their dependants earned, demanded and hugely enjoyed their relaxations—and there can have been little difference in feeling and outlook among the partners and staff of that golden time. ' We used to get a Christmas dinner in the flour mill,' one of the former remembered. ' The men used to go indoors after dinner, and the women used to go into the other room with Mrs. Colman.' It would take a good many ' other rooms ' to hold the employees of Carrow Works to-day.

It was in 1856 that J. J. Colman and his partners began building the first mustard mill on the banks of the Wensum at Carrow, by Norwich, and on October 6, 1862, he wrote : ' I was at Stoke on Tuesday and shall go down again this week to take a last look.' By that time Carrow Works were already of such dimensions that it had been thought well to institute a school for the children of the workpeople. ' It was housed in an upper room in King Street, up an opening by the " Red Lion " Inn, reached by a step ladder with a handrail. Maria Cogman, the school-mistress at Stoke, was transferred.' A school was maintained by the firm, until it was taken over by the School Board in 1900, and must suffice as an example of the advanced ideas that were prevalent at Carrow Works at that date. The numerous activities initiated or favoured by the firm would fill a long catalogue, and it can only be mentioned in passing that they were usually in advance of their time—a visit of 500 employees to the Exhibition of 1862, an Old Age Pension Scheme in 1899.

It was in the early 'eighties that the great step forward of substituting roller-milling for the various older crushing processes came to be applied, first to the mustard making, but sooner or later to the flour milling, which the firm has never forsaken. The making of starch and blue also underwent many developments as mill was added to mill and the property of the firm reached out and out along the bank of the Wensum. The sphere of its influence was broadening in another direction. Jeremiah James Colman moved into Carrow House, a substantial residence, in a property containing the ruins of the female priory of that place, which he re-edified. All around, a whole quarter of the town became filled with the dwellings of the clerical, administrative, and wage-earning staff. All this gradual building up was very important for Norwich, which had lost, from about 1830, in a very few years, the whole of its ancient textile trade, and might have suffered dire poverty had it not been for the Colman works, and perhaps Gurney's Bank. All this time Jeremiah James Colman and his relative in London attended markets together and carried on an exacting amount of personal supervision. Even to-day the Board meets alternately in Norwich and in London, the head of the Norwich family being the Lord-Lieutenant of Norfolk, and that of the London family, Sir Jeremiah Colman, Bart.

To-day, however, the name of Colman means a great deal more than the works at Norwich or the London offices, factories and branches having been established in many parts of the world. If we count the first considerable development as the move from Stoke to Norwich in 1856–1862, and the second as the promotion of the limited liability company in 1896, the third must be the extension of the company's business by the amalgamation with Keen, Robinson & Co., and the most recent alteration of the Articles of Association of the company to permit of the issue of their shares to the public.

This is the scope of a Norwich business which, a hundred years ago, was carried on in the chaise-house behind Stoke Mill.

(*b*) BOOT AND SHOE MANUFACTURING

Boot and shoe manufacturing is the staple industry of this city and occupies a proud position in relationship to other shoe-manufacturing centres of this country—more especially is this so when it is considered that from the geographical standpoint Norwich is not closely situated to any of the recognised shoe manufacturing districts.

The industry itself is of considerable magnitude, consisting of twenty-six firms, giving employment to 11,000 persons, with an annual production of approximately 6,000,000 pairs of shoes. The manufacture of high and medium class ladies' fashion footwear is its chief concern, although a considerable quantity of girls', boys' and children's shoes are made.

When speaking of the activities of Norwich in connection with its staple industry reference must be made to the ancient industry of spinning and weaving (more fully dealt with in a later section), because 'shoes apparently sprang from wool,' and in a way the enterprise of the one became the enterprise of the other.

The city is rich in historic associations and has the distinction of being the most ancient manufacturing town in the United Kingdom, having been noted for its woollen fabrics from the far-away days of Henry I, when a colony of Flemings settled in the city and spun their wool at the village of Worstead, or more anciently Wolstede (the place of wool) situated nine miles to the north.

Before the year 1388 the worsted trade in Norwich was of some magnitude for that period, and in this year it was deemed to be of sufficient importance to justify the setting apart of a building (being the dwelling-place of one John de Welbournes), where the worsted weavers were bound to expose their goods for sale.

The manufacture of dress stuffs, camelots, shawls and crêpes gave employment to a large number of spinners and weavers, which continued almost to the close of the first half of the eighteenth century, when the introduction of steam mill machinery in the Midland and Yorkshire towns, particularly Bradford, brought about a rapid decadence in the worsted industry of Norwich.

The year of Queen Victoria's Coronation (1838) witnessed an outbreak of Norwich camelot weavers, whose wages had been reduced owing to the extensive migration of the weaving industry to the north, with the consequent dwindling of the industry in Norwich. From this time the trade rapidly decreased, until now practically nothing remains of this ancient industry. Norwich, however, is still famous for its silken productions.

Following the loss of the woollen industry unemployment was rife in the city; it was undoubtedly a serious time for both employers and employed, and our City Fathers are to be congratulated on the enterprise they displayed in developing another industry, closely allied to weaving, inasmuch as boots and shoes find an essential place in the clothing category.

Between 1830 and 1840 several boot and shoe manufactories were started, and during the same period other allied businesses made an appearance, such as currying, leather dressing and merchanting, tanning and dressing raw animal hides for the use of the shoe manufacturers.

It is interesting to recall some of the early types of boots and shoes, produced at this period.

The writer of this article has before him a catalogue of one of the oldest Norwich firms, issued in 1887. It is interesting to note that many of the illustrations are actual photographs and show that the type of footwear made consisted of uppers of calf kid, levant goat, satin sheep and cashmere cloth. The styles usually favoured were boots with curved tops of ' side spring ' or ' laced ' or button-up design with scalloped button-pieces. Shoes also were made, chiefly of laced or buttoning pattern. The soles were either attached by rivets or, in the case of better shoes, sewn on.

Comparing these early productions with the present-day standard of excellence it is easy to realise the tremendous strides invention and science have made in the shoe-manufacturing industry.

Throughout the long period of industrial development the change from slow handicraft to highly skilled sub-sectional methods can be traced. No longer does a shoemaker perform all the operations hitherto done laboriously by hand; machinery has superseded these methods so much than now one hundred distinct operations are essential for the production of each shoe. This necessarily means that the old handcraftmanship is in danger of being lost; happily, however, this factor has not been overlooked, as will be seen in a later reference to our City College.

Apart from this, from the early stages to the present day much has taken place within the industry which is worthy of record. It has been mentioned that the city received a serious set-back with the loss of its weaving industry—coming to more recent times it should be mentioned that prior to the outbreak of war in 1914 approximately 30 per cent. to 40 per cent. of the footwear produced in Norwich was for overseas trade. The declaration of war naturally meant that this export trade was greatly restricted. The factories being deprived of a great part of their output, attention was immediately turned to the production of footwear for His Majesty's Forces. Only those actually engaged within the industry can really understand how great this change was. Factories had necessarily to be reorganised for the production of heavier goods and operatives trained to meet the demand the Government made upon the resources of the trade. Thousands of pairs of boots for the British, Italian and Russian armies were produced.

Upon the cessation of hostilities in 1918 Norwich found its markets for export trade practically gone. The difficulties of the Great War and the consequential repercussion upon our colonies and other countries necessitated the production of their own footwear, leaving Norwich in a very serious position indeed during the year 1919 and the immediate years that followed. Again the staple industry of the city was threatened with disaster. Faced with this set-back the manufacturers of the city once again showed their enterprise, perseverance and dogged determination to overcome obstacles. To fill this gap a method had to be devised.

The introduction of fashion shoes for ladies proved to be the remedy. Our stylists determined that styles and vogues should be changed frequently. Lasts, patterns, designs, colours and materials were used to aid this undertaking and by this means a greater number of shoes than hitherto were to be found in every lady's wardrobe.

The popularity of dancing not only influenced Norwich trade, but lent valuable assistance to the project, as both factories and operatives were well equipped and trained for the production of light satin, brocade, crêpe-de-chine, etc., footwear, suitable for such purposes.

Again, 1931 provided our manufacturers with an opportunity not to be lost. When Great Britain went off the gold standard the supply of imported footwear was naturally restricted. This opportunity was seized and the shoemen of the city found themselves supplying for the home market the better quality of the shoes previously imported from the U.S.A. and the Continent. The imposition of tariffs in turn assisted in consolidating this position.

A few words must be said of the processes used. Norwich was the home of the ladies' Louis heel trade and continues to hold its own in this respect. Again, the Turnshoe principle is another unique characteristic of Norwich craftsmanship. It is of interest to note that these shoes are made ' inside out,' there being no inner sole inside the shoe. The sole on the flesh side is channelled in a way peculiar to turnshoe work, the upper being sewn direct to the sole through this channel, after which the shoes are turned the right side out and re-lasted, bringing the shoe to its proper formation. This production is famed for lightness, flexibility and comfort.

The technical methods of manufacturing known as Machine-sewn, Littleway, Welted and Veldtschoen are extensively used.

