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REPORT

OF THE

BRITISH ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE



1917.

LONDON
JOHN MURRAY, ALBEMARLE STREET
1918

Office of the Association: Burlington House, London, W. 1.

PREFACE.

THE Annual Meeting of the British Association in 1917 was cancelled, for the first time in the history of the Association, under circumstances described in the Report of the Council included in this volume

The Organising Committees of the Sections, having been empowered by the Council to do so, held in the early part of the summer such meetings as were necessary to transact such business as was essential in spite of the cancellation of the Annual Meeting, including the forwarding to the Committee of Recommendations of proposals for the appointment or reappointment of Research Committees, and for grants of money to some of them. The Organising Committees were also empowered to receive Reports from Research Committees, and to recommend for printing in the Annual Report such of these Reports as it was thought undesirable to delay.

On July 6, 1917, in the rooms of the Linnean Society, meetings were held of:—

The Council, at 11 30 A M , to approve the Report of the Council to the General Committee, and for other business;

The General Committee, at 12 noon, to receive the Reports of the Council and of the General Treasurer, to confirm the arrangements made in connection with the cancellation of the Annual Meeting, and for other business;

The Committee of Recommendations, at 2.30 P M., to make recommendations to the General Committee concerning the appointment of, and grants of money to, Research Committees, etc.;

The General Committee, at 4 P M , to receive the Report of the Committee of Recommendations

The present volume contains, as usual, the Reports of the Council and of the General Treasurer, and the list of Research Committees appointed by the General Committee. The usual lists and other records referring to previous meetings are omitted. For the rest, the volume contains only the Reports of Research Committees, referred to above, of which the General Committee, on the advice of the other committees concerned, decided that it would be undesirable to delay the issue. The Report of the Meeting of the Conference of Delegates of Corresponding Societies, which was held in the rooms of the Geological Society on July 5 and 6, is also included.

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OFFICERS AND COUNCIL, 1917–18.

PATRON.

HIS MAJESTY THE KING.

PRESIDENT.

SIR ARTHUR EVANS, D.LITT., LL.D., PRES.S.A., F.R.S.

PRESIDENT ELECT.

The Hon. SIR CHARLES A. PARSONS, K.C.B., Sc.D., F.R.S.

GENERAL TREASURER.

Professor JOHN PERRY, D.Sc., LL.D., F.R.S., Burlington House, London, W.

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Professor W. A. HERDMAN, D.Sc., LL.D., F.R.S. | Professor H. H. TURNER, D.Sc., D.C.L., F.R.S.

ASSISTANT SECRETARY.

O. J. R. HOWARTH, M.A., Burlington House, London, W. 1.

CHIEF CLERK AND ASSISTANT TREASURER

H. C. STEWARDSON, Burlington House, London, W. 1.

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BONE, Professor W. A., F.R.S.
BRABROOK, Sir EDWARD, C.B.
CLERK, Sir DUGALD, K.B.E., F.R.S.
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SCOTT, Professor W. R.
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SURAHAN, Dr. A., F.R.S.
WEISS, Professor F. E., F.R.S.
WHITAKER, W., F.R.S.
WOODWARD, Dr. A. SMITH, F.R.S.

EX-OFFICIO MEMBERS OF THE COUNCIL.

The Trustees, past Presidents of the Association, the President and Vice-Presidents for the year, the President and Vice-Presidents Elect, past and present General Treasurers and General Secretaries, past Assistant General Secretaries, and the Local Treasurers and Local Secretaries for the ensuing Annual Meeting.

TRUSTEES (PERMANENT).

The Right Hon. Lord RAYLEIGH, O.M., M.A., D.C.L., LL.D., F.R.S., F.R.A.S.
Major P. A. MACMAHON, D.Sc., LL.D., F.R.S., F.R.A.S.
Dr. G. CAREY FOSTER, LL.D., D.Sc., F.R.S.

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Sir A. Geikie, K.C.B., O.M., F.R.S.
Sir W. Crookes, O.M., F.R.S.
Sir James Dewar, F.R.S.
Sir Norman Lockyer, K.C.B., F.R.S.
Arthur J. Balfour, O.M., F.R.S.
Sir E. Ray Lankester, K.C.B., F.R.S.
Sir Francis Darwin, F.R.S.
Sir J. J. Thomson, O.M., Pres.R.S.
Professor T. G. Bonney, F.R.S.
Sir E. A. Schäfer, F.R.S.
Sir Oliver Lodge, F.R.S.
Professor W. Bateson, F.R.S.
Professor A. Schuster, F.R.S.

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Dr. A. Vernon Harcourt, F.R.S.
Sir E. A. Schäfer, F.R.S.
Dr. D. H. Scott, F.R.S
Dr. G. Carey Foster, F.R.S.
Dr. J. G. Garson.
Major P. A. MacMahon, F.R.S.

AUDITORS.

Sir Edward Brabrook, C.B
Sir Everard im Thurn, C.B., K.C.M.G.

REPORT OF THE COUNCIL, 1916–17.

I. At their meeting in March the Council, after discussion of conditions arising out of the war as bearing upon the question of holding the Annual Meeting of the Association, passed the following resolution for transmission to the Executive Committee at Bournemouth :—

> 'That the Council of the British Association recognise the possibility that the continuous series of Meetings of the Association may have to be broken this year, and, though they would regret that contingency, they regard the question as an open one, and wish their prospective hosts to feel entirely free as to the question of renewing their invitation or not ; but would welcome a reply at as early a date as possible.'

The meeting of the Council was adjourned pending a reply, but before the date proposed for its resumption the General Officers were informed of the possibilities (*a*) that buildings which the Association would have occupied at Bournemouth might be required for purposes connected with the war, (*b*) that official objection might be taken to the holding of the Meeting. The first possibility did not take definite shape, but as regards the second the General Officers learned, on consulting members of H.M. Government, that a Meeting would be deprecated, especially on the ground of the desirability of restricting railway travelling. Having regard to this and other considerations, it was felt that there was no option but to cancel the Annual Meeting.

The Council desire to place on record their grateful appreciation of the cordial co-operation of the authorities at Bournemouth in the discussions which have taken place ; they are glad to believe that the decision to cancel the Meeting, while regretted, is approved in Bournemouth, and it is hoped that the Meeting there may be only deferred, and to no distant date.

II. In consideration of the cancellation of the Meeting, the Council recommend that Sir ARTHUR EVANS' term of office as PRESIDENT be extended over the year 1917–18, and that the Hon. Sir C. A. PARSONS' tenure of that office be deferred to the year 1918–19 (Cardiff Meeting), both these gentlemen having consented to this course.

III. Resolutions received by the General Committee at Newcastle-upon-Tyne, and referred to the Council for consideration and, if desirable, for action, were dealt with as follows :—

From Sections D and E.

> That it be recommended to the Council that a grant of £100 from the 'Caird Fund' be made to Dr. W. S. Bruce for the upkeep of the Scottish Oceanographical Laboratory.

It was resolved that a grant of £100, for one year only (1916-17), be made to Dr. W. S. Bruce for the upkeep of the Scottish Oceanographical Laboratory.

From Section K.

That the Council be recommended to ask the Government to make Section K a grant of 500 reprints of a list of economic plant products which has been prepared by Sir David Prain, and is shortly to be published in the Kew Bulletin.

It was resolved to make the above request as recommended.

From Section L.

The Committee of Section L has evidence that the separate issue of the sectional transactions has been of considerable utility both during and after the Meetings, and it regrets their discontinuance. While recognising that there are special difficulties as regards printing and paper at the present time, the Committee hope that the Council will resume next year the publication of the sectional transactions containing the President's Address, Reports of Committees, and Abstracts of Papers.

It was resolved that this expression of the Committee's views should receive consideration in due course.

IV. An informal suggestion, brought forward after consultation between members of the Research Committee on Fuel Economy and members of the Advisory Committee of the Privy Council on Scientific Research, was laid before the Council, to the effect that the work of the Research Committee should be merged in that of a (proposed) Government Standing Committee. The Council approved.

V. In view of the reduction in receipts caused by small attendance at the Meeting in Newcastle, an application was made to the Royal Society for a grant of £50 in aid of printing the Annual Volume. The grant was made, and a vote of thanks was conveyed from the Council to the Society.

VI. The Council have received reports from the General Treasurer during the past year. His accounts are presented to the General Committee, subject to audit.

VII. The retiring members of the Council are :—

By seniority.—Dr. A. C. Haddon, Principal E. H. Griffiths.

By least attendance.—Prof. W. H. Bragg, Prof. H. B. Dixon.

The vacancy created by the death of Prof. Silvanus Thompson has not been filled during the present year.

The Council has nominated the following new members :—

Mr. J. H. Jeans,
Prof. Arthur Keith,
Prof. W. H. Perkin,

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. W. A. Bone.
Sir E. Brabrook.
Dr. Dugald Clerk.
Prof. A. Dendy.
Prof. H. N. Dickson.
Dr. F. A. Dixey.
Sir F. W. Dyson.
Prof. R. A. Gregory.
Prof. W. D. Halliburton.
Dr. S. F. Harmer.
Sir Everard im Thurn.
Mr. J. H. Jeans.
Prof. A. Keith.
Sir Daniel Morris.
Prof. W. H. Perkin.
Dr. E. J. Russell.
Sir E. Rutherford.
Miss E. R. Saunders.
Prof. W. R. Scott.
Prof. E. H. Starling.
Dr. A. Strahan.
Prof. F. E. Weiss.
Dr. A. Smith Woodward.

VIII. The GENERAL OFFICERS have been nominated by the Council as follows:—

General Treasurer: Prof. J. Perry.

General Secretaries: Prof. W. A. Herdman.
Prof. H. H. Turner.

IX. Mr. I. H. N. Evans and Miss N. Layard have been admitted members of the General Committee.

X. CONFERENCE OF DELEGATES and CORRESPONDING SOCIETIES COMMITTEE:—

The following appointments have been made by the Council:—

Conference of Delegates.—Mr. J. Hopkinson (*President*), Dr. F. A. Bather (*Vice-President*), Mr. W. M. Webb (*Secretary*).

Corresponding Societies Committee.—Mr. W. Whitaker (*Chairman*), Mr. W. Mark Webb (*Secretary*), Dr. F. A. Bather, Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Mr. J. Hopkinson, Mr. A. L. Lewis, Mr. T. Sheppard, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.

The Council approved a proposal from the Committee that a Conference of Delegates should be held in London on or about July 5, and they therefore made the appointments above mentioned, as a matter of urgency.

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

RECEIPTS

	£	s.	d.	£	s.	d.	£	s.	d.
To Balance brought forward									
Lloyds Bank, Birmingham				1,769	13	0			
Williams Deacon's Bank, Manchester				1,115	18	5			
Bank of England—Western Branch :—									
On 'Caird Fund'	290	7	10						
On General Account	56	1	1						
				346	8	11			
							3,262	0	4
Life Compositions (including Transfers)							197	0	0
Annual Subscriptions							684	0	0
New Annual Members' Subscriptions							176	0	0
Sale of Associates' Tickets							221	0	0
Sale of Ladies' Tickets							73	0	0
Sale of Publications							56	18	11
Grant from Royal Society Publication Fund							50	0	0
Donations							17	3	0
Interest on Deposit, Barclays Bank, Newcastle				10	10	1			
" " Lloyds Bank, Birmingham				53	1	2			
" " Williams Deacon's Bank, Manchester				25	13	0			
							89	4	3
Unexpended Balances of Grants returned							72	3	5
Dividends on Investments :									
Consols 2½ per Cent.				87	4	4			
India 3 per Cent				81	0	0			
Great Indian Peninsula Railway 'B' Annuity				24	4	3			
War Loan 1½ per Cent				80	17	9			
							273	6	4
Dividends on 'Caird Fund' Investments :—									
India 3½ per Cent.				68	19	0			
London and North-Western Railway Consolidated 4 per Cent Preference Stock				65	2	0			
London and South-Western Railway Consolidated 4 per Cent. Preference Stock				77	10	0			
Canada 3½ per Cent Registered Stock				65	12	6			
							277	3	6

Investments.

Nominal Amount. £	s.	d.		
4,651	10	5	Consolidated 2½ per Cent Stock	
3,600	0	0	India 3 per Cent. Stock	
879	14	9	£43 Great Indian Peninsula Railway 'B' Annuity	
2,627	0	10	India 3½ per Cent. Stock, 'Caird Fund'	
2,100	0	0	London and North-Western Railway Consolidated 4 per Cent Preference Stock, 'Caird Fund'	
2,500	0	0	Canada 3½ per Cent. (1930-50) Registered Stock, 'Caird Fund'	
2,500	0	0	London and South-Western Railway Consolidated 4 per Cent. Preference Stock, 'Caird Fund'	
87	4	9	Sir Frederick Bramwell's Gift of 2½ per Cent Self-Cumulating Consolidated Stock	
2,150	0	0	War Loan, 4½ per Cent, 1925-45	
1,000	0	0	Lloyds Bank, Birmingham—Deposit Account included in Balance at Bank, Sir J. Caird's Gift for Radio-Activity Investigation	
£22,095	10	9		£5,448 19 9

The Market Value of these Securities on 30th June, 1917, amounted to £15,334 13 0.

WITH THE BRITISH ASSOCIATION FOR THE July 1, 1916, to June 30, 1917.

Cr.

PAYMENTS.

	£	s.	d.	£	s.	d.
By Rent and Office Expenses					115	3	5
Salaries, etc					730	2	7
Printing, Binding, etc					1,154	9	8
Expenses of Newcastle Meeting					110	19	5
Grants to Research Committees:—							
Seismological Observations	100	0	0				
Tables of Constants	40	0	0				
Mathematical Tables	20	0	0				
Dynamic Isomerism	15	0	0				
Absorption Spectra, etc.	10	0	0				
Old Red Sandstone Rocks of Kiltorcan	4	0	0				
Fatigue from Economic Standpoint	40	0	0				
Physical Character of Ancient Egyptians	2	11	11				
Palæolithic Site in Jersey	25	0	0				
Archæological Investigations in Malta	20	0	0				
Distribution of Bronze Age Implements	1	14	3				
Artificial Islands in Highland Lochs	2	10	0				
Ductless Glands	6	0	0				
Psychological War Research	10	0	0				
Physiology of Heredity	45	0	0				
Ecology of Fungi	8	0	0				
Mental and Physical Factors involved in Education	10	0	0				
Museums	15	0	0				
School Books and Eyesight	5	0	0				
Free Place System	15	0	0				
Science Teaching in Secondary Schools	8	1	0				
Corresponding Societies Committee	25	0	0				
					427	17	2
Grants made from 'Caird Fund'					250	0	0
Balance at Lloyds Bank, Birmingham (with Interest accrued), including Sir James Caird's Gift, Radio-Activity Investigation, of £1,000 and Interest accrued thereon £104 18*s* 8*d*				1,822	14	2	
Balance at Williams Deacon's Bank, Manchester (with Interest accrued)				421	11	5	
Balance at Barclays Bank, Newcastle (with Interest accrued)				281	0	4	
Balance at Bank of England—Western Branch—							
On 'Caird Fund'	£317	11	4				
Less General Account overdrawn	179	13	10	137	17	6	
				2,663	3	5	
Less Petty Cash Account overspent				2	15	11	
					2,660	7	6
				£5,448	19	9	

JOHN PERRY, *General Treasurer.*

I have examined the above Account with the Books and Vouchers of the Association, and certify the same to be correct. I have also verified the Balances at the Bankers, and have ascertained that the Investments are registered in the names of the Trustees, except £50 Investment in the War Loan 4½ per Cent. Stock, which stands in the name of the Treasurer.

W. B. KEEN, *Chartered Accountant.*
October 11, 1917.

APPROVED—
EDWARD BRABROOK,
EVERARD IM THURN, } *Auditors.*

LIST OF GRANTS, 1917.

RESEARCH COMMITTEES, ETC., APPOINTED BY THE GENERAL COMMITTEE, MEETING IN LONDON: JULY, 1917.