Machine-sewn (McKay) and Littleway shoes are made in the following way. A leather inner sole is attached in three places to the last (the last is the model of the foot). The upper is then placed over the last and ' lasted ' to the inner sole. In the case of machine-sewn shoes tacks are used to secure the upper, whereas in Littleway a stapling method is adopted. The cavity between the outer edge of the upper is filled with water-proofing material, the sole properly channelled is then attached. The last is withdrawn and the shoe passes to the sole sewing machine, which sews firmly together the sole through the channel, the upper and the inner sole. The channel is then solutioned and laid. After bottom-levelling the shoe is passed to the Louis-heeling department for the reception of the heel. It passes thence to the finishing room, where the sole is scoured and coloured to suit the particular design required.

In the case of welted shoes, the inner sole is channelled in a way peculiar to this class of footwear. The upper is lasted to the inner sole in a similar way. The welt is then sewn through the upper and inner sole channel. After bottom filling the soles are attached by means of solution and afterwards stitched to the welt by fine decorative stitching. Heel attaching follows, likewise the necessary finishing operations.

In the case of Veldtschoen, as the name implies this type in its early days was closely associated with the South African market. The upper, instead of being lasted over towards the inside of the shoe, as is the case of the foregoing processes, is lasted to the outside and fastened through the sole by means of a row of stitches. It can, therefore, be visualised that with the complete absence of the inner sole the shoe is extremely light and flexible, admirably suited for children's wear.

It should also be mentioned that the uppers of these exquisitely made shoes are cut from every known light leather, including reptile skins, and every conceivable shade and colour of glacé kids, calfs and suède leathers.

As our early city traders of the weaving industry planted the name of

Norwich prominently upon the map of the world, so have the present-day shoe manufacturers in turn achieved the same object, and at present there are unmistakable signs of Norwich winning back some of its ancient exporting prosperity. It appears superfluous to say that every good wish accompanies this endeavour.

The high standard of efficiency attained, and the ready adaptability of the industry's operatives to meet the constant innovations and reorganisation of manufacturing methods demanded from time to time by the stern law of progress, is in no small measure due to the technological instructors of the Technical College of this city. Students are first taught the hand principles of shoe making.

Our present city authorities are to be congratulated upon the fact that they are contemplating extensive development of the college, providing the staple industry with greater accommodation and better equipment to encourage young persons engaged in the industry to devote a portion of their evening leisure to the development of technical knowledge.

Thus fortified with the background of the past and knowing the progressive enterprise of our individual manufacturers, coupled with the development of knowledge and technique in the younger generation, the industry confidently faces the future, sure of its ability to meet and overcome any obstacles which may tend to jeopardise the prosperity of our ancient city.

(*c*) ENGINEERING AND ALLIED INDUSTRIES

Norwich as the centre of a large agricultural district has not only developed its incentive to produce agricultural machinery, but has extended its enterprise in so many directions that its varied productions carry the name of the city round the world.

Principally Norwich may be regarded as the pioneer in the manufacture of wire-netting. Charles Barnard, who first entered business in 1826, invented the original machine for weaving this product in 1844, and the earliest practicable type, dated 1854, now fittingly housed in the Bridewell Museum of Industries, was exhibited at the Crystal Palace in 1930, and actually worked by a weaver who had been employed by the original firm for over sixty years.

The fabric was first produced on a pegged roller from wire woven by hand, using cotton reels as bobbins ; this, however, was not a commercial proposition, and the inventor developed what is known as the 'half-wheel' principle (which is still the basis of all looms), by which two slides and a rack engage alternately and form the twists.

The principle was improved upon by Mr. James Garton Bower, who devised special machinery for weaving together two meshes of different sizes in one weaving on one machine. The smaller mesh in the lower part forms a protection against rabbits and the larger mesh above cheapens the fabric.

Wire-netting from Norwich firms defends Australia from rabbits, South Africa from jackals, forms fox farms in Scandinavia, fences innumerable estates, and during the World War the original firm alone supplied the Government with seven thousand miles of the material for use at the front.

Mr. Barnard was also a pioneer in the production of a noiseless lawn-mower, hydraulic rams for water supply, a slow combustion grate, the heating of large buildings by hot water, and the use of iron and glass in building construction.

Within the city is the largest foundry in the eastern counties, producing metal castings of almost every description. The beautiful entrance gates and railings to Sandringham Park, made in Norwich for the Exhibition of 1862, were so much admired that they were purchased and presented to the then Prince of Wales, afterwards King Edward VII, as a wedding gift from the city and county. In the city itself the Pavilion in Chapel Field Gardens is another example of local wrought and cast-iron work exhibited in Vienna (1873), United States of America (1876), Paris (1878), and finally presented to the Corporation of Norwich in 1880.

Norwich also takes a prominent place in the construction of timber-framed buildings, from residences, pavilions or schools to garden frames. Many of the hospitals and hutments for war use and a great deal of temporary housing for use following earthquake disasters have been contracted for in the city. Structural steel work is also a feature of the industry.

Only within recent months hopes were entertained that the making of aircraft might become a permanent local industry. During the war thousands of aircraft were built here. Subsequently the method of metal construction, which reached a very high standard of technique, brought the firm engaged in the work to the very forefront of the aircraft industry and they were entrusted with the preparation of the airship R 101, all of which was made in Norwich before erection at Cardington. Aircraft construction, however, is now operated by a newly formed company, Boulton-Paul Aircraft, Ltd., and Norwich will cease to be a centre of this form of enterprise.

Electrical Engineering.—Norwich possesses one of the three oldest firms of electrical engineers in Great Britain manufacturing electric motors and generators, Messrs. Laurence, Scott and Electromotors, Ltd., formed in 1883 through the encouragement to Norwich industries by the late J. J. Colman.

The industry developed chiefly on marine work, and the firm has made more electrical machinery for driving auxiliaries on board ship than any other in the world.

Deck winches from the Norwich works, for handling cargo, are in universal demand, and electrical auxiliaries have been installed in most of the great liners. In the *Queen Mary* the firm has been concerned in the largest installation of the kind for a single liner, comprising 25,000 B.H.P. in electric motors for driving the pumps, fans, capstan and windlass and other auxiliaries.

During the slump in shipping of the last few years important lines in land work have been introduced and perfected, and new ground has been broken in machines for the improvement of the power factor of motors in connection with the electrical 'grid' system by means of the 'Heyland Exciter,' produced in collaboration with the world-famous engineer, Dr. Alexander Heyland of Belgium. Electric machinery for Diesel electric railway work is a further development, and another interesting line is electric trawl winches for use on Diesel trawlers. These have been developed to a greater extent abroad than in England, and a number have been made particularly for French owners.

One of the most modern of Norwich industries is the manufacture of industrial and domestic electric heating apparatus. This was inaugurated in 1920, when the business started with ten hands in a corrugated iron warehouse. Six years later larger premises were required and the staff had grown to over one hundred. In 1934 the premises were practically re-modelled, and the business now employs between three hundred and four hundred skilled hands, including fitters, turners, moulders, sheet metal workers, electric and acetylene welders, coppersmiths, chromium and other metal platers, winders, wiremen, painters, packers, and others. The principal product is the Heatrae Electric Water Heater, which is sent all over the world and is stocked by the electrical undertakings of many British municipalities. Material is also supplied to the specialised requirements of H.M. Navy and other war departments.

(*d*) NORWICH TEXTILES

The high reputation of Norwich textiles carries back through many centuries. In mediæval times the industry, which was then confined almost entirely to wool, continually received fresh impetus through the arrival of skilled immigrants from the Low Countries; and in the prosperous times which followed, Norwich became the second city of the realm.

Troubles between the Flemish immigrants and the inhabitants were not infrequent, and in 1565 the Duke of Norfolk successfully petitioned Queen Elizabeth to grant protection and authorise the Dutchmen to exercise their manufactures of tapestries. Meanwhile the variety and excellence of their arts steadily grew. New arrivals brought fresh ideas and, by their skill as weavers and dyers, the most gorgeous fabrics were produced in silks, satins, velvets and brocades.

A strict code of rules was drawn up by the Privy Council and 'Sealing Halls' were established in which the finished article came under the expert eye of the 'Sealer.' The latter classified and stamped or 'sealed' the articles according to the standard of quality attained. The manufactures were carried out largely in the workers' houses, all the necessary appliances for weaving, together with the raw material, being supplied by the merchant. It is instructive to note that the earnest endeavour of these wise men was evidently to ensure honest, and so far as it was possible, perfect work. To this far-seeing policy can be fairly ascribed the renown of Norwich-made goods for many years.

During the reign of George I. the silk industry was encouraged by special allowances on silk goods exported. There was, however, some abuse of this privilege on the part of some of the manufacturers of fabrics 'called Sattins and Damasks' which (ordinarily made from worsted yarn) had specially added to them a small quantity of silk to secure the allowance made on 'all silk fabrics.' By 1790 a considerable export trade had been built up, and Norwich textiles constituted 7 per cent. of the total export trade, the goods being sent chiefly to Russia, America, and China.

The manufacture of crape, in common use at public mournings, was an important industry in the early part of the nineteenth century. The old Norwich crape was a 'bombazine' containing a silk warp and worsted weft, twill weave and dyed black, but various kinds of crape were introduced from time to time, one example which became very popular being a silk and worsted article known as a 'tammet weave.' This was adopted as a standard dress material and, when dyed in a variety of colours, could vie with the finest satins.

The manufacture of mourning crape is still an important industry, although it is exclusively an export trade. Norwich crape at the present time consists of a thin silk gauze stiffened and embossed by being passed over a heated roller on which the 'figure' is engraved.

In recent years there has been a gradual tendency towards the production of finer woven cloths. One of the most important productions is weighted all-silk fabric—georgette, crêpe de Chine, marocains, satins, etc. Originating in France, the weighting of silk with tin salts was at one time done entirely by hand, but is now done by special modern machines.

The whole of the operations, starting with the raw silk fibre to the dyed and finished fabric, are carried out in the factories of Messrs. Fras. Hinde & Hardy, Ltd. Each of these operations is highly specialised and the strictest control is enforced, which ensures perfect results in the finished fabric.

Dress materials made of artificial silk constitute another important branch of the textile trade. High-class crêpe fabrics are experiencing an ever-increasing demand, and practically every known variety of cloth is produced in these factories.

A large number of Norwich shoe manufacturers are to-day using Norwich fabrics for the uppers of ladies' shoes, and a considerable business is also done with other manufacturers all over the country, as well as in the dominions and colonies. In spite of the severe competition from abroad the prospects of an increasing trade were never better.

(*e*) PRINTING

Norwich was one of the earliest of the provincial cities to introduce the art of printing from movable type after its invention by Caxton. The first printer was Anthony de Solempne, a Dutch refugee from Brabant, who set up a press in St. Andrew's parish in 1567 and was admitted a freeman in December 1570. In addition to his trade as master printer, he also carried on business as a wine merchant. He appears to have been mostly concerned in printing books for the use of the Dutch congregation in Norwich, and one of these, dated 1586, from the collection of the late Lord Amherst of Hackney, may be seen in that section of the Bridewell Museum devoted to printing, which also exhibits a reproduction of his Perpetual Calendar, published in 1562. The Colman Library at Carrow possesses another book dated 1580.

Solempne moved from St. Andrew's parish to a house at the corner of Dove Street and the Maddermarket, later the Edinburgh Tavern, which collapsed in 1898 following a serious fire in adjacent premises.

After Solempne there was a lapse of a century, until Francis Burges or Burgess revived the art at the 'Red Well,' also in St. Andrew's parish. He died in 1706, and his principal publication appears to have been 'Some Observations on the Use and Origin of the Noble Art and Mystery of Printing'; but he was also the printer of the *Norwich Post*, a weekly newspaper, which appears to have started about 1700 and was continued by his administrators after his death. To-day the principal city newspapers are *Norwich Mercury* (1721), *Norfolk News* (1845), *Eastern Daily Press* (1870), and *Eastern Evening News* (1882). The *Norfolk Chronicle*, a county newspaper, originated in Norwich in 1761.

In the present day, the printing trade of Norwich plays no unimportant part in the industry of the city. It has its Master Printers' Association (which includes Fakenham, Bungay, and Beccles), embracing thirty-three printing houses of varying importance, and of these Norwich itself is responsible for seventeen. These thirty-three houses employ nearly 600 men and 400 women and girls.

Norwich is the 'Head Office' as it were for many sections of trade and industry, as indicated in this chapter. Consequently the demands on the printing industry are usually well maintained, and this in spite of the fact that the competition of the Metropolis and the Midlands is very keen.

Whilst being able to boast of its own publishing houses, Norwich is not behindhand in the quality of its artistic advertising literature. Its output consists of text-books, novels, trade catalogues, and colour work of every description. The city also possesses publicity and advertising houses, copy writers and lay-out experts, and artists who have been, and still are, responsible for the creation of some fine examples of poster work.

Much good work is done at the Norwich Technical College, where both practical and theoretical typography is taught.

(*f*) FLOUR MILLING

As befits an agricultural community, milling is an ancient industry in Norfolk. Roman and Saxon querns and early millstones preserved in the Norwich Museums support its antiquity. In the Milling Section of the Bridewell Museum of Local Crafts, the progress of the industry through its primitive stages to the windmill is typified by the exhibits. Particular interest attaches to the section devoted to windmills, which, at one time a prominent feature of the Norfolk landscape, are now fast disappearing. One of the last to succumb was the mill immortalised by John Crome in his famous picture now in the National Gallery. This mill, situated on the borders of Mousehold, was in course of being acquired for permanent preservation when it caught fire in March 1933 and was destroyed. A model, however, is preserved in the Bridewell, together with others typical of Norfolk mill architecture.

The windmill was gradually superseded by the water mill, of which many examples may still be found in the district surrounding the city, though not now making flour. These in their turn gave place to the steam mill. In the early 'nineties, with the introduction of the roller system, practically all the small steam mills ceased to manufacture flour and two large roller mills became the only representatives of the business in Norwich. At the present day these two important mills are situated on and practically dominate the river Wensum, through which they have direct communication with the various ports for the supply of their foreign wheat.

(*g*) CLOTHING

Ready-made clothing is a comparatively modern innovation, dating from approximately a century ago. So far as Norwich is concerned, it owed its inception to the enterprise of a firm of textile manufacturers who about 1850 took advantage of the invention of a tailor's sewing machine to make an entirely new departure in their business by adding a department for ready-made clothing. The machine used was almost the first of the kind to be invented ; it was like a large fret-saw, worked by a treadle and producing about twenty stitches a minute—the modern type of machine makes at least three thousand stitches a minute. Band knives and other machines were added, and the firm described the new enterprise as a steam clothing factory. The industry developed considerably and underwent great changes with the outbreak of the War, when many large uniform contracts came to Norwich to meet the requirements of the Government. One firm alone sent two tons of uniform clothing daily to Government departments, their total output being a million khaki garments through the clothing factory and over a million cardigan waistcoats. The same firm from 1915 onwards in its hosiery department made over a mile of knitted fabric a day until the end of the War.

The industry successfully survived the reorganisation necessitated by the end of the War and is now definitely established, turning out many thousands of garments per week ; while the hosiery section is completely modernised.

(*h*) CONFECTIONERY

The chocolate, crackers and mineral waters industry in Norwich originated in a chemist's business founded in 1863 by Albert J. Caley, who ventured on the making of home-made ginger beer. The venture developed successfully, but it was only a seasonal occupation, so to keep the workers in employment during the winter months the manufacture of cocoa and chocolate was added.

Milk chocolate became the special feature of the productions, the first English make to compete successfully against the Swiss makers. That milk could be obtained from some of the best milk-producing herds in an agricultural district was an undoubted asset.

The founder retired in 1894; and in 1898 the firm was formed into a limited liability company, under the title of A. J. Caley & Son, Limited. In the same year cracker-making was introduced.

During the War Norwich chocolate was supplied to all branches of His Majesty's Forces at home and abroad, particularly in the form of 'marching chocolate,' which became a speciality.

Under the auspices of the African and Eastern Trade Corporation, Ltd., which acquired control in 1918, large building extensions were embarked upon, and a further change in ownership took place in July 1932, when John Mackintosh & Sons, Ltd., purchased and reorganised the whole undertaking.

Entirely new plant and every modern device have been introduced to ensure the most finished production of all chocolate confections, but in the making of crackers and novelties nearly all the work is done by hand. As yet no machine has been invented capable of performing the intricate processes which go to make so simple a thing as a cracker.

(*i*) NORWICH CANARIES

It is more than probable that the cultivation of the Norwich canary as a speciality began in the latter quarter of the sixteenth century, when the Flemish, driven from their country by the persecutions of the Spanish under the Duke of Alva, took refuge in our island, indirectly repaying us for the protection afforded them by the impetus they gave to some of our manufactures. A great number of these refugees settled in the county of Norfolk, where they found congenial employment in the woollen industry, which had been originally established at Worstead by their kinsmen more than four centuries before. With the development of the weaving trade, which was subsequently followed by the manufacture of boots and shoes, the breeding of the canary was ardently pursued by craftsmen who in those early years followed their vocation in their own homes, and it was under such favourable auspices that the Norwich canary was for so many years nurtured, till its fame spread the world over.

The Norwich canary is similar in size to a German bullfinch. It is plump and chubby, bold of carriage, and lusty in its song. Its distinctive colours are yellow and buff, and as a general rule matings are paired in this way. Incubation lasts fourteen days, and the young are fed by the parents regurgitating for a period of three to four weeks, by which time the nestlings are able to feed themselves.

During the moult the birds are colour-fed with cayenne pepper, which is introduced into their diet in order to prepare them for exhibition purposes. It is only possible to improve the colour of the feathers whilst they are actually in process of formation, so it is necessary to ensure that the blood is impregnated with colour matter ready to be deposited in the tissues of the new feathers at the very source of growth.

With the advent of machinery and factory life, the breeding of the Norwich canary is not carried out so extensively as in former years, but there is still a considerable number of breeders in the city, and Norwich is able to boast of staging each year one of the leading bird exhibitions in the country, when as many as 1,500 exhibits have graced the show benches.

(*j*) NORFOLK REED THATCHING

Visitors to the Norfolk Broads in September may see the Reed Beds of *Phragmites Communis*, but harvesting does not begin until December, when the frosts and winds have cleared the stems of leaves. Most reed beds are best cut every alternate year, and produce a crop known as 'Double Wale.' The reeds are tied into bundles or 'shoves,' and five of these shoves or six slightly smaller ones measuring six feet round the binding of the shoves represent one 'Fathom,' which is the basis of all reed measurements. The best thatching reed is from 5 to 6 ft. in length, while there is a demand for the longer reed for use at the gables or down the valleys of a roof. Thatching should be 12 in. in thickness, and a well-secured roof should last about 80 years before it needs half-coating. The ridge of sedge (*Cladium Mariscus*) will hardly survive 20 years, but it is both cheap and simple to repair. The best examples of thatching in Holland boast purpose-made ridge tiles for the ridging, which could well be tried in this country to delay the necessity for ridge repairs.