1. *Receiving Grants of Money.*

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
SECTION A.—MATHEMATICS AND PHYSICS.		
Seismological Investigations.	*Chairman.*—Professor H. H Turner. *Secretary*—Mr. J. J. Shaw. Mr. C. Vernon Boys, Dr. J. E. Crombie, Mr. Horace Darwin, Dr. C. Davison, Sir F W. Dyson, Sir R. T. Glazebrook, Professors C. G. Knott and H. Lamb, Sir J. Larmor, Professors A. E. H. Love, H. M Macdonald, J. Perry, and H. C. Plummer, Mr. W. E. Plummer, Professors R. A Sampson and A. Schuster, Sir Napier Shaw, Dr G T. Walker, and Mr. G. W. Walker.	100 0 0
SECTION B.—CHEMISTRY.		
Colloid Chemistry and its Industrial Applications.	*Chairman.* — Professor F. G. Donnan. *Secretary.*—Professor W. C. McC. Lewis. Dr. E. F. Armstrong, Professor A. J. Brown, Dr. C. H. Desch, Mr. E. Hatschek, Professors H R. Procter and W. Ramsden, Mr. A. S. Shorter, Dr H. P. Stevens, and Mr. H. B. Stocks.	10 0 0
Research on Non-Aromatic Diazonium Salts.	*Chairman.*—Dr. F. D Chattaway. *Secretary.*—Professor G. T. Morgan. Mr. P. G. W. Bayly and Dr. N. V. Sidgwick.	7 7 8
SECTION C.—GEOLOGY.		
To investigate the Geology of Coal-Seams.	*Chairman.* — Professor W. S. Boulton. *Secretary.*—Dr. W. T. Gordon. Mr. G. Barrow, Professors Cadman, Grenville Cole, and W. G. Fearnsides, Dr. J. S. Flett, Dr. Walcot Gibson, Professors J. W. Gregory and P. F. Kendall, Dr. R. Kidston, Professors G. A. Lebour and T. F. Sibly, Dr. A. Strahan, and Mr. J. R. R. Wilson.	15 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Old Red Sandstone Rocks of Kiltorcan, Ireland.	*Chairman.*—Professor Grenville Cole. *Secretary.*—Professor T. Johnson. Dr. J. W. Evans, Dr. R. Kidston, and Dr. A. Smith Woodward.	5 0 0
SECTION D.—ZOOLOGY.		
Experiments in Inheritance in Silkworms.	*Chairman.*—Professor W. Bateson. *Secretary.*—Mrs. Merritt Hawkes. Dr F. A. Dixey and Dr. L. Doncaster.	20 0 0
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.		
Replacement of Men by Women in Industry.	*Chairman.*—Professor W. R. Scott. *Secretary.*—Professor J. C. Kydd. Miss Ashley, Ven. Archdeacon Cunningham, Professor E. C. K. Gonner, Mr. J. E. Highton, Professor A. W. Kirkaldy, Miss Mellor, and Miss Stephens.	10 0 0
The Effects of the War on Credit, Currency, and Finance.	*Chairman.*—Professor W. R. Scott. *Secretary.*—Mr. J. E. Allen. Professor C. F. Bastable, Sir E. Brabrook, Professor Dicksee, Mr. B. Ellinger, Mr. A. H. Gibson, Professor E. C. K. Gonner, Mr. F. W. Hirst, Professor A. W. Kirkaldy, Sir R. H. Inglis Palgrave, and Mr. E. Sykes.	10 0 0
SECTION H.—ANTHROPOLOGY.		
To excavate a Palæolithic Site in Jersey.	*Chairman.*—Dr. R. R. Marett. *Secretary.*—Mr. G. de Gruchy. Dr. C. W. Andrews, Mr. H. Balfour, Professor A. Keith, and Colonel Warton.	5 0 0
To conduct Archæological Investigations in Malta.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. T. Ashby Mr. H. Balfour, Dr. A. C. Haddon, and Dr. R. R. Marett.	10 0 0
To report on the Distribution of Bronze Age Implements.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Mr. H. Peake. Professor W. Ridgeway, Mr. H. Balfour, Sir C. H. Read, Professor W. Boyd Dawkins, Dr. R. R. Marett, and Mr. O. G. S. Crawford.	1 0 0

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
To investigate and ascertain the Distribution of Artificial Islands in the lochs of the Highlands of Scotland.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Professor J. L. Myres. Professors T. H. Bryce and W. Ridgeway, Mr. H. Fraser, Dr. A. Low, and Mr. A. J. B. Wace.	2 10 0
To conduct Explorations with the object of ascertaining the Age of Stone Circles.	*Chairman.*—Sir C. H. Read. *Secretary.*—Mr. H. Balfour. Dr. G. A. Auden, Professor W. Ridgeway, Dr. J. G Garson, Sir Arthur Evans, Dr. R. Munro, Professors Boyd Dawkins and J. L. Myres, Mr. A. L. Lewis, and Mr. H. Peake.	15 0 0
SECTION I.—PHYSIOLOGY.		
The Ductless Glands.	*Chairman.*—Sir E. A. Schäfer. *Secretary.*—Professor Swale Vincent Dr. A. T. Cameron and Professor A. B. Macallum.	9 0 0
SECTION K.—BOTANY.		
Experimental Studies in the Physiology of Heredity.	*Chairman.*—Dr. F. F. Blackman. *Secretary.*—Mr. R. P. Gregory Professors Bateson and Keeble and Miss E. R Saunders	15 0 0
SECTION L.—EDUCATIONAL SCIENCE.		
The Influence of School Books upon Eyesight.	*Chairman.*—Dr. G. A. Auden. *Secretary.*—Mr. G. F. Daniell Mr. C. H Bothamley, Mr. W. D. Eggar, Professor R. A. Gregory, Dr. N. Bishop Harman, Mr. J. L. Holland, Dr. W. E. Sumpner, Mr. A. P. Trotter, and Mr. Trevor Walsh.	2 0 0
To inquire into and report upon the methods and results of research into the Mental and Physical Factors involved in Education.	*Chairman.*—Dr. C. S. Myers. *Secretary.*—Professor J. A. Green. Professor J. Adams, Dr. G. A. Auden, Sir E. Brabrook, Dr. W. Brown, Mr. C. Burt, Professor E. P. Culverwell, Mr. G. F. Daniell, Miss B. Foxley, Professor R. A. Gregory, Dr. C. W. Kimmins, Professor W. McDougall, Professor T. P. Nunn, Dr. W. H. R. Rivers, Dr. F. C. Shrubsall, Professor H. Bompas Smith, Dr. C. Spearman, and Mr. A. E. Twentyman.	4 5 2

1. *Receiving Grants of Money*—continued.

Subject for Investigation, or Purpose	Members of Committee	Grants £ s. d.
The Effects of the 'Free-place' System upon Secondary Education.	*Chairman.*—Mr. C. A. Buckmaster. *Secretary.*—Mr. D. Berridge. Mr. C. H. Bothamley, Miss L. J. Clarke, Miss B. Foxley, Dr. W. Garnett, Professor R. A. Gregory, Mr. J. L. Paton, Professor H. Bompas Smith, Dr. H. Lloyd Snape, and Miss Walter.	10 0 0
To consider and report upon the method and substance of Science Teaching in Secondary Schools, with particular reference to its essential place in general Education.	*Chairman.*—Professor R. A. Gregory. *Secretary.*—Dr. E. H. Tripp. Mr. W. Aldridge, Professor H. E. Armstrong, Mr. D. Berridge, Mr. C. A. Buckmaster, Miss L J. Clarke, Mr. G. F. Daniell, Miss I. M. Drummond, Mr. G. D. Dunkerley, Miss A. E. Escott, Mr. Cary Gilson, Miss C. L. Laurie, Professor T. P. Nunn, and Mr. A. Vassall.	10 0 0
CORRESPONDING SOCIETIES.		
Corresponding Societies Committee for the preparation of their Report.	*Chairman*—Mr. W. Whitaker. *Secretary.*—Mr. W. Mark Webb. Dr. F. A. Bather, Rev. J. O. Bevan, Sir Edward Brabrook, Sir H. G. Fordham, Mr. J. Hopkinson, Mr. A. L. Lewis, Mr. T. Sheppard, Rev. T. R. R. Stebbing, and the President and General Officers of the Association.	25 0 0

2. *Not receiving Grants of Money.**

Subject for Investigation, or Purpose	Members of Committee
SECTION A.—MATHEMATICS AND PHYSICS.	
Annual Tables of Constants and Numerical Data, chemical, physical, and technological.	*Chairman.*—Sir E Rutherford. *Secretary.*—Dr. W. C. McC. Lewis.
Calculation of Mathematical Tables.	*Chairman.*—Professor M. J. M. Hill. *Secretary.*—Professor J. W. Nicholson. Dr. J. R. Airey, Mr T. W. Chaundy, Professor L. N. G. Filon, Sir G. Greenhill, Professor E. W. Hobson, Mr. G. Kennedy, and Professors Alfred Lodge, A. E. H. Love, H. M. Macdonald, G. B. Mathews, G. N. Watson, and A. G. Webster.
Investigation of the Upper Atmosphere	*Chairman.*—Sir Napier Shaw. *Secretary.*— Mr C. J. P. Cave, Mr. W. H. Dines, Sir R. T. Glazebrook, Sir J. Larmor, Professors J. E Petavel and A. Schuster, and Dr. W. Watson
Radiotelegraphic Investigations.	*Chairman.*—Sir Oliver Lodge. *Secretary.*—Dr. W. H. Eccles. Mr S. G. Brown, Dr. C Chree, Sir F. W. Dyson, Professor A. S. Eddington, Dr. Erskine-Murray, Professors J. A. Fleming, G. W O Howe, H. M. Macdonald, and J. W. Nicholson, Sir H Norman, Captain H R Sankey, Professor A. Schuster, Sir Napier Shaw, and Professor H. H. Turner.
Determination of Gravity at Sea	*Chairman.*—Professor A E. H Love. *Secretary.*—Dr. W. G Duffield. Mr. T. W Chaundy and Professors A. S. Eddington, A. Schuster, and H. H. Turner.
To aid the work of Establishing a Solar Observatory in Australia.	*Chairman.*—Professor H. H Turner. *Secretary.*—Dr. W. G. Duffield. Rev. A. L. Cortie, Dr. W J. S. Lockyer, Mr F. McClean, and Professor A. Schuster
To discuss the present needs of Geodesy, including its relation to other branches of Geophysics, and to report to the next meeting of the British Association, with power to present an interim report to the Council if any question of urgency should arise.†	*Chairman.*—Colonel Sir C F. Close. *Secretary.*—Colonel E. H. Hills. Sir S. G. Burrard, Dr. W. G. Duffield, Mr. Horace Darwin, Sir F. W Dyson, Sir R T. Glazebrook, Mr. A R. Hinks, Sir T. H. Holdich, Professor Horace Lamb, Sir Joseph Larmor, Professor A. E. H. Love, Colonel H. G. Lyons, Professor H. Macdonald, Mr. R. D. Oldham, Professor A. Schuster, Sir Napier Shaw, Professor H. H. Turner, and Dr. G. W. Walker.

* Excepting the case of Committees receiving grants from the 'Caird Fund.'
† Joint Committee with Section E. Empowered to report to Council.

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

Subject for Investigation, or Purpose	Members of Committee
To arrange meetings in the ensuing year for the discussion of papers and reports on Geophysical subjects, and to co-operate with existing Committees in making recommendations for the promotion of the study of such subjects in the British Empire.	*Chairman.*—Sir F W. Dyson. *Secretary*—Dr. S. Chapman. Dr. C. Chree, Colonel C. F. Close, Professor E. B Elliott, Mr. J. H. Jeans, Professor A. E. H. Love, Major H G. Lyons, Professor A. Schuster, Sir Napier Shaw, Dr. A. Strahan, Professor H H. Turner, and Dr. G. W. Walker.
Section B.—CHEMISTRY.	
Fuel Economy; Utilisation of Coal, Smoke Prevention.	*Chairman*—Mr. Robert Mond. *Secretary.*— The Rt Hon Lord Allerton, Mr. Robert Armitage, Professor J. O. Arnold, Mr. J. A F Aspinall, Mr. A. H. Barker, Professor P P. Bedson, Sir G. T Beilby, Sir Hugh Bell, Professor W. S. Boulton, Professor E Bury, Dr. Charles Carpenter, Sir Dugald Clerk, Professor H B Dixon, Dr J T Dunn, Mr S. Z. de Ferranti, Dr. William Galloway, Professors W. W Haldane Gee and Thos Gray, Mr T Y. Greener, Sir Robert Hadfield, Dr. H S. Hele-Shaw, Dr. D H. Helps, Dr. G. Hickling, Mr. Grevil Jones, Mr. W. W Lackie, Mr. Michael Longridge, Dr J. W. Mellor, Mr. C. H. Merz, Mr. Bernard Moore, Hon. Sir Charles Parsons, Sir Richard Redmayne, Professors Ripper and L. T. O'Shea, Mr. R. P. Sloan, Dr. J. E. Stead, Dr. A. Strahan, Mr. C. E. Stromeyer, Mr. Benjamin Talbot, Professor R. Threlfall, Mr. G. Blake Walker, Dr. R. V. Wheeler, Mr. B. W. Winder, Mr. W B. Woodhouse, Professor W P. Wynne, and Mr. H. James Yates.
To report on the Botanical and Chemical Characters of the Eucalypts and their Correlation.	*Chairman.*—Professor H. E. Armstrong. *Secretary.*—Mr H. G Smith. Dr. Andrews, Mr. R. T. Baker, Professor F. O Bower, Mr. R. H. Cambage, Professor A. J. Ewart, Professor C. E. Fawsitt, Dr. Heber Green, Dr. Cuthbert Hall, Professors Orme Masson, Rennie, and Robinson, and Mr St. John.
Dynamic Isomerism.	*Chairman.*—Professor H. E Armstrong. *Secretary.*—Dr. T. M. Lowry. Dr. Desch, Sir J. J. Dobbie, Dr. M. O. Forster, and Professor Sydney Young.
Absorption Spectra and Chemical Constitution of Organic Compounds.	*Chairman.*—Sir J. J. Dobbie. *Secretary.*—Professor E. E. C. Baly. Mr. A. W. Stewart.
Chemical Investigation of Natural Plant Products of Victoria.	*Chairman.*—Professor Orme Masson. *Secretary.*—Professor Heber Green. Mr. J. Cronin and Mr. P. R. H. St. John.

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

Subject for Investigation, or Purpose	Members of Committee
SECTION C.—GEOLOGY.	
To investigate the Flora of Lower Carboniferous times as exemplified at a newly-discovered locality at Gullane, Haddingtonshire.	*Chairman.*—Dr. R. Kidston. *Secretary.*—Dr. W. T. Gordon. Dr. J. S. Flett, Professor E. J. Garwood, Dr. J. Horne, and Dr. B. N. Peach.
To excavate Critical Sections in the Palæozoic Rocks of England and Wales.	*Chairman.*—Professor W. W. Watts. *Secretary.*—Professor W. G. Fearnsides. Professor W. S. Boulton, Mr. E. S. Cobbold, Professor E. J. Garwood, Mr. V. C. Illing, Dr. Lapworth, and Dr. J. E. Marr.
To excavate Critical Sections in Old Red Sandstone Rocks at Rhynie, Aberdeenshire.	*Chairman.*—Dr. J. Horne. *Secretary.*—Dr. W. Mackie. Drs J. S. Flett, W. T. Gordon, G. Hickling, R. Kidston, B. N. Peach, and D. M. S. Watson.
To consider the Nomenclature of the Carboniferous, Permo-carboniferous, and Permian Rocks of the Southern Hemisphere.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Professor E. W. Skeats. Mr. W. S. Dun, Professors J. W. Gregory and Sir T. H. Holland, Mr. W. Howchin, Mr. A. E. Kitson, Mr. G. W. Lamplugh, Dr. A. W. Rogers, Professor A. C. Seward, Mr. D. M. S. Watson, and Professor W. G. Woolnough.
To consider the preparation of a List of Characteristic Fossils.	*Chairman.*—Professor P. F. Kendall. *Secretary.*—Mr. W. Lower Carter. Professor W. S. Boulton, Professor G. Cole, Dr. A. R. Dwerryhouse, Professors J. W. Gregory, Sir T. H. Holland, G. A. Lebour, and S. H. Reynolds, Dr. Marie C. Stopes, Mr. Cosmo Johns, Dr. J. E. Marr, Professor W. W. Watts, Mr. H. Woods, and Dr. A. Smith Woodward.
The Collection, Preservation, and Systematic Registration of Photographs of Geological Interest.	*Chairman.*—Professor E. J. Garwood. *Secretary.*—Professor S. H. Reynolds. Mr. G. Bingley, Dr. T. G. Bonney, Messrs. C. V. Crook, R. Kidston, and A. S. Reid, Sir J. J. H. Teall, Professor W. W. Watts, and Messrs. R. Welch and W. Whitaker.
SECTION D.—ZOOLOGY.	
An investigation of the Biology of the Abrolhos Islands and the North-west Coast of Australia (north of Shark's Bay to Broome), with particular reference to the Marine Fauna.	*Chairman.*—Professor W. A. Herdman. *Secretary.*—Professor W. J. Dakin. Dr. J. H. Ashworth and Professor F. O. Bower.

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

Subject for Investigation, or Purpose	Members of Committee
Nomenclator Animalium Genera et Sub-genera.	*Chairman.*—Dr. P. Chalmers Mitchell. *Secretary.*—Rev. T. R. R. Stebbing. Dr. M. Laurie, Professor Marett Tims, and Dr. A. Smith Woodward.
To obtain, as nearly as possible, a Representative Collection of Marsupials for work upon (*a*) the Reproductive Apparatus and Development, (*b*) the Brain.	*Chairman.*—Professor A. Dendy. *Secretaries.*—Professors T. Flynn and G. E. Nicholls. Professor E. B. Poulton and Professor H. W. Marett Tims.
To aid competent Investigators selected by the Committee to carry on definite pieces of work at the Zoological Station at Naples.	*Chairman.*—Mr. E. S. Goodrich. *Secretary.*—Dr. J. H. Ashworth. Mr. G. P. Bidder, Professor F. O. Bower, Drs. W. B. Hardy and S. F. Harmer, Professor S. J. Hickson, Sir E. Ray Lankester, Professor W. C. McIntosh, and Dr. A. D. Waller.
To summon meetings in London or elsewhere for the consideration of matters affecting the interests of Zoology or Zoologists, and to obtain by correspondence the opinion of Zoologists on matters of a similar kind, with power to raise by subscription from each Zoologist a sum of money for defraying current expenses of the Organisation.	*Chairman.*—Professor S. J. Hickson. *Secretary.*—Dr. W. M. Tattersall. Professors G. C. Bourne, A. Dendy, M. Hartog, W. A. Herdman, and J. Graham Kerr, Dr. P. Chalmers Mitchell, and Professors E. B. Poulton and J. Stanley Gardiner.
To nominate competent Naturalists to perform definite pieces of work at the Marine Laboratory, Plymouth.	*Chairman* and *Secretary.*—Professor A. Dendy. Sir E. Ray Lankester, Professor J. P. Hill, and Mr. E. S. Goodrich.
Zoological Bibliography and Publication.	*Chairman.*—Professor E. B. Poulton. *Secretary.*—Dr. F. A. Bather. Mr. E. Heron-Allen, Dr. W. E. Hoyle, and Dr. P. Chalmers Mitchell.
SECTION E.—GEOGRAPHY.	
To aid in the preparation of a Bathymetrical Chart of the Southern Ocean between Australia and Antarctica.	*Chairman.*—Professor T. W. Edgeworth David. *Secretary.*—Captain J. K. Davis. Professor J. W. Gregory and Professor Orme Masson.
SECTION F.—ECONOMIC SCIENCE AND STATISTICS.	
Industrial Unrest.	*Chairman.*—Professor A. W. Kirkaldy. *Secretary.*— Sir H. Bell, Rt. Hon. C. W. Bowerman, Professors S. J. Chapman and E. C. K. Gonner, Mr. H. Gosling, Mr. G. Pickup Holden, Dr. G. B. Hunter, Sir C. W. Macara, and Professor W. R. Scott.