Space prevents a detailed account of the thatcher's art and the use of the leggett, liggers, broaches, sways, etc. It is essentially a craft and will never be the product of a machine. The main constructional principles have remained unchanged during its whole history, and it can be numbered among the oldest trades which have survived to the twentieth century. Except for a few subsidiary materials or ideas such as the use of three-thread jute spun-yarn in place of the hedgerow brambles to secure the sways to the rafters, it has hardly changed at all.

Uninformed critics try to condemn reed roofs. They say that they are too inflammable and harbour vermin, yet practically every thatched roof fire is caused by faulty flue construction, and while reed is far less inflammable than straw, good use can sometimes be made of fire-proofing chemicals. Vermin are the guests of the human habitants of a home, and the cleanliness of every home depends far more upon the characters of the occupants than the dwellers in the roof. Compare the merits of Norfolk Reed with any kind of straw and one can immediately appreciate the unchallenged advantages derived from the use of reed as a thatching material. Reed can withstand the varieties of our inclement weather while straw would be rapidly deteriorating.

Greater comfort can be found under a well-thatched roof of Norfolk Reed than in any other type of dwelling.

(*k*) FLINT KNAPPING

In the Bridewell Museum at Norwich may be seen a veracious reproduction of a flint knapper's workshop. The oak block, at least 250 years old, which has been used in the same family for two centuries, and the simple tools and materials of the craft are there preserved as a memorial of a dying industry which has persisted for at least two thousand years and is now confined to a very few individuals in the town of Brandon, which lies on the boundary line between Norfolk and Suffolk.

The industry derives from the need of pre-historic man for knives, hatchets and similar articles for domestic and defensive usage, and in many places in the county worked flints are still turned up in the fields. Later, the principal task of the knapper was to supply gun flints for Africa, and when this trade was at its height, some 250,000 flints per week were turned out, in the supply of which Norwich also took a hand. The knappers of Brandon are still able to produce beautiful replicas of the early flint weapons, and even ornaments.

Flint is prominent as a building material in Norfolk. Most of the churches are of this material, and in the north wall of the Bridewell Norwich possesses the finest specimen of squared-flint workmanship in England. Decorated flint-work of a very fine type is a feature of St. Mary's-at-Coslany Church. It was probably during the fifteenth century that brick began to be used as a building material to the ultimate supersession of flint.

Flint mining is still carried on in the same way and with the same kind of tools as it was two thousand years ago, and the industry at Brandon, restricted though it may be, is a remarkable survival.

In the vicinity of Brandon are Grime's Graves, a wonderful series of pre-historic flint mines which have, up to the present, been only partially explored. The mines are now under the jurisdiction of the Office of Works, and have been placed in charge of a whole-time custodian and may be visited for a small charge.

(*l*) THE HERRING INDUSTRY

'Hereabouts they begin to talk of herrings,' wrote Defoe when he came to our East Anglian coast. And so the Romans had talked in their day; and here where the fickle herrings are least uncertain in their movements and in greatest abundance they still talk of them.

But to-day this great fishery is a tragedy. It has been possible and not infrequent in recent years for willing fishermen working on the share system, as is the custom, to take less money into their homes than if they had been unemployed and on public relief.

What are the causes of this débâcle, and why do men continue to fish ?

The latter question is easy to answer. For men living in wide areas of Norfolk and Suffolk, even in spots far remote from the sea, herring fishing is a traditional calling with an element of chance which adds a spice to sea life. For an answer to the earlier question we must turn to those problems of international relationships which have increased in number as the World War has receded into the past. 'As we fought we knew we were killing our best customers,' remarked once a prominent curer who fought with the 51st Division.

The herring trade has always under modern conditions depended on export for 80 to 90 per cent. of its output. Thus when the Revolution altered the face of Russia, and a policy of autarchy made its appeal to a new Germany, our two best customers became almost as uncertain as the movements of the herring themselves.

There was a day not long before the War when a flag was hoisted in a Yarmouth curing yard to denote that the tale of herrings cured by one firm alone had passed the 100,000-barrel mark. In 1934, 1,440 women workers, working for 66 curers at Yarmouth, only mustered 190,000 barrels of pickled herrings ; and these could only be marketed with difficulty.

Until the late 'nineties sailing craft chiefly plied the herring fishery. Then an increasing continental demand brought steam as an auxiliary to increased herring production—the first steam drifter made its appearance about the time of Queen Victoria's Diamond Jubilee. The Klondyke 'gold rush' of 1898 gave a name to a new trade in fresh herrings to Germany, and a more profitable undertaking to many than the search for elusive gold. Thence onward to the outbreak of war the East Anglian herring fishery never looked back. Steam became no longer auxiliary, nets became larger and more numerous, fresh areas for fishing operations were opened up. Fishermen who had finished their corn harvest ashore before putting out after the autumn herring now became all-year fishers. The Shetland Isles, Orkneys, Hebrides and Ireland were opened up. The developing fishery moved faster than the law. As late as 1906 the Board of Trade discovered that whereas their regulations required sailing trawlers, which fished only some 70 miles from home, to carry certificated masters, steam drifters were comfortably completing the circuit of the British Isles, in charge of men who, because they were herring fishers, carried no certificates at all.

With the War development ceased, the greater part of the herring fleet, complete with crews, trained in all but naval discipline, hoisted their White Ensigns, to be exchanged a few years later for Red Ensigns, in a new world in which the call for herrings had largely passed.

Each autumn during the war-period the East Anglian fishery was carried on despite the ever imminent threat of naval operations. The fishing units were chiefly old drifters rejected for Admiralty service, the men for the most part too old, too young, or discharged from H.M. Forces. The scarcity of foodstuffs took herrings to values undreamed of, and rich shares awarded the venturesome fishermen. All these conditions created a boom which intensified the slump which was to follow, bringing ruin in its train, when drifters returning from naval duties again took up the fishery.

In 1919 and 1920 the Government came to the aid of a stricken industry with guarantee schemes. But these could not save the situation in which a fleet diminishing slowly from its prosperous pre-War dimensions was endeavouring to cater for a sadly shrunken market.

In its recent investigations the Sea Fish Commission discovered that over a 20-year span the total export of herring had dropped by about 55 per cent.; and the sale for home consumption has dropped by about 45 per cent. In almost the same period the number of drifters has only declined from 1,470 to 1,088—about a third of which belong to Yarmouth and Lowestoft. So the inability to make a living becomes patent.

And all the while, under the protection it is within their power to give, our former principal herring customers are creating industries of their own. Germany is omitting no opportunity of expanding her production of herrings. State-subsidised drifters are fulfilling the home demand to an extent increasing yearly, and the German trawler fleet, by a new method of fishing, now takes home to Germany a volume of herrings equal to our Yarmouth-Lowestoft catch. Even Poland, Finland, and Estonia have entered the ranks of herring producers instead of remaining merely customers.

The investigation into the life history of the herring has made great strides in recent years, and from a yearly census which is taken of herring population of the southern North Sea it has been found possible to forecast the composition of the herring catch with some accuracy.

During the past few months the regulation of the herring fisheries has passed to the Herring Industry Board, to which many look to rescue this great East Anglian industry from the slough of despond to which the recent difficult years have brought it.

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XI.

EDUCATION IN NORWICH

BY

E. W. WOODHEAD, M.A., Barrister-at-Law.

DIRECTOR OF EDUCATION, NORWICH.

The handing on of a tradition, together with an intelligent desire to improve upon it, is an important function of education. Wherever there exists a strong sense of citizenship and pride in the history of a city, there is certain to be real enthusiasm for education; and Norwich possesses both the one and the other. From the time of the earliest 'Grammar' School, associated with the St. Giles or Great Hospital founded in 1256, there appears to have been not only the Claustral School for the boys of the wealthier classes, but also an Almoner's School for the children in the neighbourhood of the cathedral; and a School House in the monastery of the Black Friars in 1376, and a Choir School in the College of St. Mary were no doubt typical of the schools attached to the larger religious houses till the Reformation. Then was shown the city's characteristic care for the provision of educational facilities, for when the Black Friars' Convent building was granted by Henry VIII to the city, a grammar school was established in its infirmary; and again, when in 1547 St. Giles Hospital was given to the city, the conveyance demanded the provision of 'one schoolmaster and one usher,' though the school was actually established in 1549 in the Close, where it stands to this day. The same concern for education led the Mayor of the city, Thomas Anguish, in 1617 to endow hospital schools, whose good work is still perpetuated in the Anguish Home and the Anguish Trust; while successive benefactors from 1708 onwards bequeathed for the establishment of charity schools various sums which give aid to those proceeding to colleges and universities to-day. Only this year, the naming of a recently built school after the Norman School founded by John Norman in 1720 has served to remind the citizens of Norwich of her age-long devotion to the cause of education.