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

Subject for Investigation, or Purpose	Members of Committee
SECTION G.—ENGINEERING.	
To report on certain of the more complex Stress Distributions in Engineering Materials.	*Chairman.*—Professor J. Perry. *Secretaries.*—Professors E. G. Coker and J. E. Petavel. Professor A. Barr, Dr. Chas. Chree, Mr. Gilbert Cook, Professor W. E. Dalby, Sir J. A. Ewing, Professor L. N. G. Filon, Messrs. A. R. Fulton and J. J Guest, Professors J. B. Henderson, F C. Lea, and A. E. H. Love, Dr. W Mason, Dr F. Rogers, Mr. W. A. Scoble, Dr. T. E. Stanton, Mr. C E. Stromeyer, and Mr. J. S. Wilson.
The Investigation of Gaseous Explosions, with special reference to Temperature.	*Chairman.*—Sir Dugald Clerk. *Secretary.*—Professor W. E. Dalby. Professors W. A. Bone, F. W. Burstall, H. L Callendar, E. G Coker, and H. B Dixon, Sir R. T. Glazebrook, Dr. J. A. Harker, Colonel Sir H. C. L. Holden, Professors B. Hopkinson and J. E. Petavel, Captain H. Riall Sankey, Professor A. Smithells, Professor W. Watson, Mr. D L. Chapman, and Mr. H. E. Wimperis.
To consider and report on the Standardisation of Impact Tests.	*Chairman.*—Professor W. H. Warren. *Secretary.*—Mr J. Vicars. Professor Payne and Mr. E H. Sainter.
SECTION H.—ANTHROPOLOGY.	
To investigate the Physical Characters of the Ancient Egyptians.	*Chairman.*—Professor G. Elliot Smith. *Secretary.*—Dr. F C. Shrubsall Dr. F. Wood-Jones, Professor A. Keith, and Dr. C. G. Seligman.
The Collection, Preservation, and Systematic Registration of Photographs of Anthropological Interest.	*Chairman.*—Sir C. H. Read *Secretary.*—Dr. Harrison. Dr. G. A. Auden, Mr. E. Heawood, Professor J. L. Myres, and Dr. H. O. Forbes.
To conduct Archæological and Ethnological Researches in Crete.	*Chairman.*—Mr. D. G. Hogarth. *Secretary.*—Professor J. L. Myres. Professor R. C. Bosanquet, Dr. W. L. H. Duckworth, Sir Arthur Evans, Professor W. Ridgeway, and Dr. F. C. Shrubsall.
The Teaching of Anthropology.	*Chairman.*—Sir Richard Temple. *Secretary.*—Dr. A C. Haddon. Sir E. F. im Thurn, Mr. W. Crooke, Dr. C. G. Seligman, Professor G. Elliot Smith, Dr. R. R. Marett, Professor P. E. Newberry, Dr G. A. Auden, Professors T. H. Bryce, A. Keith, P. Thompson, R. W. Reid, H. J. Fleure, and J. L Myres, Sir B C. A. Windle, and Professors R. J. A. Berry, Baldwin Spencer, Sir T. Anderson Stuart, and E. C. Stirling.

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

Subject for Investigation, or Purpose	Members of Committee
To prepare and publish Miss Byrne's Gazetteer and Map of the Native Tribes of Australia.	*Chairman.*—Professor Baldwin Spencer. *Secretary*—Dr. R. R. Marett. Mr. H. Balfour.
To excavate Early Sites in Macedonia.	*Chairman*—Professor W. Ridgeway. *Secretary.*—Mr A. J. B. Wace. Professors R. C. Bosanquet and J. L. Myres.
To conduct Anthropometric Investigations in the Island of Cyprus.	*Chairman.*—Professor J. L. Myres. *Secretary.*—Dr. F. C. Shrubsall. Dr. A. C. Haddon.
To investigate the Lake Villages in the neighbourhood of Glastonbury in connection with a Committee of the Somerset Archæological and Natural History Society.	*Chairman.*—Professor Boyd Dawkins. *Secretary.*—Mr. Willoughby Gardner. Professor W. Ridgeway, Sir Arthur Evans, Sir C. H. Read, Mr. H Balfour, Dr. A. Bulleid, and Mr. H. Peake.
To co-operate with Local Committees in Excavations on Roman Sites in Britain.	*Chairman.*—Professor W. Ridgeway. *Secretary*—Professor R. C. Bosanquet. Dr. T Ashby, Mr. Willoughby Gardner, and Professor J. L. Myres.
Section I.—PHYSIOLOGY.	
Colour Vision and Colour Blindness.	*Chairman.*—Professor E. H. Starling. *Secretary.*—Dr. Edridge-Green. Professor A. W. Porter, Dr. A. D. Waller, Professor C. S. Sherrington, and Dr. F. W. Mott.
Physiological Standards of Food and Work.	*Chairman* and *Secretary.*—Dr. A. D. Waller. Professors W D. Halliburton and W. H Thompson.
Section K.—BOTANY.	
To consider and report upon the necessity for further provision for the Organisation of Research in Plant Pathology in the British Empire.	*Chairman.*—Professor M. C. Potter. *Secretary.*— Professor Biffen, Mr. F. T. Brooks, Professor T. Johnson, Mr J. Ramsbottom, Mr. E S. Salmon, Dr. E. N. Thomas, and Mr. H W. T. Wager.
To consider the possibilities of investigation of the Ecology of Fungi, and assist Mr. J. Ramsbottom in his initial efforts in this direction.	*Chairman.*—Mr. H. W. T. Wager. *Secretary.*—Mr. J. Ramsbottom. Mr. W. B. Brierley, Mr. F. T. Brooks, Mr. W. Cheesman, Professor T. Johnson, Dr. C. E. Moss, Professor M. C. Potter, Mr L. Carlton Rea, Miss A. Lorrain Smith, and Mr. E. W. Swanton.

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

Subject for Investigation, or Purpose	Members of Committee
To carry out a Research on the Influence of varying percentages of Oxygen and of various Atmospheric Pressures upon Geotropic and Heliotropic Irritability and Curvature.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor A. J. Ewart. Professor F. F. Blackman.
To cut Sections of Australian Fossil Plants, with especial reference to a specimen of Zygopteris from Simpson's Station, Barraba, N S.W.	*Chairman.*—Professor Lang. *Secretary.*—Professor T. G. B. Osborn. Professors T. W. Edgeworth David and A. C. Seward.
The Collection and Investigation of Material of Australian Cycadaceæ, especially Bowenia from Queensland and Macrozamia from West Australia.	*Chairman.*—Professor A. A. Lawson. *Secretary.*—Professor T. G. B. Osborn. Professor A. C. Seward.
The Investigation of the Vegetation of Ditcham Park, Hampshire.	*Chairman.*—Mr. A. G. Tansley. *Secretary.*—Mr. R. S. Adamson. Dr. C. E. Moss and Professor R. H. Yapp.
The Structure of Fossil Plants.	*Chairman.*—Professor F. W. Oliver. *Secretary.*—Professor F. E. Weiss. Mr. E. Newell Arber, Professor A. C. Seward, and Dr. D. H. Scott.
The Renting of Cinchona Botanic Station in Jamaica.	*Chairman.*—Professor F. O. Bower. *Secretary.*—Professor R. H. Yapp. Professors R. Buller, F. W. Oliver, and F. E. Weiss.
Section L.—EDUCATIONAL SCIENCE.	
To consider the relations between the State and Education, and the means of giving effect to proposals for Educational Reform.	*Chairman.*—Sir Napier Shaw. *Secretary.*—Mr. Douglas Berridge. (Membership to be determined.)
To examine, inquire into, and report on the Character, Work, and Maintenance of Museums, with a view to their Organisation and Development as Institutions for Education and Research; and especially to inquire into the Requirements of Schools.	*Chairman.*—Professor J. A. Green. *Secretaries.*—Mr. H. Bolton and Dr. J. A. Clubb. Dr. F. A. Bather, Mr. C. A. Buckmaster, Mr. M. D. Hill, Dr. W. E. Hoyle, Professors E. J. Garwood and P. Newberry, Sir H. Miers, Sir Richard Temple, Mr. H. Hamshaw Thomas, Professor F. E. Weiss, Dr. Jessie White, Rev. H. Browne, Drs. A. C. Haddon and H. S. Harrison, Mr. Herbert R. Rathbone, and Dr. W. M. Tattersall.

Synopsis of Grants of Money appropriated for Scientific Purposes by the General Committee at the Meeting in London, July 1917. The Names of Members entitled to call on the General Treasurer for Grants are prefixed to the respective Committees.

Section A.—Mathematical and Physical Science.

	£	s.	d.
*Turner, Professor H. H.—Seismological Investigations	100	0	0

Section B.—Chemistry.

*Donnan, Professor F. G.—Colloid Chemistry and its Industrial Applications	10	0	0
*Chattaway, Dr. F. D.—Non-Aromatic Diazonium Salts	7	7	8

Section C.—Geology.

*Boulton, Professor W. S.—The Geology of Coal Seams	15	0	0
*Cole, Professor Grenville.—Old Red Sandstone Rocks of Kiltorcan, Ireland	5	0	0

Section D.—Zoology.

*Bateson, Professor W.—Inheritance in Silkworms	20	0	0

Section F.—Economic Science and Statistics.

*Scott, Professor W. R.—Women in Industry	10	0	0
*Scott, Professor W. R.—Effects of the War on Credit, &c....	10	0	0

Section H.—Anthropology.

*Marett, Dr. R. R.—Palæolithic Site in Jersey	5	0	0
*Myres, Professor J. L.—Archæological Investigations in Malta.....	10	0	0
*Myres, Professor J. L.—Distribution of Bronze Age Implements	1	0	0
*Dawkins, Professor Boyd.—Artificial Islands in Highland Lochs	2	10	0
*Read, Sir C. H.—Age of Stone Circles	15	0	0

Section I.—Physiology.

*Schäfer, Sir E. A.—The Ductless Glands	9	0	0

Section K.—Botany.

*Blackman, Dr. F. F.—Heredity	15	0	0
Carried forward	£234	17	8

* Reappointed.

Section L.—Educational Science.	£	s.	d.
Brought forward	284	17	8
*Auden, Dr. G. A.—School Books and Eyesight	2	0	0
*Myers, Dr. C. S.—Mental and Physical Factors involved in Education	4	5	2
*Buckmaster, Mr. C. A.—The 'Free-place' System	10	0	0
*Gregory, Professor R. A.—Science Teaching in Secondary Schools.....	10	0	0
Corresponding Societies Committee.			
*Whitaker, Mr. W.—For Preparation of Report.....	25	0	0
Total ....£	286	2	10

CAIRD FUND.

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

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

The following allocations have been made from the Fund by the Council to September 1917 :—

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

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

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

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

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

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

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

Rev. T. E. R. Phillips, for aid in transplanting his private observatory.—20*l.* (1915).

Oceanographical Laboratory—100*l.* (1916-17).

Committee on Fuel Economy.—25*l.* (1915-16).

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

* Reappointed.

REPORTS

ON THE

STATE OF SCIENCE.

REPORTS ON THE STATE OF SCIENCE.

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

I. *General.*

OWING to the cancelling of the Bournemouth meeting proposed for 1917, and to other reasons connected with the war, the present Report is made brief. It has been drawn up by the Chairman, except where specially mentioned.

The Committee asks to be reappointed with a grant of 100*l.* (including printing), in addition to 100*l.* from the Caird Fund already voted. The grant was formerly 60*l.*, with 70*l.* for printing—130*l.* in all; but during the war it has been reduced to 100*l.*, partly to meet the need for economy, partly because the printing has necessarily been less. The Government Grant Fund administered by the Royal Society has voted a subsidy of 200*l.* for 1917 as in recent years. With the above modification the budget remains practically the same as given in the 20th Report.

The Shide staff has remained unchanged, though it is probable that changes must shortly be made. The general question of organisation of seismology has not only been discussed at several meetings of the present Committee, but is also under consideration by the Geodetic Committee, appointed by Section A of the British Association in 1916. This Committee contemplates approaching the Government with a proposal for a Geodetic Institute. It has been suggested that before taking definite steps in this direction the similar needs of other branches of geophysics (seismology, magnetism, tides, &c.) should be reviewed; and the Geodetic Committee, suitably enlarged for the purpose, is proceeding to this review.

The collation of the records for 1913 was completed and printed as a separate pamphlet, with a preliminary discussion. Further discussion is given in a later section of this Report.

II. *Instrumental.*

The time signals at Shide have been received regularly, with some interruptions chiefly due to bad weather, and consequent derangement of the instrument.

The transit lent by the Royal Astronomical Society has been used in supplement; but it is found difficult to secure the instrument in a permanent azimuth. The method used has been to fix the feet to the pier with plaster-of-Paris; and this holds for a time, and then seems to give way for some unknown reason. On the first occasion it was naturally assumed that there had been some accidental blow to the instrument, but it is difficult to believe that this can have happened on all the occasions noted.

The following note has been received from the Astronomer Royal for Scotland :—

An Improved Method of Registration for Milne Seismographs.

An attempt was made to improve the trace of the Milne Seismograph at Edinburgh by using a very small source of light. Though some improvement was obtained, a limit was soon reached in the diffraction pattern resulting from the crossed slits. The following arrangement was then adopted. The boom ends in a plate of blackened aluminium foil, in the centre of which is a hole rather less than 1 mm. diameter. Over this hole is mounted a small lens, which forms an image on the bromide paper of a specially small source of light. The lens used is achromatic, of 9 mm. focal length. The fixed slit-plate was at first left undisturbed; but subsequently the slit was widened to about 1 mm. To obtain a sufficiently small source of light, a four-candle-power electric lamp with coiled-up filament is fixed 30 cm. above the end of the boom, and 10 cm. below this is placed a telescope ocular of 1 cm. focus.

The results show a striking improvement on the previous records. The trace is a line well under $\frac{1}{20}$ mm. thick, and can be magnified ten or twenty times with advantage. In this way the short-period oscillations of the boom, which formerly resulted in a blurring of the trace, are clearly resolved. To obtain the full benefit of the magnification it would be an improvement to run the paper at a much slower rate than at present (say, at 100 mm. per hour instead of 240 mm.).

Milne-Shaw Seismographs.

It was submitted in the last Report that *the most important work of the Committee for the present lies in replacing the Milne machines* (either by Galitzin machines or) *by Milne-Shaw machines.* The difficulties of obtaining Galitzin machines have not decreased; but it is gratifying to report that a number of orders have been received for M.-S. machines, and that a generous subsidy of 200*l.* has been made from a private source. Hence Mr. Shaw has been working early and late to make a number of machines. It is perhaps better to reserve the list for the end of the war, but it may be stated that two have been safely delivered to America, and others are nearing completion. There have been considerable difficulties in obtaining some of the materials, but Mr. Shaw's patience and ingenuity

have overcome them. In the course of construction and testing he has obtained a number of interesting results of which he has made the following notes. It may be added that, in spite of the pressure of this work, he has found time to make regular visits of superintendence to Shide, either in company with the Chairman or alternating with him. His instrumental skill and knowledge have been freely put at the disposal of the Committee throughout.

Notes on the Comparison of two Milne-Shaw Seismographs.
By J. J. S.

The testing of two Milne-Shaw seismographs, No. 8 and No. 9, at West Bromwich, during May of the present year, showed not only how standardised machines may be relied upon to give similar seismograms, but also afforded an opportunity of investigating the questions of daily tilt and microseisms, and the degree of sensitivity to which a machine can be set.

Statements have been published that, due to the mechanical imperfections of seismographs, there is a difficulty in obtaining long periods of oscillation; anything of the order of 60 seconds being an impossibility. The facilities for making refined adjustment provided in the Milne-Shaw type prompted the writer to investigate the possibilities.

No difficulty was experienced in obtaining a period of 60 seconds, and, in order to test its constancy, the machine was left for five days, at the end of which time the period remained unchanged.

The period was then increased to 90 seconds; the machine had now become highly sensitive to the slightest tilt. With a nominal magnification 150 times the horizontal ground movement, this period gave such a sensitivity to tilt that 1 sec. of arc produced 1·5 metre displacement of the light spot; or conversely 1 mm. displacement corresponded to a tilt of 1 inch in about 5,000 miles.