Tradition, however, is fraught with danger unless it be accompanied by vision; but the readiness to initiate and experiment which characterised the foundation in Norwich in 1608 of one of the earliest provincial libraries, has found issue in more recent years in the establishment of the East Anglian School for Blind and Deaf Children at Gorleston-on-Sea in co-operation with neighbouring authorities, in the provision of a large open-air school, of playing fields, and of meals, as soon as power was given to do so. Another proof that while respecting tradition she is not hidebound by it, is found in the experiments in a cheaper form of school building, combining modern standards of accommodation with adaptability to changing conditions and new needs. In line with this is the provision of Nursery accommodation; while commercial classes in secondary schools and extension of science and biology teaching in the senior schools are part of the same determination to keep abreast of present practice and to anticipate future needs.

Paradoxically, the present-day tendency towards specialisation makes it imperative that there shall be a fully comprehensive educational system with carefully planned and diversified types of education to meet the great variety of needs. In the field of elementary education, the realisation of this led to the rapid implementing of the Hadow Report, with the gratifying result that Norwich was one of the first cities to complete reorganisation into infant, primary and senior departments. The needs of the new housing estates, too, have been met by many schools already built, and fresh estates now being developed have had their educational needs anticipated by the purchase of suitable sites for schools and playing fields. For these reorganised schools, old and new, extended facilities for science, handicrafts and domestic subjects are in course of provision.

Extensive provision has been made for higher education, in the City of Norwich School for 600 boys, and in the Blyth Secondary School for 530 girls. The first, built in 1910, is a fine building with large playing fields, while the second, opened in 1929, is a modern school on open-air lines. In addition, there are three grant-aided, non-maintained schools—the King Edward VI Grammar School with some 250 boys in attendance, the Norwich High School for Girls with 345 girls, and the Notre Dame High School for Girls with 380, the two last having, during recent years, removed to new premises. Bracondale School, recognised by the Board of Education but not grant-aided, and several other private schools, offer further provision for higher education. Pupils from the secondary schools are enabled, by means of State and open scholarships and exhibitions, with grants or loans from the Norwich Authority, to pass on to college or university; and an interesting and valued feature of the educational life of the city is the number of endowments, the chief of which are the Town Close Trust, the Anguish Trust and the Joanna Scott Trust, which assist children to attend the secondary schools and universities.

Nor has the technical side of education been neglected; and this provision represents the work of the Education Committee in developing the points of contact between the general educational system and the needs of industry and commerce. Thus, at the Technical College, the needs of the boot and shoe and engineering industries, as befits their importance locally, have been specially considered, and there are departments also for printing, architecture and building, and for science and domestic subjects. The college is approved by the University of London for the preparation of students for the degree of B.Sc. in engineering; and other examinations of a similarly high standard are taken in other subjects. Advisory committees have been formed in the various departments, and as on these there serve representatives of employers, foremen and men, as well as of the Education Authority, close co-operation is maintained with the industries of the city; and by means of the Junior

Technical School, providing a two-year course of general education and special training for certain trades, a regular supply of entrants to those trades is assured. Housed at present in the same building there is the School of Art and Crafts, with courses closely related to the industrial needs of the city and making provision also for æsthetic training ; while the present arrangements, by which elementary school children who show special promise attend classes at the School of Art, are to be developed into a Junior Art School. It is also the intention of the Authority to provide additional modern accommodation for technical, art, and commercial education in view of the growing local demand.

Contributory to this same aim of providing for the needs of industry and commerce is a still further side to the work of the Education Committee, that of ensuring opportunities to the citizens for the cultural use of leisure ; and to this end, not only is there co-operation between that Committee and the Public Libraries Committee, but also, at the Literary and Commercial Evening Institute, there are classes where commercial subjects, languages, and literature can be studied. Junior Institutes, too, receive students between the ages of fourteen and sixteen in preparation for the senior work. Assistance is granted to the Y.W.C.A. to maintain classes ; and by means of grants the Authority also assists the Norwich Musical Competition Festival and the local branch of the Workers' Educational Association. Thus is fulfilled the purpose of the Authority to provide a comprehensive educational system to meet the varied needs of a modern community.

So far, little has been said of the provision made for the physical well-being of the children, but the Authority is fully alive to the importance of physical training and athletics. In consequence, there has been a steady increase in the number of playing fields used by the children of the elementary schools for football and cricket, netball and hockey, and the more recently built schools have been provided from the outset with the necessary facilities. Swimming instruction, too, has of late been rapidly extended, and more than 3,000 children are under regular instruction at the baths. The excellent voluntary work of the Norwich Schools Athletic Association encourages the full use of the facilities thus provided. Moreover, the school medical service is an integral part of the educational system, working through its regular inspections in the elementary and secondary schools as well as through its clinics. These inspections are more frequent than in most areas, each child being examined five times during his school career, instead of the usual three. For the education of crippled children unable to attend school there is a visitor who attends regularly at their homes ; and for delicate children there is a new Open Air School, from which very many are able after a period to return to ordinary schools. Care for blind, deaf, defective, and epileptic children is also part of this important service.

Closely related to these health activities is the welfare work of the Public Assistance Committee for which the Education Department administers children's homes and the boarding-out of children, organises an annual summer camp, and makes arrangements for apprenticeships to various trades. Another section of the work of this Department is the administration of the Juvenile Employment Bureau and of the recently established Junior Instruction Centre compulsorily attended by unemployed youths under the age of eighteen.

Implicit in this comprehensive service is the conception of education as at once an art and a science. While schemes of work are carefully graded to suit the children of various age-groups and varying ability, there is liberty of interpretation which discourages standardisation, with a resulting variety which shows itself pre-eminently in the diversity of crafts pursued and in the methods of treating retarded children. A valued source of inspiration and fresh ideas is the local Training College, whose students practise in the schools of the city. Realisation of the educational possibilities of the Castle Museum has led not only to organised visits, but also to the provision of classes in nature study and biology; and in the same way, visits from the schools to places of historic interest and to factories, as well as to the library, serve as a valuable extension of the classroom lessons. Moreover, the need for contact with new methods and subjects and for refresher courses is not overlooked, the Authority having recently availed itself of courses in science and handicraft arranged by the Board of Education, and itself providing voluntary classes for teachers in biology, handwork, physical training, swimming, Greek dancing and eurhythmics. The enthusiasm shown for these courses and classes is a gratifying proof that the teachers, with proper professional outlook, ungrudgingly support the efforts of the Authority to make the education service play its vital part in the life of the city.

That there is locally a real interest in education in its widest sense may be gauged from the number of educational societies which flourish. In addition to those connected with specific subjects, such as the Archæological, the Egyptian, the Prehistoric, the Historical, the Geographical, and the Modern Languages Associations, there are others of a more general character, including the Science Gossip Club, founded as a direct result of the meeting of the British Association in Norwich in 1868, the Workers' Educational Association, the Photographic Society, the University Extension Society and the Sunday School Union; while the Musical and Philharmonic Societies and the Norwich Players testify to the deep interest in music and the drama.

Such is, in outline, the education service at work to-day in this ancient city. Education in Norwich, like the city itself, has grown from ancient foundations, adapting itself to new needs as they have arisen. It is conceived as something organic, vital to the community which it serves, and it will continue to fit succeeding generations for a constantly changing world, for it is supported by the citizens of Norwich, whose faith in it is at all times its inspiration.

XII.

THE MUNICIPAL LIFE OF NORWICH

BY

NOEL B. RUDD, M.A., Town Clerk.

Introductory.

It is extremely difficult in a short article to do justice to the municipal life of Norwich. In fact, it is impossible if this term is to include the municipal life of past centuries. I intend, therefore, to deal only with some of the present civic activities. Mention, however, should be made of the fact that the city received its first Charter so long ago as 1158, and that the first Mayor, William Appleyard, was elected in 1404. Originally there were two Sheriffs, as in the City of London, but the number was reduced to one on the passing of the Municipal Corporations Act of 1835. In 1910 the last Mayor, Alderman Dr. Blyth, became the first Lord Mayor under grant of letters patent from His Majesty King Edward VII.

The City Council, which carries on the work of local government in Norwich, comprises sixteen Aldermen and forty-eight Councillors, in addition to the Lord Mayor, if not otherwise a member of the Council. One-third of the Councillors are elected annually in the sixteen wards, while half the Aldermen are elected every three years. The detailed work of administration is undertaken by twenty committees (excluding Special Committees), and the number of meetings of committees and sub-committees in a year approximates to 800. In fact, the average citizen can have little idea of the volume of work involved in dealing with the problems of local government in Norwich to-day, nor the amount of time willingly devoted by their representatives to such work. I am afraid local government in this country suffers somewhat from a lack of the right kind of publicity, with a consequent failure of interest on the part of the general public. We hear a good deal of the deficiencies of local governing bodies, but not enough of the good work that is done. Much of the critical attitude towards local government is in fact due to lack of understanding on the part of the public. At the same time I think that interest in the activities of a municipality is growing rather than decreasing owing to the wide range of such activities at the present day, and there is a more intelligent appreciation of the difficult problems that local government has to face.

Housing.

In considering the matters with which the Norwich City Council is particularly concerned at the present time, the housing of the citizens is naturally a question which is very much to the forefront. Since the War eight large areas have been purchased and developed as housing estates, while a further area has recently been acquired. The number of houses built and occupied under the various housing schemes at the time of writing is approximately 5,000. These consist of parlour and non-parlour houses, but the majority are non-parlour with three bedrooms. The weekly rent of each of the non-parlour three-bedroomed houses is 5*s.* plus rates, at present amounting to 3*s.* 3*d.*, and, except for abatements in rent to certain tenants removed from slum areas, there is no system of varying rents as in some towns.