A subsequent attempt produced a period of approximately 120 seconds, which represents a sensitivity of 1 mm. amplitude for a tilt of 1 inch in upwards of 8,000 miles.

With the apparatus in this condition the smallest movement of the observer affects the position of the light spot; therefore the observer took up a seated position 6 feet from the column; but even so, a swaying of the body in the chair produced an appreciable effect.

This machine, No. 8, was mounted upon a pier measuring about a cubic yard, built up from the cellar floor of the writer's house. The weight of one person (150 lb.) in a bedroom two floors above, and not immediately over the instrument, produced a tilt in the cellar floor of about ·04 second of arc, causing the light spot to be deflected more than 100 mm.

A test was made of the machine's sensitivity to temperature change at this 120 seconds period. Approaching the column for this purpose was out of the question, therefore the rays from a small Bijou incandescent gas mantle, with which the chamber was lighted, were, by means of a small hand mirror, so projected that they fell upon one side of the column and not upon the other. The heat from this small increase of illumination expanded the one side of the column sufficiently to drive the light spot off the scale.

When timing the period of oscillation in these higher sensitivities it

was noted that the effect of amplitude upon the period became very marked—increasing the amplitude of swing rapidly increased the period.

With the pendulum set to oscillate in 10 or 12 seconds this difference amounts to only about $\frac{1}{10}$ of a second over a wide range of amplitude; but at 120 seconds the fluctuation becomes important. With a change in amplitude from 1,000 mm. to 100 mm. there was a drop in the period of 20 to 30 per cent.

Time did not permit of an investigation to determine the rate of change with differing periods. There was insufficient change in the damping ratio to account for the phenomenon, therefore it is probable that it is an extreme case of 'circular error.'

This variation of period with amplitude, even when small, suggests that some standard amplitude should be used when determining the period. 10 mm. is the prescribed standard with the Milne-Shaw machine.

The Milne-Shaw boom is short, and the magnification includes mechanical leverage. Though the friction of same is extremely small, it was expected that it would be sufficient to operate against obtaining excessively long periods, and would compare unfavourably with a simple elongated pendulum of the Milne type. The result was quite the reverse, thus establishing the fact that the air resistance on a long boom forms the major part of the total friction, and suggests that, though the design is simple, it is not necessarily the best for obtaining free oscillations.

The second machine, No. 9, was mounted upon a pier in an out-building 60 feet from No. 8. It was oriented in the same azimuth, and connected in series with the same time circuit. The constants of both machines were made equal, viz.:—

Period	12 seconds.
Sensitivity to tilt .	26 mm = 1 sec. of arc.
Magnification . . .	150 : 1.
Damping ratio . . .	20 : 1.

The early part of the month was favoured by calm nights, and it was at once observed that the microseisms were identical on both machines, in epoch, phase, period, and amplitude, thus demonstrating that microseisms are pure ground movements as distinguished from convection currents in the observatory or instrument cases, and that the term 'air-tremors,' as used by so many observers, is a misnomer; for it is not conceivable that air disturbances should so exactly coincide in separate buildings 60 feet apart. It was found that when the microseisms were intermittent they could easily be identified by their amplitude and number of waves in a group, also by the interval between successive groups (see A and B, Plate). In the past, microseisms have been investigated by observing their period and intensity, and the results compared with similar data from other stations. It is here suggested that a more fruitful method may be by gradually separating two or more machines, commencing with a few hundred yards or a mile or two, and, if the trains of waves could be still identified, increasing the distance to form a base line of sufficient length to determine their speed of propagation and the direction in which they were travelling. If this much could be achieved it is possible their cause and origin might be discovered.

A horizontal pendulum has two types of sensitivity, one to tilt, and the other to horizontal displacement. The former is regulated by the inclination of its supports; the latter is a result of its design, and is proportional

to the ratio of the leverage about the mass acting as a steady-point, and magnifies and records the horizontal ground movements; this sensitivity is termed its 'magnification.' The constants of one of the instruments were then altered so that, while the magnification remained the same, the tilt sensitivity was raised very considerably. But alterations in sensitivity to tilt had no effect upon the recorded amplitude of the microseisms, suggesting that microseisms are purely compressional waves.

The constants used were :—

No. 8. Mag. 150 . . . . . Tilt 1 sec. = 110 mm.
No. 9. „ 150 . . . . . „ „ = 26 mm.

On May 4 a small earthquake shock was recorded at a moment when the constants of the machines were alike, and it was gratifying to find that two damped machines when properly standardised may be relied upon to give similar results. The Plate shows comparable sections of this record from each machine; also part of the record taken at Shide (126 miles distant), which shows the same characteristics as the other two—note the isolated movement C. (Up the film at West Bromwich compares with down the film at Shide, and the paper speed is slower.) The letters A, B, C, &c., identify corresponding movements. The discrepancy at G was due to a fault in the driving motor, which has since been remedied, otherwise the West Bromwich records are identical.

On May 15 the maximum of another small shock was recorded when the periods were 40 seconds and 12 seconds respectively, and the damping 7 : 1 *v.* 14 : 1. The longer period gave from three to seven times the amplitude according to the impressed earth period. As the dampings were unequal, the result was not strictly comparable; but it was noted that the longer period, notwithstanding the advantage of less damping, was much slower to take up the earth wave. The long period pendulum showed a lag of from 5 to 9 seconds behind the other, according to the impressed wave period being short or long respectively.

This points to the desirability of machines conforming to some standard period if the times from different records are to be strictly comparable.

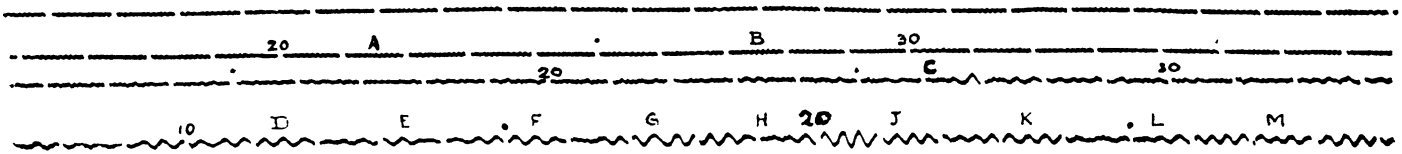
A further important observation was the fact—previously referred to in these Reports—that two sites comparatively near together may be quite different as regards daily wandering of the zero.

In the Plate the difference in the spacing of the lines on the two machines shows this clearly. The one with the wider spaces was taken in the out-building, and the displacement corresponded to an elongation of the sunny side during the day and a contraction at night, and was greatest on hot days. Time did not permit of sufficient investigation to discover whether the pier, cast-iron column, or whole house were affected. If only one or both of the former, then, since the heat rays are from the infra red end of the spectrum, protection may be afforded by interposing some athermanous substance, such as glass or water.

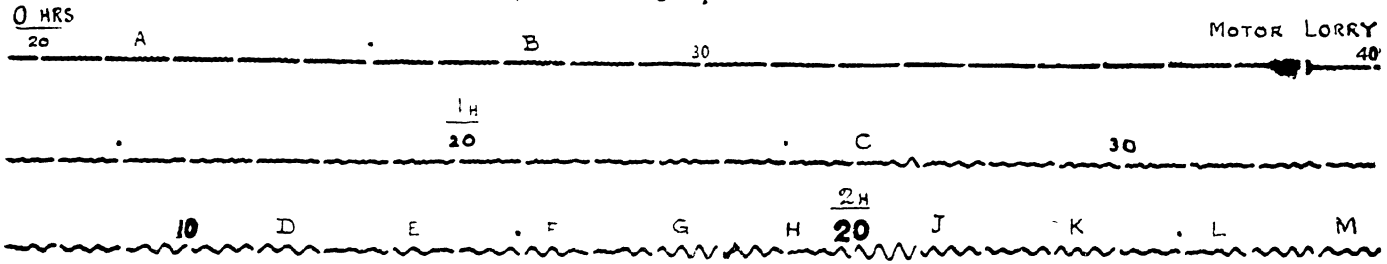
In the 1915 Report attention was drawn to two machines in the same azimuth, at Shide, behaving quite differently as regards wandering. The Milne-Burgess was not only less affected, but also showed a time lag behind the Milne-Shaw. The Milne-Burgess machine was fitted with a large glass cover. It seems probable that the athermancy of glass to dark heat may have been the cause of the observed effect.

If the iron column only is affected, then a great advance might be secured by making the column of substances with very low co-efficients of expansion, such as silica or invar steel.

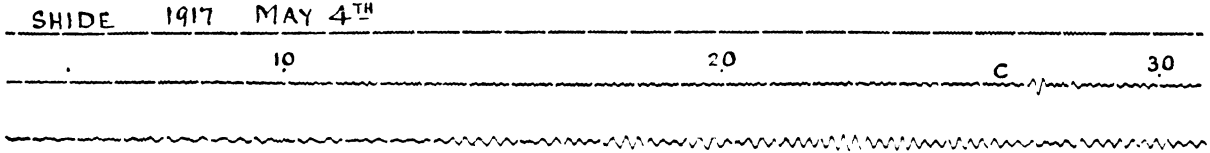
WEST BROMWICH 1917 MAY 4TH No 8



WEST BROMWICH 1917 MAY 4TH No 9



SHIDE 1917 MAY 4TH



III. *Tables for P and S.*

'The Large Earthquakes of 1913' were collated and printed in a special pamphlet of xii+74 pages. In the xii pages of introduction a provisional analysis of the residuals for P and S is given; but, the deductions there made not proving workable, a new analysis of all the 1913 and 1914 material has been undertaken, in which the residuals for different types of machine were kept separate. The help of Dr. G. W. Walker, F.R.S., in pointing out some errors and unworkable deductions is gratefully acknowledged.

The correction of greatest importance refers to the identification of S at distances exceeding 90°. The provisional analysis of the 1913 results shows that there are several phenomena which have been confused as S, but are really separate. They were denoted First Set, Second Set, &c. The First Set lay near the adopted tables, but there were few of them; the Second Set, arriving about a minute *earlier* than the First at $\Delta=100°$, is favoured by the great majority of records from $\Delta=90°$ to 105° (115 records against 29), and for this reason was assumed to be the true S. This assumption led to the inference that the times of transmission for S and P became nearly constant beyond $\Delta=100°$, and an explanation was suggested why they became faint or even disappeared (p. viii). But Dr. G. W. Walker pointed out some grave objections to this identification, which must clearly be given up, with its consequent inferences. The true S is the 'First Set,' not far from the existing tables; the 'Second Set' is probably the Y phenomenon to which attention was called in the 20th Report. and it follows that *most* observatories have recorded Y in mistake for S; only at Pulkovo and in cases where special care is taken has the true S been identified. The examples given in the 20th Report will serve to show how readily the mistake may be made. Y comes before S; and if the *first* big movement is taken, it is natural to record Y.

The discussion in the introduction to the 1913 earthquakes was made in terms of S−P, under the assumption that the ratio of S to P was nearly constant. But this assumption was one of the faulty consequences of the wrong identification of S, and falls with it. Hence a new discussion of S and P separately was undertaken, using the whole of the 1913 and 1914 material together. The data were written on cards which could be arranged in various ways, and it was determined to separate the different types of machine. It was found that there was enough material to find the errors of the tables from Galitzin machines alone, and even more for Wiechert machines alone. Accordingly these two determinations were made and are given side by side in Table I.

The first column shows the mean Δ for the group. On the cards Δ was entered to 1°, and a long list of residuals was made for every 1°; but examination showed that little was gained by grouping in less than 5° sets. Under G are shown the mean residuals for Galitzin machines, followed by the number of records, and under W the corresponding numbers for Wiechert machines. In forming these means obvious mistakes were excluded; there is no practical difficulty in doing this except near $\Delta=90°$ for S, to which we must devote special attention.

It will be seen that there is a systematic difference W−G of +3·3s. for P and +5·5s. for S. If these mean values be subtracted from the columns for W−G, the numerical mean of the residual differences is $\pm$2·3s. for P and $\pm$3·5s. for S.

TABLE I.

Observed Corrections to P and S from Galitzin and Wiechert Machines in 1913-1914.

	P					S				
Δ	G	No	W	No.	W−G	G	No	W	No.	W−G
°	s		s		s	s		s		s
8	0·0	7	+4·4	43	+4·4	−1·7	3	+8·8	25	+10·5
13	+0·6	8	+3·2	22	+2·6	−12·9	7	−1·1	14	+11·8
18	−0·3	18	+0·3	34	+0·6	−0·6	16	+4·1	28	+4·7
23	−0·5	20	−0·3	41	+0·2	−6·7	21	−1·4	29	+5·3
28	−6·2	26	−4·2	39	+2·0	−10·9	23	−7·7	34	+3·2
33	−5·3	20	−1·0	26	+4·3	−24·0	10	−10·7	14	+13·3
38	−6·6	22	−3·3	33	+3·3	−18·8	20	−13·5	26	+5·3
43	−2·0	13	−0·2	26	+1·8	−12·5	12	−14·4	18	−1·9
48	−3·1	27	+2·8	25	+5·9	−10·2	24	−3·8	21	+6·4
53	−1·9	24	+3·6	14	+5·5	−2·1	17	−3·0	10	−0·9
58	+1·8	43	+8·8	17	+7·0	+2·8	37	+2·2	9	−0·6
63	1·5	34	5·4	14	3·9	4·0	34	6·8	11	10·8
68	2·2	47	2·2	16	0·0	3·9	46	1·3	11	5·2
73	−1·0	54	4·7	38	5·7	5·5	51	3·2	36	8·7
78	−1·7	51	−1·1	56	+0·6	−8·3	51	−1·1	53	+7·2
83	−1·6	37	−1·4	101	0·2	−11·8	36	−7·1	99	+4·7
88	+2·1	36	+1·0	52	−1·1	16·7	36	11·1	55	+2·6
93	−5·7	19	−1·8	34	+3·9	—	—	—	—	—
98	−7·3	11	−0·7	35	+6·6	—	—	—	—	—
103	−12·7	24	−3·2	14	+9·5	—	—	—	—	—
108	−11·4	21	—	—	—	—	—	—	—	—
113	−15·6	9	—	—	—	—	—	—	—	—
118	−6·4	7	—	—	—	—	—	—	—	—
123	−1·2	6	—	—	—	—	—	—		

In the last Report corrections to the adopted tables for P were suggested of about +17s. near Δ=19°, and about −23s. near Δ=30°, with correspondingly larger corrections for S. These large corrections are not confirmed by the present investigation, which shows quite small corrections in this neighbourhood. The attempted explanation of the phenomenon PX on these lines must therefore be given up. There is no doubt about the reality of the phenomenon, or of that designated Y; but the explanations of both must be sought on other lines.

Turning to the bottom of the table we see that records of P fail rapidly after Δ=110° even for G machines, and entirely for W machines. After Δ=105° there are two records only by W machines at all near the tables: −7s. at Δ=106°, and +10s. at Δ=115°. Other records are (in seconds of time):—

Δ	
° °	
106–110	−91 −61 +62 +148 +156 +242 +268
111–115	−110 +36 +147 +154 +205 +214 +271
116–120	+204 +269 +328 +359 +611
121–125	+180 +192 +194 +196 +197 +197 +198+208+209 +209+211+218+274+277+283+331 +340+621

At distances Δ=121°–125° it is clear that the records of P relate to what has been called PX, following P by about 200 seconds, but it is not altogether clear whether the transition is gradual or abrupt. Several investigators have treated PX as the true P; have remarked on the

'discontinuity'; and have inferred surfaces of discontinuity within the earth to account for it. The view taken in the last Report is that PX is not P; that the true P may be recorded alongside PX, but that as P tends to become faint after $\Delta=90°$, PX is read as P by mistake. By $\Delta=121°$–$125°$ P has become so faint as only to be read very rarely even, on Galitzin machines (and only twice on W as above). Galitzin machines mistake PX for P at times. We have

Other Records of Galitzin Machines.

Δ			Δ				
° °	s	s.	° °	s.	s.	s.	s.
96–100	+75	+220	111–115	+68	+114	+195	+257
101–105		+169	116–120	+61	+200	+274	+297
106–110	+77	+256	121–125	+51	+60	+199	

The discussion of the tables for both P and S beyond 90° thus involves special difficulties and is deferred to the next Report. Meantime the following table gives the best values for P and S that can be got from the above discussion, as applicable to G machines. In deriving them the W machines have of course also been used, with the above constant corrections. Further a little 'smoothing' has been used, and the values of S and P compared and slightly modified so that the ratio of S to P may vary continuously; the change appears indeed to be sensibly linear. The tenths of seconds are inserted merely to make the tables smooth; in deriving the corrections, the means of five consecutive figures in the adopted tables have been taken.

TABLE II.

Suggested Corrections to Adopted Tables for G Machines only.