The rents of the houses are collected by the staff of the Corporation, and the management of the estates is based upon what is known as the Octavia Hill system. The Corporation's staff are not mere rent collectors, but do their best to consider the welfare of the tenants and give them friendly advice where necessary. A handbook containing useful information is issued to each tenant, and to encourage tenants to interest themselves in their gardens a competition is held annually and prizes given for the best gardens. The rent roll of the Housing Estates is £120,000 per annum.

With regard to slum clearance schemes, the Corporation have a programme involving the demolition of 2,900 houses, and the rehousing of 9,500 persons. A good start has been made, and I think it would be correct to say that Norwich can be included among those cities which are most active in proceeding with slum clearance. Up to date thirty-five Clearance Orders or Compulsory Purchase Orders have been made, involving 1,200 houses and 4,000 persons: 750 new houses and flats have been erected or are being erected, and 2,000 persons have been rehoused.

The Housing Estates of the Corporation are laid out upon the most up-to-date town-planning lines, and the difference between the amenities of these estates and the conditions existing in the areas from which the slum tenants are moved is very marked.

Schools, branch libraries and shops have been erected in conjunction with the development of the estates, while in some cases allotments and recreation grounds have been provided in the vicinity. In fact, the housing work of the Corporation, although by no means complete, is one for legitimate pride of achievement.

The removal and rehousing of such a large number of persons involves many difficult problems. Norwich is not a city where there are large blocks of insanitary dwellings in an area and nothing else, as in some of the larger towns in the North. The dwellings here are frequently intermingled with factories and business premises, and, apart from that, some of the dwellings are of considerable antiquarian interest.

The problem of redevelopment after the insanitary houses have been demolished is therefore difficult, and it is essential in most cases to include in the area other properties, so as to ensure a proper scheme. Another factor which has a considerable bearing on the question is the narrowness of some of the streets, and in this connection it is obvious that if rebuilding is to take place the streets must be widened. It will be seen, therefore, that redevelopment in Norwich is not only difficult but expensive, and largely arises from haphazard lay-out of the city in past years. At the same time it must not be forgotten that the irregular development of an ancient city is often part of its charm, and provided that proper sanitary conditions of living can be obtained, it is important to retain as much of the ancient character of the city as is possible. Norwich could hardly contemplate a redevelopment analogous to that of a modern American city.

Electricity.

Turning to another phase of Council work, that of electric supply, the Norwich Corporation area of supply extends over 700 square miles, and is the largest area in the country operated by a municipal authority. The major part of the area is rural in character, and by reason of the low density of population involves special problems in development. A district of 100 square miles in Norfolk, being part of the Norwich area, was selected by the Electricity Commissioners as a demonstration area of supply, with the object of testing the actual demand in a typical rural neighbourhood. A grant is being made by the Government towards this scheme, the idea being to obtain as intensive a development as possible without waiting for a demand, and without regard to the economic factor. The scheme has not been in operation for sufficient time to judge the result of the experiment, but it is probable that it will become self-supporting within a comparatively short period.

The electricity undertaking was purchased by the Corporation from the Norwich Electricity Company in 1902, and it is interesting to note the progress made since that date. In 1904 the total number of consumers was 3,010, while in 1934 the consumers numbered 43,264. In the same years the number of units sold increased from 1,235,180 to 29,642,459. The number of electric cookers connected has risen from 47 in 1917 to 7,383 in 1934. In the city area approximately 85 per cent. of the total possible number of domestic consumers are now receiving supplies, and one-half of the remaining 15 per cent. represent houses included in the Corporation's slum clearance programme. Quite apart from the general progress of electricity in the country as a whole, these figures do indicate that the Corporation have shown considerable energy and foresight in developing the business of electricity supply during their period of ownership.

So far as generation is concerned, a new power station was built in 1926 and since that date additions have been made from time to time. The present capacity of the station is 42,500 kw., and its efficiency is proved by the fact that it is a base-load station operated throughout the year on behalf of the Central Electricity Board.

Water Supply.

The water undertaking of the Corporation was purchased from a private company in 1921, and has developed considerably since then. In 1922 the total number of supplies, both domestic and meter, was 31,440, and in 1934 this figure had increased to 40,089. Since the acquisition of the undertaking, capital expenditure to the amount of £60,000 has been provided out of revenue, and charges have been reduced.

The Corporation have recently made application for a Provisional Order extending the area of supply to include twenty-seven rural parishes in the county of Norfolk and also the town of Aylsham, which is twelve miles from Norwich. No alteration in the area of supply has been made since 1876, and the proposed extension is largely of an experimental nature.

The Norwich supply is obtained from the river Wensum and is of ample quantity and excellent quality. In 1934–35 the average daily flow past the intake was 67 million gallons, while the average daily consumption was 4 million gallons. Norwich is, therefore, fortunate in having a considerable margin of supply on which to draw. The water is treated by filtration in open sand filters and also in mechanical pressure filters which have recently been installed. Although the supply is of high purity for a river supply the water is also chlorinated as an extra precaution. The water is pumped by electrically driven pumps to the city, distribution taking place from the rising mains, the surplus water entering the service reservoirs at Lakenham and Mousehold. These reservoirs are used for supplying the city by gravity when the pumps are not in use.

Markets.

The Cattle Market extends over more than 8½ acres and is the second largest cattle market in the country. For the year ending March 31, 1934, 212,304 head of stock were exhibited for sale.

During the autumn a large trade is carried on in store cattle imported from Ireland, which are sold for fattening on the Norfolk farms.

On the market the Corporation have provided covered sale rings for the sale of fat cattle, dairy cattle, pigs and calves. In 1933 a new covered poultry market, with accommodation for the display of 3,000 poultry, was opened, and during the following year over 152,000 birds were exhibited for sale.

The open general market is situated in the centre of the city between the Church of St. Peter Mancroft and the Guildhall. The principal market days are Wednesday and Saturday, but since the War trading has been carried on every week-day. Fruit, flowers, vegetables, meat, eggs, butter, poultry, fish and other commodities are sold on the market.

A wholesale fruit and vegetable market from which the city and surrounding district is supplied is held in the early morning in the market place.

The Corporation also own a wholesale fish market in Mountergate Street.

Municipal Aerodrome.

During the War the Government established an aerodrome adjoining Mousehold Heath and constructed extensive hangars. After the War these were occupied by Messrs. Boulton & Paul, Ltd., a local firm who specialised in aircraft design and manufacture. In 1927 the Norfolk and Norwich Aero Club was formed under the auspices of the then Lord Mayor (Alderman C. R. Bignold) and Sheriff (Mr. A. A. Rice, M.C.), with the object of providing facilities for civilian flying and stimulating interest in civil aviation. The aerodrome, however, was not sufficiently level to qualify for an Air Ministry licence for a public aerodrome, and the Corporation were urged to undertake the work of levelling and to lay out a municipal airport. A scheme was prepared in 1930 and was approved by the Air Ministry.

The Corporation were the more ready to carry out the scheme as it provided work for the unemployed of the city, and a grant towards its cost was obtained from the Unemployment Grants Committee. The site (205 acres in area), together with the hangars and existing buildings, was acquired and one of the hangars was converted into a club house for the Aero Club. The landing area was thoroughly levelled, and this provided work for an average of forty-five men per week for eighty-two weeks. The aerodrome and hangars were leased to the Norfolk and Norwich Aero Club, and arrangements made for the Club to manage the airport on behalf of the Corporation. The airport was formally opened by H.R.H. The Prince of Wales on June 21, 1933.

Parks and Open Spaces.

Norwich has often been described as a city of gardens, and its area of nearly 8,000 acres is large in comparison with its population of 126,000. The percentage of open spaces is, in fact, high, and the Corporation have been particularly active in providing recreation grounds. Under Town Planning the area taken as an ideal for open spaces is 10 per cent. of the acreage, and in Norwich the area actually provided is just over 9 per cent. For every 178 of its population there is one acre of open space.

The largest parks and open spaces in the city are Eaton Park, Waterloo Park, Earlham Park and Mousehold Heath.

Generally speaking the Corporation, in the development of open spaces, have endeavoured as far as possible to satisfy the demands of those desiring to participate in any form of sport, and at the same time they have not forgotten the needs of the younger children, for whom children's playgrounds have been provided.

The work of the Parks and Gardens Committee also includes the upkeep of certain closed churchyards in the city, thus enhancing the beauty of the numerous medieval churches for which Norwich is famous.

Allotments.

The total number of allotment gardens in the city is 3,370 comprising an acreage of 452 a. 2 r. 27 p.; 2,070 of these are under the control of the Corporation on land which is either owned or leased by them. The Allotments Committee in conjunction with the Local Unemployed Welfare Committee have made a special effort to induce unemployed men of the City to take over plots for cultivation, and an area of 14 acres at Ipswich Road has been set apart for this purpose, special concessions in the matter of rent and supply of seeds and tools, etc., being granted under the provisions of the Agricultural Land (Utilisation) Act, 1931.

Allotments in the mind of the public are rather associated with unsightly sheds, but the Corporation in the lay-out of their allotments have provided standardised huts for the use of the allotment holders, thus improving the general appearance of the allotments. Recently also they have decided to offer prizes for the best kept allotments with the object of encouraging good cultivation and general tidiness.

River Traffic.