Δ	Corrections P	S	S–P	New P	New S	Ratio
°	s	s.	s.	s	s	
8	2·4	— 1·1	— 3·5	123·4	215·3	1·745
13	0·3	7·7	8·0	192·5	335·7	1·749
18	2·2	5·6	7·8	259·0	454·0	1·753
23	0·4	7·9	8·3	316·6	556·3	1·757
28	— 1·8	—13·3	—11·5	366·2	645·3	1·762
33	— 5·3	—18·7	—13·4	410·5	724·9	1·766
38	— 6·5	—18·8	—12·3	451·7	799·4	1·770
43	6·5	15·8	9·3	491·7	872·4	1·774
48	3·2	10·4	7·2	530·4	943·2	1·778
53	1·2	4·7	5·9	567·4	1011·5	1·782
58	4·1	1·3	5·4	602·9	1077·3	1·786
63	4·4	0·9	— 5·3	636·2	1139·7	1·792
68	+ 3·9	2·3	6·2	668·1	1199·5	1·796
73	2·2	— 5·3	— 7·5	698·0	1256·7	1·800
78	0·2	— 8·9	— 8·7	726·8	1311·3	1·804
83	2·1	—13·0	—10·9	754·1	1364·0	1·808
88	— 4·3	—17·4	—13·1	780·3	1414·6	1·813
93	— 6·6	—21·1	—14·5	805·6	1464·1	1·818
98	— 9·5	—23·6	—14·1	830·3	1512·4	1·822
103	—10·3	—23·5	—13·2	854·5	1560·3	1·826
108	—10·2	—22·8	—12·6	878·0	1607·2	1·831
113	— 9·6	—19·3	— 9·7	901·6	1654·5	1·835
118	— 8·9	—12·9	— 4·0	924·7	1700·9	1·840

As regards seismographs other than G, the corrections to G appear to be sensibly constant at any rate to a good first approximation. They are assigned by the 1913 and 1914 results as follows, omitting some of which observations are scanty :—

TABLE III.

Corrections to G from other Seismographs.

Type	Correction to P	No. Observatns	Correction to S	No. Observatns	Correction to S–P
	s.		s.		s
Alfani	+ 3·8	17	— 3·2	17	- 7·0
Bosch	+ 1·8	27	- 2 9	22	—4·7
Bililar	+ 1·3	19	+ 9·4	16	+ 8 1
Bosch-Omori	+ 1·9	18	+ 4·0	39	+2·1
Cartuja	+ 3·3	36	+ 6 8	31	+3 5
Heidelberg	+ 2·3	27	+ 4·3	34	+2·0
Hamburg	+ 4·1	39	+ 1 2	32	-2·9
La Paz	+13·8	17	+17 0	10	+3·2
Mainka	- 0·7	124	0 2	112	+0·5
Omori	+ 6·5	95	+ 9 8	57	+3 3
Omori-Alfani	— 0·7	21	3 5	10	+4·2
Omori-Ewing	— 2·6	29	- 11·5	17	-8·9
Riverview	+ 1·6	25	+ 7·2	29	+5·6
Stiattesi	— 0·6	53	- 1 6	65	1·0
Vincentini	+ 0·6	48	+ 2·6	33	+2·0
Wiechert	+ 3·3	720	+ 5·7	493	+2·4

It will be seen that the corrections to the tables for G instruments, and the differences between one instrument and another, are such as to involve sensible corrections to the determinations of epicentre; and the next step is clearly a revision of the epicentres before forming definitive corrections to tables. This revision, and the analysis of the errors beyond $\Delta=90°$, must be reserved for another Report.

Distribution of Epicentres.

The epicentres for 1913 and 1914 were entered on a map and were found to lie near two great circles cutting at right angles. The first of these has its pole just east of Malta, in

longitude 17° E., latitude 35° N.,

which is the centre of a very good 'land-hemisphere,' the boundary of which skirts the E. coast of Asia; it crosses both the Americas, and leaves Australia and several of the large islands in the 'water-hemisphere.'

The other has its pole in

longitude 236° E. = 124° W.; lat. 48° N.

A third circle cutting both these at right angles does not seem to be active ; its pole is at 122° E.; 20° N.

In view of the proposed revision of epicentres (which, however, is not likely to modify these figures seriously), the reproduction of the maps is held over for the present.

[The following note was received after the rest of the Report had been sent to press.]

Focal Depth and the Time Curve. *By* Dr. G. W. WALKER, *F.R.S.*

Assuming that P, the first impulse on a seismogram, corresponds to a longitudinal wave from the focus of an earthquake, the slope of the time curve for P as a function of the epicentral distance Δ is connected with the apparent angle of emergence $\bar{e}$ by the well-known relation

$$\frac{d\mathrm{T}}{d\Delta} = \frac{1}{\mathrm{V}_2}\left\{\frac{1-\sin\bar{e}}{2}\right\}^{\frac{1}{2}}$$

V_2 being the speed of transversal waves at the surface.

$\bar{e}$ has been directly measured by Galitzin at Pulkovo for Δ from 2,500 kms. to 13,000 kms., and the results differ markedly from the values of $\bar{e}$ calculated from Zöppritz's time curve for P. Galitzin finds a clear minimum of 42° for $\bar{e}$ at Δ =1,000 kms., whereas no minimum is indicated in the calculated values of $\bar{e}$ (*cf.* 'Modern Seismology,' p. 54).

Further observations are required before we can regard Galitzin's results as characteristic of the whole earth, but I think it will be difficult to explain these results as peculiar to Pulkovo.

It is important to see how far we can reconcile these conflicting results.

By graphical integration of the observed values of $\bar{e}$, we get the time curve, and using Zoppritz's value of V_2 I find that the two curves can be fitted from 6,000 kms. to 12,000 kms. with a time discrepancy of $\pm$11 seconds. The discrepancy would, however, reach 100 s. at 3,000 kms.

Using a larger value of V_2 we can fit the curves from 3,500 kms. to 8,000 kms., with a discrepancy of only $\pm$5 sec., but the discrepancy mounts up beyond those limits of distance. It is not yet possible to decide what compromise is most reasonable. We may note, however, that considerable discrepancy may be allowed for distances $<$ 3,000 kms., as soon as we admit finite depth of focus.

Kovesligethy has shown the connection that exists between a minimum angle of emergence and focal depth, and the obvious inference from Galitzin's results is that the focal depth is about 1,300 kms., or even a little more.

This a very startling result, being 10 times the greatest estimate of depth hitherto given. Yet there appears no escape from the conclusion if we accept Galitzin's results, and it is remarkable that this depth is about the same as the depth of Wiechert's layer of discontinuity.

If such a depth of focus is correct, the whole question of reflexions has to be re-examined. As a qualitative guide to this, I have considered a uniform earth with focal depth 0·2 of the earth's radius taking $\mathrm{V}_1/\mathrm{V}_2=\sqrt{3}$. Some remarkable results follow, which I can indicate but briefly.

(1) Surface reflexion of waves either entirely longitudinal or entirely transversal over their whole path cannot occur till Δ =103°, and beyond this there are two paths for a once-reflected wave. There are no paths for a twice- or multiply-reflected wave. I suggest the possible association of this with the ambiguous character of S at 90°, noted by Professor Turner.

(2) PS and SP waves are no longer coincident in point of time. PS does not occur until Δ=149°, and beyond this there are two possible

paths, but there is no PS_2 or higher term. On the other hand, SP with an infinite series SP_n may begin at $\Delta = 11°$, and there is only one path for each member until $\Delta = 99°$, beyond which there are two possible paths for each member.

In the range $\Delta = 11°$ to 99°, the manufacture of Rayleigh waves goes on.

Actual figures for the earth will, no doubt, modify these numbers in the sense that they will be smaller than those for a uniform earth, and careful analysis must be made to see if the phenomena of the seismogram are consistent with a focus as deep as 1,300 kms.

Meanwhile, it appears desirable to draw attention to this direct inference from Galitzin's measurements.

Preliminary Report on Terrestrial Magnetism.

By Dr. Charles Chree, *F.R.S.*

(Prepared at the request of the Organising Committee of Section A.)

§1. There are two existing agencies which should be taken into account by everyone anxious to promote any new or large scheme of work, especially co-operative work, in terrestrial magnetism, viz., the International Magnetic Committee and the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. In most countries, terrestrial magnetism is officially regarded as a branch of meteorology, and most professional terrestrial magneticians are attached to the meteorological services of their respective countries. The International Magnetic Committee thus comes to be an offshoot of the International Meteorological Commission. The latter is composed of the directors of the meteorological services of the principal countries, but the International Magnetic Committee is a more numerous and heterogeneous body. The list published in connection with the last meeting of the International Magnetic Committee, held in 1910, at Berlin, contained the following names: Rykatcheff* (President) and Dubinsky (Russia); Schmidt* (Secretary) and Messerschmitt (Germany); Bauer, Faris, and Mendenhall (United States); Angot* (France), Rucker, Schuster, and Chree* (Great Britain), Liznar and Kesslitz (Austria); Palazzo (Italy); van Everdingen* (Netherlands), Carlheim Gyllenskold* (Sweden); Tanakadate (Japan); Stupart (Canada); Bigelow (Argentine). The British representation has suffered a severe loss in the death of Sir Arthur Rücker.

The International Committee can pass resolutions, but their doing so carries no compulsion with it. A number of definite opinions have been expressed, *e.g.*, as to terminology, data to be published, time to be observed and sensitiveness of magnetographs, some of which have exerted a considerable influence. Besides debating and passing resolutions, the International Committee has got certain things done whose utility is generally recognised. Probably the most successful of these is the scheme of international magnetic 'quiet' days, the organisation in connection with

* Those to whose names an * is attached compose the working Bureau, which is more especially intended to interest itself in current topics.

which has been provided at De Bilt by the Meteorological Institute of the Netherlands, at present under the directorship of Professor van Everdingen. This scheme is so well known that a brief reference to it will suffice. All co-operating observatories send in a quarterly list in which each day has assigned to it the 'character' figures 0, 1, or 2, according as the magnetograph curves are regarded as quiet, moderately disturbed, or highly disturbed. Using these returns, the director at De Bilt assigns a mean 'character' figure to each day, and selects for each month the five days which seem the best representatives of quiet conditions. He also selects a variable but smaller number of highly disturbed days. It is hoped that all co-operating observatories will derive and publish diurnal inequalities for the five monthly 'quiet' days, and also that they will publish copies of their curves for some at least of the selected disturbed days. A good many observatories do both these things. Some publish diurnal inequalities from the 'quiet' days alone, but most which publish 'quiet' day inequalities publish other inequalities as well. An international 'quiet' day, it is important to notice, is a twenty-four hour period commencing at Greenwich midnight, and international 'quiet' day inequalities thus refer to exact hours (G.M.T.). One of the recommendations of the International Committee, which has not been universally acted on, has been that magnetic observatories should employ local mean time (L.M.T.). Any observatory, however, other than Greenwich, which employs L.M.T., or any time which differs from G.M.T. by fractions of an hour, has to take two different sets of measurements if it adopts the international 'quiet' day system. The amplitude of magnetic disturbance varies immensely at different stations, and the attachment of 'character' figures is so arbitrary an operation, that the standard is apt to vary considerably, even at the same observatory. Thus a desire to replace the existing method of discriminating between days by something based on exact numerical measurement has been somewhat widely felt. A scheme based on what its author, the late Professor Bidlingmaier, of Munich, called 'magnetic activity' seemed to present possibilities, and the International Bureau appointed a sub-committee consisting of Professors van Everdingen and Schmidt, and the writer, to consider it. A discussion of the subject by the writer, based on a comparison of curves from more than twenty observatories, appeared in the journal *Terrestrial Magnetism* for June 1917, along with a similar article by Mr. D. L. Hazard

Another scheme set going by the International Committee relates to the intercomparison of the absolute magnetic instruments of different countries. The scheme was that each of the principal countries should, in succession, undertake the duty of observing at foreign observatories, with a view to finding the difference between its own standard instruments and those of the countries visited. One or two such sets of comparisons have actually been made.

§2. The second agency mentioned above, the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, is in some ways the antithesis of the first. It is not international, its policy is largely that of a single man, the Director, and it has large funds at its disposal. It is thus an institution which does not primarily exist for ventilating opinions, but for getting things done. Hitherto, it has chiefly concentrated on a single problem, the execution of a general magnetic survey of the earth, but there are indications of the development of other lines of activity.

The work of the Carnegie Institution has two aspects which specially call for attention. Its work at sea by the employment of a vessel, the 'Carnegie,' practically free from iron, appears to be so superior in accuracy to that hitherto done by the different Hydrographic Departments as to rather encourage these bodies to leave to the Carnegie Institution the business of obtaining the data necessary for the construction of charts. There is some risk lest the work of the Carnegie Institution be made an excuse for reducing official provision for necessary magnetic work, especially survey work. The other aspect, though perhaps less intrinsically important, seems more pressing. The Carnegie Department of Terrestrial Magnetism naturally aim at a uniform standard in their survey work, and they desire to use not merely their own but all available field observations. To this end they have carried out a large number of comparisons between numerous instruments of their own, and also between their instruments and those of many foreign observatories. They have recently been reducing their results to what they hope may be accepted as an international standard, and this standard has been already adopted at several observatories, including those of the U.S. Coast and Geodetic Survey. But it is important to remember that this standard is a purely American choice, and does not at present embody any formal international agreement. It seems not improbable that magneticians may presently find themselves in a somewhat similar position to that occupied twenty years ago by electricians as regards resistance standards. The increased refinements of late years may enable electrical measurements to be made with an accuracy justifying six significant figures, but I hardly think a 5-figure accuracy—which the so-called international standards seem to postulate—can yet be satisfactorily claimed for absolute magnetic measurements. Until this accuracy can be secured, not occasionally and accidentally, but regularly, no convincing answer can be given to the query whether the indications from a so-called standard instrument are unchangeable from year to year.

The construction of absolute magnetic instruments, giving a 5-figure accuracy, is presumably merely a question of time and expense. In the meantime, we shall probably have to content ourselves with something less. But a good deal might be learned, and a very useful purpose would be served, if a workable scheme could be arranged for the systematic comparison of the instruments in use at the magnetic observatories in the British Isles. It is clear that any international scheme which may come into operation after the war would be much facilitated if each country made itself responsible for the intercomparison of all instruments within its own bounds. A satisfactory comparison of instruments, however, involves considerable time and expense; thus, unless its necessity is generally felt, it is unlikely to be accomplished.

At one time, magnetographs of the Kew pattern were in a considerable majority, and absolute instruments—magnetometers and dip-circles—were largely made in England and verified at Kew Observatory. Also, at one time, a considerable number of foreign, Colonial, and Admiralty observers came for instruction to Kew. All these things tended to uniformity of practice. Circumstances have, however, greatly altered. Large magnets, such as those of the Kew pattern magnetograph—in their day representing a great reduction from the magnets of the Gaussian era—have gone out of fashion, partly for substantial reasons, and partly because

the defects of more recent patterns have had less time to become generally recognised. The lesser cost of the small magnet Eschenhagen magnetograph, and to some extent, doubtless, the greater pushfulness of German makers and magneticians, have led to the adoption of German magnetographs in the majority of the more recent observatories. Again, the tendency has been to replace dip-circles in observatory work by dip-inductors, for which a higher degree of accuracy seems fairly to be claimed, and the great majority of these instruments have been made in Germany. The number of new magnetic instruments wanted in a single year by all the observatories of the world may seem a trifle from the point of view of a large manufacturer. The construction of these instruments is not an industry which promises large financial returns. On the other hand, the country that dominates the market, such as it is, is the one most likely to exert an influence on magnetic development, *i.e.*, to be successful in what is known as 'peaceful penetration.' Thus the position created by the war calls for consideration.

§4. Amongst the questions on which, at one time or another, the International Magnetic Committee has expressed opinions, mention may be made of the time scale and the sensitiveness of magnetographs. A resolution was once passed recommending 15 mm. per hour as the best time scale. Originally the time scale in the Kew magnetograph was three quarters of an inch per hour, but this was reduced to 0·6 inch (15·2 mm.), which is in close agreement with the resolution. All recent Kew-pattern magnetographs have adopted the more contracted time scale, and the same is true of the Watson type magnetographs. A more open scale, 20 mm. per hour, has, however, been generally adopted for the Eschenhagen instruments.

Again, the sensitiveness of 1 mm. = 5γ once received international approval This may have been suggested by the fact that if 1 mm. represent 1′ in the declination magnetograph—a convenient round figure—this represents not far from 5γ at an average European station. Another consideration was probably the risk, when high sensitiveness is adopted, of loss of trace during disturbances. Of late years, however, many observatories using Eschenhagen instruments have adopted a considerably higher sensitiveness These instruments use a wider photographic sheet than the ordinary Kew-pattern magnetograph, and the H magnet carries two mirrors inclined at a small angle. In this way, greater sensitiveness can be secured without increasing the risk of loss of trace.

A common time scale is a great convenience for the comparison of disturbed curves from different stations, and there are also advantages in an approach to uniformity in the sensitiveness Thus both subjects are of importance for international co-operation.

A point, however, that should not be lost sight of, is that the advantages of great sensitiveness are thrown away and may become positive disadvantages at stations in high latitudes which are naturally disturbed, or at stations in temperate latitudes which are exposed to artificial sources of disturbance. In the former case, in the Eschenhagen pattern, confusion ensues from crossing of the traces; in the latter case the attention is distracted by the artificial movements.

§5. There are two questions of considerable importance relating to diurnal inequalities, which invite discussion. It may seem that the five 'quiet' days provide an absolutely common set of data for all observatories.

The ordinary observatory, however, has only one set of magnetographs, and accidents will occasionally happen. There may be loss of the whole or part of the trace of one or more of the five selected days of a month, and there is no general agreement as to the course to be then adopted. The omission of one day represents the absence of 20 per cent. of the material. On the average 'quiet' day at Kew, the n.c. (non-cyclic) change in H in the 24 hours is a rise representing some 10 per cent. of the total range, but it varies much on different 'quiet' days, and has not even an invariable sign. Thus the absence of one or two days from the selected five *may* make an enormous difference in the n.c. change. Then there is the allied question of whether or not to apply an n.c. correction. The theoretical aspect is complicated by the fact that most, if not all, force magnetographs have an instrumental drift. In some it is comparable with the true n.c. change on 'quiet' days, and sometimes it is even larger, especially in vertical force instruments. Everyone will allow that what is a purely instrumental effect should be eliminated, but the difficulty is to say what is instrumental and what is not. The question of how to deal with n.c. changes has an importance which has generally been somewhat imperfectly appreciated.

A second question in connection with diurnal inequalities arises at stations which do not confine themselves to the international 'quiet' days. The natural view to take, especially for a theorist, is that all days should be included in the diurnal inequality. If we take, however, a station like Sitka or Eskdalemuir, when a really big storm comes along it is largely a matter of chance whether the trace remains on the sheet. When the limit of registration is exceeded, the hourly value is quite unknown. Even the rigid moralist in such a case recognises the necessity of omitting the hour, and the average physicist will concede the omission of the whole day. But the omission or inclusion of even one day of very large disturbance may produce a large effect in the diurnal inequality for the month. Recognising this, and also the great uncertainty in measurements made on highly disturbed curves, those brought into intimate contact with magnetographs have usually decided to omit highly disturbed days, and others have gone a great deal farther. Disturbance is immensely greater at some stations than others, and even at a single station, in estimating disturbance, the personal element counts for a great deal. Thus, without some systematised scheme, a common choice of days cannot be hoped for. This would not so much matter if disturbances were absolutely erratic phenomena, exercising no systematic effect on the diurnal inequality. Disturbance, however, influences both the type and the amplitude of the diurnal inequality, and the influence may be much greater in one magnetic element than in another. At stations in high latitudes, a diurnal inequality, based on selected disturbed days, may have double the amplitude of one based on selected 'quiet' days.

§6. Another question of some practical importance may be mentioned. The practice of recording declination (D) and H changes was once nearly, if not absolutely, universal, but there are now at least four observatories (Batavia, Potsdam, Eskdalemuir, and Greenwich) which have departed from this practice, the three former recording changes in two rectangular components. This departure may have a balance of advantages at a very fully-equipped observatory, though that is a matter of opinion, but at the average magnetic observatory it has some very obvious practical disadvantages. A declination magnetograph requires less attention and less

time spent in observations than any force magnetograph. Also no temperature correction is required, and there is no variability in the scale value. The expediency of introducing changes which are unlikely to be generally adopted is not a question on which general agreement is at all likely, but it is perhaps as well the question should be ventilated.

A similar remark applies to a second practice introduced at Potsdam, viz., taking mean values, not for 60 minutes centring at an hour, but for 60 minutes commencing at an hour. There are arguments of some weight for the change, and they would be weightier than they are if there were no such things as drift in instruments or natural n c. changes, which stand in the way of treating the day as an isolated unit. This is a case in which magneticians might exchange ideas with meteorologists, as the problem presents itself in meteorology in a variety of connections.

§7. There are two matters, less obviously of international interest, which call for notice, even in a preliminary report, viz., the relation of magnetic disturbance to Aurora, and the taking of observations in high latitudes. The discovery by Professor Stormer, of Christiania, of a practical method of securing photographs of Aurora and reference stars, and of thus determining auroral heights and positions, has rendered possible a comparison of auroral and magnetic phenomena likely to throw fresh light on magnetic disturbances, and to provide a means of developing and checking theory. If this country is to participate in this promising field of discovery, provision must be made for auroral observations.

Eskdalemuir is, of course, much better situated for such a purpose than any observatory in the South of England or Ireland, but not nearly so well situated as an observatory in the extreme North of Scotland. Some parts of Canada would probably be even more suitable for this purpose.

The other subject is the desirability of securing continuous magnetic records in very high latitudes. The records obtained by Professor Birkeland in the Arctic, and those obtained by recent Antarctic expeditions, show conclusively that these are the regions where really momentous things in terrestrial magnetism have a way of happening. Records from high latitudes may prove a key to many magnetic problems.

Colloid Chemistry and its Industrial Applications.—First Report of the Committee, consisting of Professor F. G. DONNAN (*Chairman*), Professor W. C. McC. LEWIS (*Secretary*), Dr. E. F. ARMSTRONG, *and* Mr. A. S. SHORTER.

INTRODUCTION.

THE Committee was formed with the object of compiling information regarding the advances which have been made in capillary and colloid chemistry with special reference to industrial processes. For this purpose it is essential to take a broad view of the term 'colloid.' The Reports which it is proposed to issue will refer to the more important scientific investigations published in recent years as well as to those possessing a more immediate technical bearing. The Committee has been fortunate in obtaining the collaboration of a number of specialists in various branches of the subject who have undertaken the work of compilation. The advantage of this mode of procedure lies in the fact that the necessary selection and presentation of material has been carried out by those particularly qualified to deal with the various sections concerned. To these gentlemen the Committee would express its deep sense of obligation.

As regards the classification and division of the whole, two methods present themselves: first, a classification according to the nature of the property, principle, or phenomenon concerned, based on the recognised divisions of the science of colloid chemistry, *e.g.*, Coagulation, Viscosity, Adsorption, Peptonisation, &c.; secondly, a classification in terms of the various technical processes themselves, each of which involves in general more than one scientific principle, *e.g.*, the process of Tanning, which includes Adsorption, Coagulation, 'Membrane Equilibria,' &c. Both of these modes of classification have been adopted. This naturally involves a certain amount of overlapping, but it is felt that the disadvantage is not serious. It is hoped that this treatment of the subject-matter will not only be comprehensive, but will serve at the same time to illustrate the close connection which exists between scientific principles and technical practice. At the present time many of the operations in technical colloid chemistry are largely empirical, the scientific basis being unknown or only imperfectly understood. One of the objects which the Committee has had in view is to emphasise the existence of this state of affairs. It is clear that the present position demands a vigorous prosecution of scientific research over the entire range of colloid chemistry.

The marked differences of opinion which exist at the present time in regard to various colloid problems are themselves evidence of the relatively undeveloped state of the subject. As an illustration we might instance the phenomenon of Adsorption. On the one hand, we have the capillary view first stated quantitatively by Gibbs, a view which at the present time occupies a very strong position especially as regards liquid surfaces. On the other hand, we find the capillary idea dropped and the concept of valency beginning to take its place as an explanation of the phenomenon,

more particularly in connection with the condensation of gases upon metallic and other solid surfaces (investigations of Langmuir and others). This is merely illustrative, but it is sufficient to emphasise the point referred to.

A further object of the Committee is to render available as far as is practicable the information on applied colloid chemistry which is believed to exist among chemical technologists at the present time, but which from its possibly unco-ordinated nature is not regarded as suitable for publication through the ordinary channels. It is hoped that those possessing such 'incidental' information, as well as those whose information regarding various special technical colloid problems is of a more systematic nature, will see their way to communicate with the Secretary (Muspratt Laboratory, University of Liverpool), so that the Committee may be able to consider the question of publication of such material as it considers suitable. In the present state of the subject it is felt that more will be gained by co-operation of this kind than by isolated investigation; and further it is believed that much may be made public without detriment to individual interests.

It will be obvious that under the present exceptional conditions the subjoined Report is of a preliminary nature only.

As regards classification according to scientific subject, one subject only, namely, the Viscosity of Colloid Systems, is dealt with. As regards classification according to technical processes and applications generally, the following subjects are treated:—

1. Tanning.
2. Dyeing.
3. Fermentation Industries.
4. Rubber.
5. Starch, Gums, Albumin, Gelatine, and Gluten.
6. Cements.
7. Nitrocellulose Explosives.
8. Celluloid.
9. Physiological and Bio-chemical Subjects.

It is proposed to deal with other branches of colloid chemistry in next year's Report.

VISCOSITY OF COLLOIDS.

By EMIL HATSCHEK, *Sir John Cass Technical Institute, London.*

General Review.

An excellent general survey of the subject as it stood at that time is given by the General Discussion by the Faraday Society in 1913. The most important advance since then is the proof, by v. Smoluchowski, that the electric charge on suspensoid particles contributes to the viscosity of systems containing such particles, and the numerical expression deduced by him for this increase.

The Einstein formula, according to which the increase in viscosity is simply proportional to the aggregate volume of suspended spheres, has again been tested by Humphrey and Hatschek on a suspension of starch grains (average diameter 3μ) in a mixture of carbon tetrachloride and toluene. The increase in viscosity was found to be more than linear for concentrations between 2 and 6 per cent.; in addition, the viscosity

was found to be a function of the rate of shear, and not, as has been tacitly assumed in measurements with the capillary viscometer, independent of it. A similar result for emulsoid sols had been obtained by Hatschek in 1913. The theoretical reasons why Einstein's formula fails, and the general difficulties of a universally applicable formula for systems of two liquid phases, have been fully discussed by v. Smoluchowski.

As regards emulsoid sols, Hatschek's formula has been applied to the calculation of the solvation factors of proteins by Miss Chick, and of rubber in various solvents by Kirchof. The latter's results are of interest, as a comparison is possible between the amounts thus calculated from viscosity measurements and the amounts taken up by the rubber in the preliminary swelling—remarkable agreement exists between the two sets of values. Arrhenius has criticised the figures for proteins, or rather the viscosity formula leading to them, as the hydration factors are much in excess of those found for hydrates of salts in solution. By applying his logarithmic formula to Miss Chick's measurements he obtains hydration factors of the same order as those of electrolytes. Hatschek has, however, shown that the application of Arrhenius's formula to sols in organic solvents (rubber and nitrocellulose) leads to factors which sometimes are negative, and thus without any physical meaning, and sometimes positive, but many times larger than those to which Arrhenius takes exception.

The great importance of viscosity measurements as the most delicate means of tracing slight changes in colloidal solutions is fully recognised, but in the present state of theory all that can be deduced from such measurements is that some change has taken place, the nature of which is either a matter for speculation or for empirical interpretation. As the latter is sufficient in many instances, viscometric methods appear to find increasing use in fields as widely different as the industries of rubber and nitrocellulose on one hand, and physiology and pathology on the other. There is also a fairly general and gratifying tendency towards the use of correctly designed capillary viscometers, instead of the grossly incorrect types used for other industrial purposes.

Further decided progress must depend on the development of theory, which, considering the great inherent difficulties of mathematical treatment and the incompleteness of our knowledge of even simple liquids and binary mixtures, cannot be expected to be rapid, and also on the much extended use of methods of measurements permitting variation of the rate of shear within wider limits than have so far been attained.

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COLLOID CHEMISTRY OF TANNING.

By Professor H. R. PROCTER, *University of Leeds.*

*General Review.**

The conversion of skin into leather is an art dating back many thousand years, and the group of phenomena now classed as capillary or colloid has also been long known, though the relation of the two is a matter of modern knowledge. Under these circumstances it is difficult to know where to begin the discussion, and the question is further complicated by the work of the present writer and his pupils, who have recently shown that much which has been attributed to the surface-action which is implied in the name 'capillary chemistry' is really subject to more general laws, and can be fully explained by mass action, electro-chemical attraction, and osmotic pressure. The title must therefore be taken, with a wider meaning than its etymology would imply, to include much of physical chemistry, complicated, however, by structure and the special properties of colloids.

The skin is constituted of collagen (probably a polymerised anhydride

* Among the abbreviations employed in this Section are the following:—*Coll.* = *Collegium*; *J.A.L.C.A.* = *Journ. of the American Leather Chemists' Association*; *L. Coll.* = *London Collegium*, Jan. 1915 to June 1917; *T.C.S.* = *Transactions of Chemical Society* (*London*).

of gelatine) and physically is a network of fibres of colloidal jelly. In its natural state it has an outer coat of epidermis, with its hair and sebaceous and sudoriferous glands, but it is not necessary in this Report to consider in detail the chemical, mechanical, and bacteriological processes which are used to free it from these appendages or to separate its fibre-bundles into their smaller constituent fibres. These gelatinous fibres in the dried raw hide adhere together to form an almost homogeneous horny mass, and the problem of the tanner is so to treat them, either by chemical change or by surface-coating, as to prevent their adhesion, so that on drying they remain isolated and free to move, and the skin consequently flexible and porous, and at the same time without tendency to putrefactive change. While the durability of wet raw hide is measured in days or weeks, Roman boots have been dug up which are hardly in worse condition than those which the tramp leaves, worn out, at the roadside. The methods employed by the tanner, though very similar in their effects, are so various that no single explanation, physical or chemical, will cover all of them; and often various actions are combined to produce the desired result.

The first general problem, then, regards the nature of the jelly state, which has many peculiarities. Van Bemmelen [1] and Butschli [2] believed it to be a network or cellular structure of microscopic dimensions, and this view long held the field, but is now abandoned for that which regards it as a solid or semi-solid solution of which the colloid and water (or some other solvent) are the constituents. The question is still an open one whether the colloid is in the form of 'micellæ' (submicroscopic particles) or of large conjugated or polymerised molecules, but this is mainly a matter of terms, and at least it is clear that the mixture is so intimate that both constituents are within the range of molecular and electro-chemical forces.

The colloid most fully investigated in this relation is gelatine, which in its chemical constitution is almost identical with hide fibre, while its homogeneous character renders exact quantitative study much more possible. Soaked in water at laboratory temperature, it does not dissolve, but swells to a definite volume dependent to some extent on the particular sample and the temperature. When the temperature is raised above 25°, the jelly melts and becomes miscible in water in all proportions, though even when diluted considerably beyond its original equilibrium volume, it still 'sets' on cooling to a coherent elastic mass. Gelatine, both as jelly and solution, always shows a slight Tyndall effect, reflecting a beam of light sideways; but the ultramicroscope shows no defined particles. Arisz [3] has shown that the Tyndall effect increases with concentration and with lowered temperature, but without any break or sudden change at the setting point. The viscosity shows a similar increase, with no actual break, but a rapid rise at the temperature of gelatinisation, below which it speedily becomes too great to measure by ordinary methods. Both these effects are reversed on gradual heating, but there is a 'lag' in both directions, a cooling solution only acquiring its full viscosity and

[1] *Z. Anorg. Chem.*, 1896, **13**, 304; **18**, 15.

[2] *Untersuchungen über mikroskopische Schaume und das Protoplasma*, Leipzig, 1892. *Verh. des naturh.-med. Vereins zu Heidelberg*, 1892, N.F. **5**, 28-41; *ibid.*, 42-43; *ibid.*, 1893, 89-102; *ibid.*, 1896, 457-472; *ibid.*, 1894, 230-292.

[3] *Kolloidchem. Beihefte*, 1915, **7**, 22.

Tyndall effect after the lapse of considerable time, which may even extend to weeks, but below 60°, given time, the process seems completely reversible. Above 60°–70° some permanent change takes place (hydrolysis or depolymerisation) which results in lowered viscosity, Tyndall effect, and setting power. These facts are best explained by the hypothesis that below 60° the gelatine solution is one of molecules or small molecular aggregates, which, as temperature falls, gradually unite to form larger ones, and at the setting point unite to a complete molecular network analogous to a mass of tenuous crystals. Cases are known in which such crystalline masses closely simulate colloid jellies. Time is of course needed for this rearrangement, as it is for actual crystallisation, and owing to the size and comparative immobility of the particles, rearrangement is very slow. Kundt [4] has shown that under the influence of rapid flow at 18° (which is below the setting point) even very dilute and quite liquid solutions of gelatine show the polarisation effects of strain, while no such effect could be observed with glycerine or sugar solutions of much higher viscosity. The writer proposes to repeat these experiments at higher temperatures, but in the meantime it is clear that the viscosity of such solutions is not due simply to liquid friction, but includes an element of strain.

Proteids, among which gelatine must be included, are now known to consist of open or closed chains of amino acids, linked by the carboxyl group of one to the amino group of the next with elimination of OH_2. In closed chains, groups within a single molecule, forming terminal amino and carboxyl groups are also similarly united ring-structures. In this case the molecule is electrically neutral, and non-reactive till the ring is broken, while the open chains are amphoteric—basic by their terminal amino group and acid by their carboxyl. A very useful practical distinction is that ring proteids are unattacked by trypsin alone, while pepsin is able to open the ring.[5] Gelatine can be digested by trypsin, but collagen is only attacked by pepsin, hence the view, supported by other facts, that collagen is the ring or anhydride form of gelatine into which it is converted by continued boiling or by the action of acids or alkalies.

If gelatine (or hide fibre) be placed in dilute acid, it swells very much more than in water alone, and at the same time a considerable amount of free acid disappears (*i.e.*, is no longer capable of reddening methyl orange). The effect is most readily investigated with a strong monobasic acid such as hydrochloric acid. In this case the maximum swelling, which may reach an absorption of 50 c.c. of liquid for 1 grm. of dry gelatine, occurs at an acid concentration under 0.005 N, from which it rapidly falls in a curve of hyperbolic type as the concentration is increased, the equilibrium being completely reversible up to about 0.25 N, beyond which some secondary reaction, probably a further breaking up of the proteid chain, begins to take place. At the same time the total absorption of acid steadily increases with concentration in a curve which may be closely represented by the ordinary adsorption formula, $a=kx^{\frac{1}{p}}$ (where a is total acid, x the concentration of external solution, and k and p are

[4] *Wied. Ann.*, 1881, **13**, 110.