In recent years navigation on the river Yare has developed considerably on commercial lines and a new type of seagoing motor vessel has been specially designed for carrying cargoes of large bulk on a shallow draught. In 1923 the number of trading ships arriving at Norwich was only 101, but in 1934 this figure had increased to 628, the cargoes including coal, grain, cement, bricks, tiles, timber, granite setts and pig iron. These ships come from ports in Great Britain and on the Continent direct to Norwich, and the development of this trade presumably arises from the fact that the cost of conveyance is considerably lower than by rail.

The largest type of vessel visiting the port of Norwich is 140 ft. long and 24 ft. wide, and there is no doubt that considerable demand exists for through shipping facilities to Norwich.

Museums.

The city of Norwich has adopted a progressive policy with regard to museums, and at present has four, each with its own definite purpose, i.e., the Castle Museum, with collections of art, archæology and natural history; the Strangers' Hall Folk Museum; the Bridewell Museum of local industries, past and present; and the St. Peter Hungate Church Museum of Ecclesiastical Art.

The Castle Museum.—The Norwich Museum was founded in 1825 as a private institution and continued as such until 1893 when the collections formed by the Norwich Museum Society were transferred to the Corporation. The present Castle Museum was opened by Their Majesties the King and Queen (then Duke and Duchess of York) in 1894. The building had been purchased by the Corporation and the work of restoring the interior of the Keep and converting the adjacent buildings into spacious galleries had been carried out at a cost of £26,474.

The Norman Keep of the Castle gives the Museum one of its largest exhibition galleries and the main floor is used to illustrate the story of 'Norwich through the Centuries' by means of period rooms with appropriate fittings. The exhibits include collections illustrative of the prehistory and archæology of the county of Norfolk, and of Norwich silver and Lowestoft porcelain.

Natural history has for a century past formed an important feature of the Norwich Museum. John Henry Gurney, father and son, were very closely associated with the ornithological collections.

The Geological Gallery is rich in remains of elephants and other animals from the Norfolk Forest-beds, and the Norwich Crag and Chalk. These collections were formed by the Rev. John Gunn, F. W. Harmer and other local geologists.

The Art Galleries contain a collection of pictures representative of the Norwich School of Painting, whose founder, John Crome (1768–1821), is acclaimed one of the world's greatest landscape painters. Thanks to the munificent bequest of Jeremiah James Colman, M.P. for Norwich 1871–1895, the art of John Crome, John Sell Cotman, James Stark, George Vincent, and other members of the School is illustrated by authentic examples of their work in oils and water colours.

The Bridewell Museum of Local Industries.—This historic building was given to the city in 1925 by the present Deputy Lord Mayor, Alderman Sir Henry Holmes, for the purpose of forming collections illustrating the past history and present progress of the industries of Norwich and Norfolk. The sections include boots and shoes, textiles, milling (mustard, etc.), agriculture, building, transport and engineering.

The Strangers' Hall.—This medieval merchant's house was one of the first folk museums in England, owing to the public spirit of the late Mr. Leonard G. Bolingbroke, who acquired the property in 1900 and formed the nucleus of the present collections. He presented the building and its contents to the city in 1922, and as the Corporation have since been able to acquire adjacent property there are 23 rooms at the present time furnished to show the evolution of the domestic life of the citizens of Norwich from the thirteenth century to Victorian times.

St. Peter Hungate Church.—In 1933 the Corporation acquired the disused church of St. Peter Hungate situated on Elm Hill, with the idea of the utilisation of the church for the exhibition of objects of ecclesiastical art. The church is of the Perpendicular period and its most noteworthy features are the hammer-beam roof of the nave with its unusual treatment at the crossings, and the fifteenth- and sixteenth-century glass in the east window and in the window under the tower arch. The Corporation have leased the premises to the Norfolk Archæological Trust, and, with the co-operation of the Castle Museum Committee, special exhibitions are formed in the church during the summer months with a view to illustrating Church art in its many and varied forms and its cultural effects on the people through the centuries.

The popularity of the museums is shown by the following statistics for the year 1934:

	Number of Visitors.
Castle Museum and Art Galleries	171,552
Strangers' Hall	13,233
Bridewell Museum	30,632
St. Peter Hungate Church Museum	10,244*

* During period of Exhibition of Church Pewter, June 12 to October 10.

In addition 11,845 school children attended classes at the Castle Museum, and 752 unemployed men attended in organised parties for talks on the museum collections; 4,332 visitors and school children visited the Strangers' Hall and the Bridewell in organised and special parties.

Public Libraries.

Norwich has the distinction of being the first municipality to adopt the first Public Library Act which was passed in 1850. The Corporation having decided to adopt the Act subsequently purchased a site and erected the present central library which was opened in 1857.

In 1920 the open access system was adopted in the lending library and immediately there was a great increase in the number of issues.

In 1921 Sir Eustace Gurney presented the historic Lazar House to the city for the purpose of a branch library, and it was opened in November 1923. Additional branch libraries were erected and opened at the Earlham and Mile Cross Housing Estates in 1929 and 1931 respectively.

The lending libraries consist of about 70,000 volumes in all departments of knowledge. The news and reading rooms at the central and branch libraries contain a representative selection of leading newspapers and periodicals. The Reference Library contains about 33,000 volumes.

The Central Library is an approved depository for manorial documents and the local collection has a rich store of material, valuable, not only to the antiquary, but to all those who desire to know something of the literature and art of the county or its natural and geological history. The local collection now comprises 9,173 volumes, 12,656 pamphlets, 8,216 topographical prints, 1,925 portraits, 453 maps and several hundred manuscripts. A valuable adjunct to the local collection is the Norfolk and Norwich Photographic Survey Record which was inaugurated in January 1913, the object being to preserve by permanent photographic process, records of antiquities, art, architecture, geology, and palæontology, natural history, passing events of local or historical importance, portraits, old documents, prints and characteristic scenery of the county of Norfolk. The record now numbers 5,847 prints and 3,052 slides.

The libraries are bureaux of information and as such play an important part in the life of the city.

Courses of free public lectures are arranged throughout the winter months, and the staff of the libraries co-operate with local educational societies by providing books to meet their requirements and preparing special book lists in connection with lectures.

Conclusion.

I must not close this article without referring to one of the latest developments, namely the erection of new buildings for the carrying on of the administrative work of the city. These buildings will occupy a site between St. Peter Mancroft Church and the Guildhall and the site is undoubtedly a unique one and worthy of a splendid building. The Council regarded the scheme as of such importance that they inaugurated an architectural competition which attracted 143 competitors. The winning design was submitted by Messrs. James and Pierce of Bedford Place, Bloomsbury Square, London, and has been approved by the Fine Arts Commission.

XIII.

SOME NORFOLK SCIENTISTS

BY

FRANK LENEY, CURATOR, CITY MUSEUMS, NORWICH.

THE following list of men either born or long resident in Norfolk, whose work is associated with the advancement of science, is admittedly incomplete; but the aim has been to record little-known workers as well as eminent local scientists. Portraits of a number of these pioneers are on exhibition in one of the art galleries of the Norwich Castle Museum.

AMYOT, THOMAS, F.R.S. (1775–1850), *b.* Norwich, contributed papers to the *Transactions of the Society of Antiquaries.* One of the founders and directors (1839–1850) of the Camden Society. Elected F.R.S. 1823.

AMYOT, T. E. (1817–1895), *b.* London, long resident at Diss, Norfolk. Interested in botany, geology and astronomy.

ARDERON, WM., F.R.S. (1703–1767), *b.* Yorkshire, long resident at Norwich. Naturalist, microscopist and meteorologist. Author of many contributions to the *Philosophical Transactions.* Elected F.R.S. 1745.

BARLOW, PETER, F.R.S. (1776–1862), *b.* Norwich, long resident in London. Mathematician, physicist and optician.

BARNWELL, C. F., M.A., F.R.S., F.S.A. (1761–1849). Assistant Keeper of the Department of Antiquities, British Museum.

BARRETT, C. G. (1836–1904), *b.* Devon, long resident at Norwich and Lynn. Monographed the British Lepidoptera.

BAYFIELD, T. G. (1817–1893). Formed collection of Norwich chalk fossils in the British Museum (Nat. History).

BIRD, GOLDING, M.A., M.D., F.R.S. (1815–1854), *b.* Downham, Norfolk. Co-author (with Charles Brooke) of *The Elements of Natural Philosophy*, 1860.

BROWNE, Sir THOMAS, M.D., M.A. (1605–1682), *b.* London, long resident at Norwich. Author of *Religio Medici*, 1642; *Urn Burial*, 1658.

BURNEY, CHAS., Mus. Doc. (Oxon.), F.R.S. (1726–1814), *b.* Shrewsbury; resident at King's Lynn, *c.* 1750. Wrote *Essay . . . History of Comets*, 1769.

CAIUS, JOHN, M.A. (1510–1573), *b.* Norfolk. Scholar and physician at Cambridge.

CLARKE, W. G., F.G.S. (1877–1925), *b.* Yorkshire, long resident in Norwich. Founder of the Prehistoric Society of East Anglia. Naturalist, topographer and archæologist.

COKE, T. W., first Earl of Leicester (1752–1842.) 'Coke of Norfolk.' M.P. for Norfolk, 1776–1806, 1807–1832. Famous for improving breeds of sheep, cattle and pigs.