[5] Plimmer, *Chemical Constitution of the Proteids*, Part II p. 11 (Sec. Ed., Longmans, Green, & Co.). The statement seems to require confirmation.

constants); but which is really due to a complicated osmotic equilibrium which must be further explained.[6]

Gelatine, being amphoteric, acts as a very weak alkali in presence of hydrochloric acid, and forms a gelatine chloride, which like most salts is highly ionised (in fact to practically the same extent as hydrochloric acid itself). The base, however, is *very* weak, its ionisation being of the same order as that of water, and consequently the salt is largely hydrolysed, and can only exist in the presence of free acid. Thus gelatine base, gelatine chloride, and free hydrochloric acid are necessarily present in such a jelly in proportions determined by the concentration of the acid, and instead of a definite point of neutrality such as is given by a strong base, we have only a curve approaching, but never reaching, complete neutralisation. This is the explanation of the apparent indefiniteness of proteid compounds, which has led many chemists to deny the existence of definite proteid salts. By determining the hydrolysis curve and calculating the upper limit to which it tends, it is possible to calculate quite definite combining equivalents. Procter [7] in this way, on the assumption that gelatine had a second valency negligible at low acid concentrations, found a combining weight of 839, while Wilson,[8] from the same experiments, but regarding the apparent second valency as due to incipient decomposition or experimental error, found 768. It is not to be supposed, however, that these comparatively low weights represent the real complexity of the probably polymerised molecule in aqueous solution, but merely the smallest molecular division chemically possible.

It has been stated that the swelling of gelatine in acids is due to a complicated osmotic equilibrium, and that it reaches a maximum at a very small acid concentration, and is repressed if the concentration is increased A similar repression is caused by the addition of any salt with the same anion to the outer solution, and as neutral salts have no decomposing effect on gelatine, the repression can be carried much further than with acid; thus a chloride jelly treated with sodium or potassium chloride is reduced to a horny mass. Seeing that the jelly is almost as permeable as water both to ionised and unionised salts and acids, it is hard to see how this repressive osmotic pressure is exerted. The following is the explanation:—

In equilibrium between a jelly and its external solution not only must all osmotic pressures be equally balanced, but, as has been shown by Donnan,[9] the electro-chemical condition must be fulfilled that the *products* of the concentrations of any pair of diffusible anions and cations common to both phases must be equal. Thus with gelatine chloride and free acid the chloridions multiplied by the hydrions must be equal in the jelly and the external acid. On the other hand, the osmotic pressures depend not on the *products* but simply on the *sum*

[6] It may be well to point out here that the 'adsorption formula' just quoted is absolutely void of theoretical basis, as regards adsorption, but is a mathematical expression which will closely represent any chemical or physical phenomenon which proceeds at a diminishing ratio. It is, for instance, the exact law of distribution of a solute between two immiscible solvents, in one of which its molecular complexity is p times that in the other.

[7] *T.C.S.*, 1914, **105**, 320.

[8] *J.A.L.C.A.*, 1917, **12**, 108,

[9] *Zeits. Elektrochem*, 1911, **17**, 572; Donnan and Harris, *T.C.S.*, 1911, **99**, 1575.

of diffusible particles present. In the external acid the numbers of hydrions and chloridions are obviously equal, while in the jelly the chloridion of the gelatine chloride is added to the equal hydrion and chloridion concentrations of the free acid present, thus making the final concentrations of these ions in the jelly unequal. Now, as the sum of two unequal factors is always greater than that of two equals giving the same product, or, geometrically the perimeter of a square is always less than that of any other rectangle of equal area, and as the sides represent the osmotic pressure, while the area represents the product, it is clear that the two equalities cannot at once be completely fulfilled, but in electro-chemical equilibrium the osmotic pressure must be in excess and the jelly must tend to swell unlimitedly and finally to dissolve. That it does not do so is a consequence of its colloid nature, which depends on cohesive attractions drawing the colloid particles together to polymerised masses or to a continuous network, and which consequently opposes swelling and solution, while the diffusible ions are held to the colloid ions by electro-chemical attractions, and, as they cannot escape from the jelly, tend to drag it apart and dilute it by absorption of the external acid, from which they expel a part of its acid concentration. The equilibrium is therefore a very complex one, but finally depends on the excess of internal osmotic pressure being balanced against the internal attraction or cohesion of the colloid particles, both ions and molecules. For its mathematical discussion the reader must be referred to original papers by Procter and his pupils. It will, however, be obvious that as the external solution becomes more concentrated the proportion of absorbed acid (or salt) is increased, while that of gelatine chloride is limited to the quantity of gelatine present. The difference of concentration of hydrion and chloridion in the jelly is therefore diminished, and it contracts under the influence of its own internal attractions. Precisely similar considerations apply to the action of alkalies on gelatine. Ionisable salts are formed by combination of the base with the carboxyl group of the proteid, and the osmotic equilibrium is with the cation and OH instead of with the anion and H. Neutral gelatine, as an amphoteric body, of course ionises to a limited extent with water alone, and its dissociation constants are of the same order of quantity as those of the water with which it is in equilibrium. It is, however, slightly stronger as a base than as an acid, and consequently its neutral point of minimum swelling is slightly on the alkaline side. This has important bearings on manufacturing practice, the greatest flaccidity of the raw skin, which is required for the softest leather, being obtained in weakly alkaline liquids.

It has been pointed out by Donnan [10] that in consequence of the unequal distribution of positive and negative diffusible ions which has just been described, the surface of an acid or alkaline jelly in equilibrium has necessarily an electrical charge or potential, greatest at the maximum swelling, and such charges seem an essential condition of the colloid state. The surface is positive or negative according to whether the diffusible anion or cation is retained in the colloid. Thus gelatine and hide fibre are negative in alkaline and positive in acid solutions, and it will be shown later that this has an important bearing on the theory of leather manufacture.[11]

[10] *Zeits. Elektrochem.*, 1911, **17**, 579.
[11] See below and Papers under 13.

Wilson[12] has extended these facts to a general theory of colloids and adsorption, showing that all surfaces must possess a potential due to unbalanced chemical forces on the surface, and therefore in a liquid containing electrolytes must condense ions or particles of the one sign on its surface, and repel those of the opposite sign; and also showing that surfaces must therefore be surrounded with a film of liquid of different concentration to the bulk, to which the same considerations and equations are applicable as to the absorbed solution of colloid jellies. For fuller mathematical treatment the reader is referred to original papers.

Some of the views just explained are so recent that their bearing on actual tanning processes has hardly had time to make itself felt in technical literature, and for its latest applications Papers by Procter and Wilson must be consulted,[13] but a brief summary may here be given.

As has been explained, the leather-hide, freed from epidermis, consists of a sort of felt of fibres of gelatigenous tissue, which are themselves bundles of finer fibrils cemented together by some substance nearly identical with, but somewhat more soluble than that of the fibrils themselves. Treated with dilute alkalies or acids, this cementing substance is more or less completely dissolved, and the fibrils themselves are swollen. Accurate chemical investigation of skin is complicated by this fact of structure, for while the free acid or alkali absorbed in the jelly of the fibre is subject to the mathematical laws which have been explained, the interstices between the fibres are also filled with external solution by capillarity, and no accurate means has been found of measuring the proportion between the two. Hide swollen in acid or alkali is tense and firm, and containing its liquid in jelly-form in the fibres only parts with it under heavy pressure; but when the fibres are dehydrated by neutralisation, the skin becomes 'fallen' or flaccid, and apparently much wetter, since the imbibed water is easily squeezed out. If in this condition the loose water is removed by soaking in alcohol or other dehydrating agents, the fibrils no longer adhere to each other, and a soft leather is produced, which, however, on again soaking in water, rapidly returns to its raw or 'pelt' condition.[14] If, however, a little stearic acid is dissolved in the alcohol so as to coat and partially waterproof the dehydrated fibrils, the leather at once becomes tolerably permanent. This led Knapp to the view that the process of tanning was merely an isolating and coating of the fibrils, and, though the explanation is incomplete, it unquestionably is part of the true one.

In order to make a soft leather, it is therefore necessary to have the skin in a flaccid or unswollen condition, and, assuming that it has been swollen by lime, this is brought about essentially by neutralisation. The older processes depend on fermentations of bran, pigeon and dog dung, and the like, and just as liming serves the several purposes of swelling the hide, loosening the hair, and partially saponifying the fat, so these fermentation processes not merely neutralise the lime by weak acid, or salts of weak bases, but remove cementing substance

[12] *Jour. Am. Chem. Soc.*, 1916, **38**, 1982.

[13] Procter, *Koll. Beihefte*, 1911, **2**, 270; *T.C.S.*, 1914, **105**, 313; and Wilson, *T.C.S.*, 1916, **109**, 307; 'Swelling of Colloid Jellies,' *J.A.L.C.A.*, 1916, **11**, 399; and Burton, D., 'The Swelling of Gelatinous Tissues,' *J.S.C.I.*, 1916, **35**, 404.

[14] Knapp, *Natur und Wesen der Gerberei*, Braunschweig, 1888; Meunier and Seyewetz, *Coll.*, 1912, **11**, 54.

from the fibres by the digestive effects of bacterial enzymes, and complete the emulsification of fats and the solution of residues of the epidermis. It is obvious that the attainment of all these varied results by an artificial preparation is no easy matter, but an approach to a complete solution has been made by J. T. Wood [15] (followed by Dr. Rohm, who has improved working details), by a mixture of ammonium chloride and pancreatic digestive ferments, which for many purposes fulfils its object better and much more safely than the old materials. The tryptic ferments dissolve the epidermis residues and cement-substance, but scarcely affect the collagen fibres (v.s.). They also facilitate emulsification of fats by reducing the surface tension between jelly matters and the liquid, while the presence of free ammonia and excess ammonium salts regulates the hydroxyl concentration to something near the alkalinity required for minimum swelling (v.s.). Possible improvement lies in the direction of the discovery of new enzymes, and of suitable weak bases and 'buffer' substances, to give the precise degree of solution and of acidity or alkalinity required for the various leathers. For firmer leathers the use of weak acids regulated by excess of their salts produces a sufficient degree of neutralisation and flaccidity.

We must now consider the conversion of the still raw and very putrescible skin into permanent leather. We have seen that this can be accomplished by dehydrating the fibrils without allowing them to adhere (v.s.), and by coating them with water-resisting substances; but it is known that similar effects of an even more permanent character can be produced by reagents (notably formaldehyde and bromine) which act chemically on the collagen fibre rendering it insoluble in water, but which in their nature cannot deposit any exterior coating such as was assumed by Knapp. We must therefore conceive the process as being in most cases a combination of both chemical and physical effects, of which sometimes one, sometimes the other, preponderates, according to the method employed. We have also to consider reactions which from their colloid character differ somewhat widely from those of free ions to which the term 'chemical' is generally applied. It is therefore best to proceed from simple cases of which definite explanation can be given, to the complex in which more than one sort of reaction takes place.

Knapp's alcohol leather, in which a material is produced with all the physical characteristics of a complete leather by simple dehydration of the hide fibres under conditions preventing adherence, has been already mentioned (v.s.). The theory of acid swelling has also been described, and it has been shown that as the anion concentration of the external solution is increased the difference of osmotic pressure between it and the jelly which causes swelling is diminished without limit, and the fibre contracts by its internal attractions. This fact is applied in the process of 'pickling' which is principally employed in the preservation of sheepskins before tanning. The skins, after unwooling, are treated in a bath of dilute acid, generally sulphuric, to which some salt is added to prevent excessive swelling, and are then transferred to a saturated solution of common salt. The dehydration of the fibre is very great—the skin becomes thin and flat, and can be preserved almost unlimitedly in the wet condition; and if dried out and loosened by a little mechanical

[15] Wood, *Puering, Baiting and Drenching*, Spon, 1912, p. 186.

stretching, forms a very perfect white leather, which, however, softens and swells at once in water through the removal of the restraining salt. It is not essential that the acid should be a 'strong' one. Skins pickled with formic acid and salt by Mr. Seymour-Jones were sent on a voyage up the Amazon, and returned in perfect condition. It is obvious that if a skin swollen with some acid other than hydrochloric be subsequently treated with salt, a quadruple equilibrium results, most of the proteid salt being converted into chloride by the great excess of sodium chloride, with the formation of the sodium salt of its acid, each proteid salt being balanced against its own anion in the external solution. In a direct experiment with gelatine formate almost the whole of the formic acid was replaced by hydrochloric. It is probable that the so-called 'free' hydrochloric acid in the gastric juice has been liberated in this way, and really exists as a salt of some weak colloid base.

In the ordinary processes of production of 'alumed leathers' it is impossible to work without considerable addition of salt, and the process is largely a pickling one, the hydrolysed acid of the aluminium salt combining with the skin and leaving a basic salt which is also absorbed, the quantitative relation between the two independent actions depending on the relative concentrations. If, instead of alum or normal aluminium sulphate, a basic alumina solution is used, salt can be reduced or dispensed with, and the tanning action depends less on pickling and more on the fixation of alumina. What has been said about alumina tannage applies with little variation to tannage with chrome and iron salts.

As regards the fixation of alumina and chrome, there is little doubt that in the first instance it takes place in the form of basic insoluble salts and is largely physical. The more basic a solution of these metals and the more readily and completely it is precipitated by the withdrawal of a further portion of acid, the more heavily it tans. If we imagine a normal salt to diffuse into the skin, and its acid to combine with the amino group of the proteid, then the remaining insoluble basic salt must remain precipitated in and on the hide fibre. Whether this is the final stage may be doubtful—Wilson, in a recent Paper on 'Theories of Leather Chemistry,'[16] suggests that ultimate combination takes place with the carboxyl group, and this view seems well in accordance with known facts. A. L. Lumière[17] has shown that the maximum amounts of chrome and alumina which can be fixed by gelatine accord well with this view; and Wilson points out that if, as he supposes, the ultimate gelatine molecule is monacid and monobasic, a divalent ion such as $Ca^{\cdot\cdot}$, joined to two gelatine molecules, should exert only the same osmotic pressure as the monovalent $Na^{\cdot}$, and hence its swelling effect should be much less as is known to be the case; while the trivalent $Al^{\cdot\cdot\cdot}$ or $Cr^{\cdot\cdot\cdot}$ should swell still less and be yet more easily repressed; and that therefore chrome or alumina gelatinates, if they exist, should be very stable and insoluble compounds. It is well known in practice that change in the direction of stability gradually takes place on storing or 'ageing' alumed leather, and probably the same is true of chrome, though not so easily demonstrated.

Vegetable tannage appears to be of a more colloidal or physical character than that with alum or chrome. Tannins, like the proteids, appear

[16] *J.A.L.C.A.*, 1917, **12**, 108.
[17] *Brit. Jour. Phot.*, 1906, **53**, 573, Abst., *J.S.C.I.*, 1906, **25**, 770.

to form colloidal, rather than true ionic solutions, and the particles are negatively charged, going to the anode in electrophoresis. Whether the change is due to ionisation or to the fixation of an electrolyte ion is immaterial for our purpose. The gelatinous fibres, as we have seen, take a positive charge in acid, and a negative one in alkaline solutions (v.s.). Hence in faintly acid solution, which produces the strongest positive charge, they attract and precipitate the tannin particles, while in alkaline solution no tannage takes place, and in those too strongly acid, the tannins themselves are precipitated.[18] In fact, such colloid precipitations due to electric charges do not seem to differ in principle from ionic reactions, though owing to the varying size of the particles and of their charges they are less definite and quantitative. Whether ultimately any closer combination with the fibre ensues, as is suggested in the case of mineral tannages, remains for the present uncertain, but in long-continued tannage there is a further deposition of difficultly soluble matters on and between the fibres by forces generally called 'adsorption.' We may thus divide vegetable tannage into two stages, in the first of which the tannins combine electrically or chemically with the fibre and render it insoluble, and in the second matters are deposited upon it which add to the weight and solidity of the leather; but of course the two stages overlap in time, and the different qualities of leather produced by different tannages are largely due to their relative proportion, and the amount of precipitable matter which the tanning materials contain. It does not appear that the same affinities are saturated in mineral and vegetable tannages—chromed leather will fix as much vegetable tannage as raw hide, and *vice versa*; and corresponding differences occur in their behaviour to dyestuffs.

Besides the mineral and vegetable leathers there is a third class which demands consideration. If raw skins are fulled with oxidisable oils, their water is gradually expelled and replaced by the oil, and if the skins are now allowed to oxidise (which they do with considerable liberation of heat and of acryl aldehyde and other volatile products), and are then freed from unfixed oil by pressing and subsequent washing with alkaline solutions, such leathers as 'chamois,' 'wash-leather,' 'buckskin,' and 'buff-leather' are the result. Oil leathers, like chrome leathers, are very resistant to hot water, and also to hot soap or alkaline solutions, and may even be shrunk or 'tucked' to increase their thickness and solidity by dipping in these liquids at boiling temperature. Their resistance to hot alkaline solutions, in which all oxidised oil products are soluble, proves that something more has occurred than a mere coating of the fibres with oils, but a full explanation has not yet been given. Since aldehydes are known to produce insoluble conjugated products with hide fibre, the explanation that acryl aldehyde (derived from the glycerine by dehydration) was the active agent was a plausible one, but is negatived by the recent knowledge that equally good leathers can be made with the free fatty acids alone. This, however, does not altogether disprove the aldehyde theory, since the unsaturated oils which alone will chamois are apt on oxidation to break at a double linkage with the production of higher aldehydes. Another possibility is that these oils, which are more or less colloid, form emulsions of which

[18] *T.C.S.*, 1916, 109, 1329.

the particles are electrically charged, and which combine with the fibre in the same way as the tannin particles may be supposed to do, though probably with an opposite charge (v.s.).