Coke, T. W., second Earl of Leicester (1822–1909), *b.* Holkham, Norfolk. Agriculturist.

Cooke, M. C., D.Sc. (1825–1914), *b.* Norfolk, long resident in London. Author of numerous standard works on mycology.

Cooper, Sir Astley, Bart., F.R.S. (1768–1841), *b.* Brooke, near Norwich. Lecturer on Anatomy at St. Thomas's Hospital.

Cooper, B. B., F.R.S. (1792–1853). Surgeon at Guy's Hospital.

Crompton, Rev. J. (1813–1878). Long resident in Norwich and closely associated with the Norwich Microscopical Society and Science Gossip Club.

Crosse, J. G., F.R.S. (1790–1850). A well-known Norwich surgeon famous as a lithotomist.

Dalrymple, Arthur, F.S.A. (1808–1868), *b.* Norwich. Interested in local antiquities.

Dalrymple, John, F.R.S. (1803–1852), *b.* Norwich. Author of *The Anatomy of the Human Eye*, 1851.

Denny, Henry (1803–1871), *b.* Norwich. Entomologist. Wrote *Monographia Pselaphidarum et Scydmænidarum Britanniæ* and *Monographia Anoplurorum Britanniæ.*

Edwards, James (1856–1928), *b.* Norfolk, long resident at Colesbourne, Glos. Monograph of *British Homoptera.*

Fitch, Robert, F.S.A., F.G.S. (1802–1904), *b.* Norwich. Presented his collections of local antiquities and geological specimens to the Norwich Museum.

Geldart, H. D. (1831–1902), *b.* Norfolk. Author of ' Norfolk Botany ' in *Victoria County History.*

Glasspoole, H. G., M.A., F.G.S. (1825–1887), of Ormesby, Norfolk. Local botanist and geologist.

Gunn, Rev. John (1801–1890), *b.* Irstead, Norfolk. Collected mammalian remains from the Norfolk Forest-beds, and studied the local deposits. See *Memorials of John Gunn.*

Gunn, T. E., F.L.S. (1844–1923), *b.* Norwich. Ornithologist and taxidermist.

Gurney, Miss Anna (1795–1857). One of the Norwich Gurneys. An Anglo-Saxon scholar interested in local scientific studies. Collected fossils from the Norfolk coast.

Gurney, J. H. (1819–1890), *b.* Norwich. Authority on ' Birds of Prey,' and formed the famous collection of these birds in the Norwich Museum.

Gurney, J. H., F.L.S. (1848–1922), *b.* Norwich. Norfolk ornithologist and nature lover.

Haggard, Sir Rider, K.B.E. (1856–1925), *b.* Bradenham, Norfolk. Studied agricultural and social conditions. Author of *Rural England* and *A Farmer's Year.*

Harmer, F. W., M.A., F.G.S. (1835–1923), *b.* Norwich. Geologist, collaborated with Searles Wood in surveying the glacial deposits of East Anglia; studied the Pliocene Mollusca (*vide* Monograph, Palæontographical Society).

HOOKER, Sir W. J., LL.D., F.R.S. (1785–1865), *b.* Norwich. Botanist; authority on the British flora. Director of Royal Botanic Gardens, Kew, from 1841.

IVES, JOHN, F.S.A., F.R.S. (1751–1776), *b.* Great Yarmouth. Author of MS. *The History and Antiquities of the Hundred of Lothingland* (near Great Yarmouth) in the British Museum.

KITTON, FREDERICK, F.R.M.S. (1827–1895), *b.* Cambridge, long resident in Norwich. Microscopist and authority on Diatoms.

LEMAN, Rev. T., M.A., F.S.A. (1751–1826), *b.* near Norwich. Student of Roman Britain.

LINDLEY, JOHN, Ph.D., F.R.S. (1799–1865), *b.* Norwich. The distinguished botanist and horticulturist. Author of *Synopsis of the British Flora*, 1829.

LUBBOCK, Rev. RICHARD (1798–1876), *b.* Norwich. Wrote *Fauna of Norfolk*, 1845. See appreciation by H. Stevenson in *Trans. N. & N. Naturalists' Society*.

MANBY, G. W., F.R.S. (1765–1854), *b.* Downham Market. Famous inventor of devices for saving life from wrecks. His models are exhibited in the Norwich Bridewell Museum.

MARSHAM, ROBERT, F.R.S. (1708–1797), *b.* Stratton Strawless. Pioneer phenologist. Correspondent of Gilbert White.

PAGET, Sir G. E., M.D., F.R.S. (1809–1892), *b.* Great Yarmouth. Instituted regular clinical examinations in United Kingdom. Professor of Physic at Cambridge.

PAGET, Sir JAMES, D.C.L., F.R.S. (1814–1899), *b.* Great Yarmouth. Famous surgeon of Queen Victoria's reign. Wrote, with his brother, C. J. Paget, the *Natural History of Yarmouth*, 1834.

PITCHFORD, J., F.L.S. (1737–1803,) *b.* Norfolk. One of the first botanists in Britain to use the Linnæan classification.

PLOWRIGHT, C. B., M.D., F.R.C.S. (1849–1910), *b.* King's Lynn. A mycologist noted for his experiments with the British rust and smut fungi, of which he wrote a monograph.

REEVE, JAMES, F.G.S. (1833–1920), *b.* Norfolk. Curator of Norwich Museum for over sixty years. Worked at the Crag deposits at Bramerton, with Searles Wood, for the monograph on Crag mollusca.

SCALES, JOHN, M.A. (1794–1884), *b.* Yorkshire; resident in Norfolk, 1808–1842. An entomologist of repute, better known for the assistance he gave to the experts of his time than for his few published papers.

SEDGWICK, ADAM, F.R.S., F.G.S. (1785–1873), *b.* Yorkshire. Professor of Geology at Cambridge. Spent two months of each year at Norwich from 1834, where he stimulated local interest in science.

SMITH, Sir J. E., M.D., F.R.S. (1759–1828), *b.* Norwich. Botanist. Bought the Linnæan collection in 1783, and founded the Linnæan Society in 1788. Wrote *English Botany* (illustrated by Sowerby), *Flora Britannica*, *The English Flora*, etc.

SOUTHWELL, THOMAS (1831–1909), *b.* King's Lynn. A general naturalist and topographer of Norfolk. A well-known student of the Cetacea, he wrote *Seals and Whales of British Seas*, 1881.

STANLEY, EDWARD, F.R.S. (1779–1849), *b.* London. Bishop of Norwich from 1837. Educationist; took an active interest in ornithology, entomology and geology. Wrote *Familiar History of Birds* in 1836.

STEVENSON, HENRY, F.L.S. (1833–1888), *b.* Norwich. Author of *Birds of Norfolk.*

STILLINGFLEET, BENJAMIN, B.A. (1702–1771), *b.* Wood Norton, Norfolk. Naturalist and dilettante. Wrote *Miscellaneous Tracts relating to Natural History, Husbandry and Physick*, 1759.

SUTTON, CHARLES, D.D., A.L.S. (1756–1846), long resident in Norfolk. Botanist. Wrote monograph of Orobanche.

SUTTON, FRANCIS (1831–1917), *b.* near Norwich. Analytical chemist. Wrote the well-known *Handbook of Volumetric Analysis.*

TAYLOR, JOHN, F.R.S., F.G.S. (1779–1863), *b.* Norwich. A mining engineer; one of the founders of the British Association and of University College, London. Wrote and edited works on mining in England.

TOMES, Sir CHARLES, L.D.S., F.R.C.S., LL.D., F.R.S. (1846–1928). Histological work on teeth.

TURNER, DAWSON, F.R.S., F.L.S., F.S.A. (1775–1858), *b.* Great Yarmouth. Botanist and antiquary. Wrote *Natural History of Fuci*, 1808–1819, and (with L. W. Dillwynn) *Botanists' Guide throughout England and Wales*, 1805.

VINCE, SAMUEL, M.A., F.R.S. (1749–1821), *b.* Suffolk, long resident in Norfolk. Wrote *Treatise on Practical Astronomy*, *A Complete System of Astronomy*, and mathematical textbooks.

WIGG, LILLY, A.L.S. (1749–1828), *b.* Smallburgh, Norfolk. Botanist. Discoverer of marine algæ and a competent student of East Norfolk plants.

WOLLASTON, W. HYDE, M.D., F.R.S. (1766–1828), *b.* Dereham, Norfolk. Physiologist, geologist, chemist and physicist. His researches on optics and chemistry placed him among the foremost scientific men of Europe, and the Wollaston Medal, highest award of the Geological Society of London, was founded in his memory.

WOODWARD, HENRY, LL.D., F.R.S. (1832–1921), *b.* Norwich. Palæontologist. Keeper of Geology at the British Museum, 1880–1901. Authority on fossil crustacea.

WOODWARD, SAMUEL (1790–1838), *b.* Norwich. Antiquary and Naturalist. Formed large collection of Norfolk fossils and antiquities. Wrote *An Outline of the Geology of Norfolk* and *A Synoptical Table of British Organic Remains.*

WOODWARD, S. P., A.L.S., F.G.S. (1821–1865), *b.* Norwich. Author of *A Manual of the Mollusca*, and numerous papers on geology and conchology.

WRIGHT, EDWARD (1558 ?–1615), *b.* Garveston, Norfolk. Mathematician and hydrographer. Wrote *Certaine Errors in Navigation.*

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