The oil squeezed out and known as *moellon* or *dégras* is a natural emulsion, and finds wide use in leather-dressing for the 'stuffing' of light leathers. This stuffing, the primary object of which is to lubricate the fibres and make the leather supple and water-resisting, may in many cases be also regarded as a supplementary and partial oil-tannage. The fats are applied to the moist leather either by hand as a pasty mixture of oils and harder fats, or in a melted state in a heated rotating drum. In the first method the main effect of the harder fats is to retain the mixture on the surface until the oils are absorbed. The water in the leather lowers the surface tension between oil and leather at the interface, and as the water dries out the oil replaces it by capillarity, leaving the harder fats outside. The surface tension of the various fats with regard to water and their consequent easy emulsification is thus of great practical importance.

A third way of applying fatty matters to leather much used for chrome and other light leathers, and called 'fat liquoring,' consists in drumming the skins with a prepared emulsion, which at first was the alkaline liquor from the washing of oil-leathers, but is now usually an artificial mixture of oils and soaps, though occasionally acid emulsions are employed. It has been found that sulphonated oils, especially castor and fish oils, have extraordinary emulsifying powers even on hydrocarbon oils, and the writer has examined a commercial product containing 80 per cent. of mineral oil, which yet was perfectly and spontaneously emulsifiable when poured into water. The question of surface tension at interfaces and against solid surfaces is one of much technical importance, and probably its effect on adsorption is greater than that of the Willard Gibbs law that 'substances which lower surface tension accumulate on that surface.' The action of protective colloids on metallic sols has been explained as due to the fact that the surface tension of the medium at the metallic surface is greater than the sum of the tensions of the medium and the metal with regard to the protective colloid, which therefore spreads in a thin film between them. This coating of the metal by the colloid is of course an adsorption; and a similar action may account for many cases of the latter which are called 'anomalous,' that is, to which the Willard Gibbs law does not apply.

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GENERAL REVIEW AND BIBLIOGRAPHY OF DYEING.

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The Present State of Development of the Theory of Dyeing, with special reference to colloidal and electrical hypotheses and phenomena leading thereto.

In the present stage of the evolution of an adequate theory to explain the phenomena of the dyeing process, four somewhat conflicting theories prevail:—

The mechanical or physical theory,
The chemical theory,
The colloid-diffusion and adsorption theory,
The electrical theory.

The two former were long the cause of energetic discussion between their respective upholders, the two latter have been developed since the beginning of the present century, and are to be looked upon, less as parallel theories to the first two, than as more scientific attempts to supplement and correlate, in the light of later physico-chemical discoveries, the phenomena observed and partially explained by the older theorists.

The upholders of the mechanical theory[1] looked upon it merely as an adsorption phenomenon, of the dyestuff particles in the fibre; the second group took for granted a chemical combination between fibre and dye. The holders of the first view based themselves primarily on the analogy which subsists between dyeing and the absorption of dyes by animal charcoal. More modern investigations by Justin-Mueller, however, indicate that pure carbon absorbs only very little dyestuff. The decolourising effect of charcoal is connected with the presence of organic nitrogenous compounds, which are produced by the combustion of protein substances. The upholders of the chemical theory of dyeing, which may be described as the salt-formation theory, base their views upon the fact that the fibres, especially wool and silk, which by hydrolysis give amino-acids, contain salt-forming groups and produce actual salts with the dyestuffs, which, as is well known, contain acid and basic groups.

At present the most prominent upholder of the purely mechanical

[1] P. Sisley, 'Augenblicklicher Stand unserer Kenntnisse über die Theorie der Farbung,' *Chem. Zeit.* 1913, 1357, 1379.

theory is G. von Georgievics.[2] He has a long line of predecessors, from the earliest dyeing theorists of the first half of the 18th century, Hellot[3] Dufay,[4] Macquer,[5] and Le Pileur d'Apligny.[6] down to Walter Crum,[7] Persoz, Engel, and Napier. He rejects categorically the theory of chemical combination between dye and fibre in the case of wool, on the grounds that such indifferent substances as glass beads, kaolin, and various other inorganic substances may be dyed in exactly the same way. He objects in details to O. Witt's theory of 'solid solution' (of the dyestuff solute in the fibre solvent) by combating each of Witt's statements from experiments of his own His theory of the dyeing process is that the dye particles are in a state of adhesion on and in the fibre, and neither of solution nor chemical combination; the same he considers to be true of the various mordants. But this 'adhesion' is, he says, analogous to capillary attraction, to the adhesion of solute to solvent, and to that exerted, for example, by glass on a liquid which 'wets' it, and such forces as these, he admits, lie on the borderline between chemical and physical forces. A very similar conclusion had been drawn before by H. v. Perger,[8] L. Hwass,[9] and G Spohn.[10]

Georgievics admits that basic dyestuffs when dissolved in water are dissociated, and that if the base has an attraction for a substance, a coloured body will be formed when the two are brought together. As evidence for the physical and against the chemical nature of dyeing, he relies chiefly on various forms of Henry's law of distribution.

He states from his experiments that in the majority of cases dyeing takes place according to the equation

$$\frac{\sqrt[x]{C_f}}{Cw} = \text{constant},$$

in which C_f denotes the colour taken up by the fibre, Cw that left in the bath and x indicates the affinity of the colouring-matter for the fibre. In some later experiments[11] with indigo extract and picric acid on wool and methylene blue on mercerised cotton, he states that dyeing proceeds according to the equation

$$\frac{\sqrt[x]{\text{C dyebath}}}{\text{C fibre}} = \text{K}$$

where x may be equal to one or greater than one and its value depends upon the temperature and additions to the bath. The rule only holds within certain limits of concentration of the dyebath, comparatively more colour being taken up from dilute than from concentrated baths.

[2] *Mitteilungen des K.K. Gewerbemuseums in Wien*, pp. 165, 205, 349 (1904), p. 345 (1905). See also *Journ. Soc. Dyers and Col.* 1895, pp. 79 and 121.

[3] 1734, *L'art de la teinture des laines et des étoffes de laine.*

[4] 1737, *Traité sur la Teinture, observations physiques sur le mélange de quelques couleurs à la teinture.*

[5] 1763, *L'art de la teinture de la soie.*

[6] 1776, *L'art de la teinture des fils et étoffes de coton.*

[7] 1843, *Journ. Chem. Soc.* 16, 1, p. 404.

[8] 'Einige Farbersuche,' in *Farbenzeitung*, 1890–1.

[9] *Farbenzeitung*, 1890, pp. 221, 243.

[10] Essay, 'Zur Erkenntnis des Farbevorganges' in *Dinglers' Polytech. Jour.* 1893

[11] *Journ. Soc. Dyers and Col.* 1904, p. 105.

From his experiments Georgievics considers he has proved beyond doubt that the dyeing process takes place according to a definite physical law in the case of acid colours on animal fibres and salt colours on cotton. He uses Henry's law very indiscriminately and alters it to fit his figures.

The earliest mechanical theorists had been content with the theory that the dye particles from the solution wandered by endosmosis into the 'pores' of the fibres and were there fixed by the formation of an insoluble 'lake' with the mordant. This being done in a hot bath, the contraction of the pores on cooling, aided by a possible astringent action of the various mordants, held the dye particles fast. The first investigator to suggest adhesion of dye particles to the surface of the fibre was Macquer[12] in 1768, followed by Berthollet,[13] Thomas Henry,[14] Bancroft,[15] and finally Walter Crum,[16] the greatest of von Georgievics' predecessors, who defined this (purely physical) adhesion as 'catalytic force' and insisted on the analogy between the dyeing process and the absorption of gases, salts dissolved in liquids and colouring matters, in an unchanged form, by wood-charcoal and bone-black. Crum also points out the capillary attractive force of fibres, in common with other porous bodies. So well reasoned were his theories that the upholders of the then extremely vague and nebulous chemical theory felt themselves impelled to greater clarity and more logical statement of their point of view.

The title of 'first chemical theorist' is given to Bergmann,[17] who, in an essay on indigo, suggests that the wool extracts the whole of the indigotine disulphonic acid from the bath because it has a greater 'affinity for it than the latter. This vague 'affinity' satisfied Berthollet, Henry, and Chaptal, but it was left to Chevreul,[18] the head of the Gobelin Dye-works in Paris, to speak the first clear words on the nature of this 'affinity' in his 'Mémoire' of the year 1834. He divides dyes into chemical compounds, simple mixtures and substances that partake of the nature of both. Then, investigating those dyeing processes which appear to lead to chemical combinations, he says. 'Chemical combination is analogous to salt formation,' but the combinations between fibre and dyestuff are looser and evolve less heat than is observed in the case of acid reacting with base, and the combining proportions are not always constant. In dyeing, moreover, he recognises a 'contact-effect,' adhesion, which he places in a position next to affinity in importance, and calls 'capillary-affinity'; his conclusion is that there are molecular forces at work between bodies in contact, which slowly combine. Dyeing will not take place unless there is a greater affinity between the fibre and the dye than between the dye and its solvent, and in judging of the probable result it is necessary to take into consideration the water, with dissolved acids, bases, or salts; dyestuff; fabric, and one or more mordants of more or less complex character. That one fibre dyes better than another in the same bath he explains by the principle of 'elective affinity,' which at that time so greatly exercised the minds of the students of the infant science of chemistry.

[12] *Dictionnaire de Chemie*, article 'Teinture.'
[13] 1791, 1804, *Éléments de l'Art de la Teinture.*
[14] 1790, *Nature of Colouring Matters.*
[15] 1794, 1813, *Philosophy of Permanent Colours.*
[16] *loc. cit.*
[17] 1776, *Mémoires des Savants Étrangers*, t. 9.
[18] *Mémoires de l'Académie des Sciences*, 1853, 1861. *Cours de Chemie appliquée à la Teinture*, 2me partie, 1838–1864.

Chevreul deserves honour not only for the pioneer quality of his statements, but also for the detailed tabular accounts of his experiments, which gave a stimulus to other investigators.

He was quickly followed by F. F. Runge[19] who confines his researches to cotton, discussing first the 'combat' between the water of the bath and the fibre for possession of the dye, and thus explaining the decrease in rapidity of deposition as the bath nears exhaustion. Mordants he conceives to be substances which eagerly combine (enter into) the fabric to form a substance that in its turn combines with the dye.

Persoz[20] postulates an attraction between the fibre and dye particles analogous to inter-molecular forces, but does not suggest true chemical combination between dyes and fibre. In 1856 F. Kuhlmann drew attention to the nitrogenous nature ('azoted fibres') of the fibres which readily absorb dye, experimenting with pyroxylin and cotton. He suggests that the part played by capillarity and adhesion in dyeing is subordinate if important, and also makes the remark that 'a chemical change which results in a change of dyeing-capacity may often be a mere re-grouping of molecules.' J. B. Schlossberger[21] follows with a little more leaning towards the physical theory. P. A. Bolley[22] reverts, after very careful research with the microscope into the place and nature of the deposition of the dye on the fabric, to the physical theory, finding that the deposition is only on the surface with silk and cotton, though partly within the wool fibre. His experiments finally lead to the conclusion that the absorption of the dye, with or without mordant, is a surface phenomenon entirely analogous to adsorption of charcoal, and that the use of the mordant is merely to form lakes. But the discovery of aniline colours in 1856 by Perkin, and the rapid spread of inquiry into their nature and application, emphasised the trend of opinion in favour of the chemists. Schutzberger[23] pointed out that in the dyeing of wool with aniline colours there was necessarily chemical action, usually between dyestuff and mordant, but does not suggest that the fibre in any way enters into the reaction; he looks on fibres as porous bodies, carriers of the dye. Again the physicists prevailed, until E. J. Mills[24] reported experiments in the dyeing of silk red from a colourless rosaniline solution, which he took to prove that the silk actually entered into combination with the dissociated colourless rosaniline base. The observation that wool is dyed red from a colourless solution of rosaniline base was first pointed out by Jacquemin in 1876. Mills gives careful tables showing the laws governing the rate of absorption of colour from a cold bath, also of various acid and basic solutions, and finally for the result of dyeing from mixed dye-baths.

R. Meyer,[25] on the subject of microscopic research into printed cottons, doubts whether the fibre enters into composition of a compound with the dye or acts as a containing vessel for the latter, he considers that the essential factor in true dyeing is that the dye or the materials which produce it in the bath should penetrate the fibre, and inside it be changed

[19] *Farben Chemie*, Pt. 1, 1834, Pt. 11, 1850.
[20] 1846, *Traité de l'Impression*.
[21] 1857, *Lehrbuch der organischen Chemie*.
[22] 1859, *Kritische und experimentelle Beitrage zur Theorie der Farbere Journal für praktische Chemie*.
[23] 1868, *Traité des Matières colorantes*.
[24] *Journ. Chem. Soc.* 1883, 144; *Journ. Soc. Chem. Ind.* 1889, 263.
[25] 1883, *Berichte*.

to an insoluble form. He, however, in 1895, admits that with animal fibres dyeing is a chemical process. The researches of P. Richard [26] into the nature of wool and silk led him to assert the existence of an amido group in these substances which can be diazotised and the resulting diazo compound coupled with phenols &c. At the same time, by decomposition of the diazo compound, a hydroxy group is formed which can be coupled with diazo compounds.

Champion's discovery of lanuginic acid being published, Knecht [27] now turned his attention to this in a long series of researches that have finally confirmed his position as leader of the purely-chemical faction. In 1888 he showed that, having prepared lanuginic acid either by Champion's method or by dissolving wool in barium hydrate solution, precipitating the barium with carbon dioxide and from the filtrate precipitating the acid with lead acetate, then removing the lead with sulphuretted hydrogen and evaporating the filtrate, the resultant substance gave brightly coloured precipitates with dye solutions of acid and basic dyes and also with solutions of metallic salts. Comparing this with the facts observed: that wool and silk absorb and hold with a tenacity which will not yield even on boiling acids and alkalies; that they also absorb dye-bases from neutral baths, leaving the whole of the acid from the dyestuff in the bath as ammonium salt, he deduces that definite chemical compounds must be formed between the colour-base (or under given conditions colour-acid) with some break-down products of the wool or silk of the nature of lanuginic or sericinic acid. With acid colours, the action of the acid produces in the fibre a substance capable of forming lakes with the acid colouring-matter. The behaviour of the fibre in presence of great excess of substantive dye in some experiments even shows the probability of combinations according to the law of multiple proportions. Knecht [28] undoubtedly proved that in dyeing wool with a series of acid colours belonging to the same homologous series the amount of colour taken up was in exact proportion to their molecular weights; hence the laws of chemical combination are obeyed.

These convictions of Knecht have been continuously combated by von Georgievics and the physicists, but a series of investigators reported experiments which corroborated Knecht's observations. L. Vignon [29] tested for the amount of heat evolved in the absorption of acids (sulphuric, hydrochloric, stannic) and alkalies respectively by silk, wool, and cotton, and found that the first fibre evolves the greatest heat, even during absorption of salts. Cotton only evolves heat with strong acids or alkalies, and then only feebly, this he explains by the fact that cotton has no nitrogen (citing empirical formulæ),

$$\text{silk} = C_{111}H_{222}N_{48}O_{56}, \quad \text{wool} = C_{88}H_{149}N_{27}S_3, \quad \text{cotton} = C_6H_{10}O_5,$$

and that cotton previously treated with ammonia will react evolving heat. He obtains a substance by treating cotton with ammonia, which contains nitrogen, and this substance possesses greater dyeing powers, but in the opinion of the writer this compound is far more likely to be a degradation product of cotton. Wool and silk he knows to be capable of

[26] 1884, *Soc. Ind. de Mulhouse*, 'Aufklarung der chemischen Konstitution de Wolle.'

[27] *Journ. Soc. Dyers and Col.* 1888, p. 72; 1889, p. 71.

[28] *Ibid.*, 1904, p. 242.

[29] *Comptes Rendus*, 1890.

acting either as acid or as base under determining conditions, and postulates a definite acid or basic character both in the fibre and in the dyestuff before true dyeing can take place (dyestuff here being taken to mean the system solvent plus solute dye plus mordant). In 1893, criticising the new Witt theory, he emphasises the chemical nature of his own hypotheses as being far more 'rational and in accord with facts.' That there is no clearly demonstrable adhesion to the law of multiple proportions he considers to be no unanswerable argument; the fibre molecules are complicated and large in comparison with those of many dyes. Vignon on this and other occasions pointed out the dissociation of dye-solutions in presence of the fibre; the constitution of dyes like Congo red (R$\langle^{N}_{N}$ or $=N-N=$) that possibly makes them capable of the direct dyeing of cotton by combination with the cellulose. Finally, he admits the great value of the physical structure of the fibre in dyeing, its $\frac{\text{surface}}{\text{volume}}$ co-efficient being so large that it acts as a porous body. As did Zacharias later, he admits of two actions of the fibre: porosity with capillarity, and (usually) chemical combination. Knecht[30] also showed that hydrolytic dissociation played a part in dyeing and that there was an intimate connection between the dissociation of a colour and its dyeing power.

L. Hwass and G. Spohn[31] adduce experiments in favour of the mechanical deposition theory, the latter insisting on deposition pure and simple, conditioned by molecular forces, and giving as evidence the microscopically visible crystals of lead chromate and manganese bistre, which at a distance of 60$\mu\mu$ one from the other give the illusion of homogeneous colour to the naked eye, but are separately and sharply deposited, some within, some upon, the fibre. He, like von Georgievics, refuses to admit of any chemical combination, since inorganic and unaffected matters like asbestos can be dyed just like animal and vegetable fibres, but Hwass admits the possibility of such combination (*e.g.*, silk saturated with iron hydroxides). He looks on dyeing as dissociation phenomena; dyestuffs readily dissociate, and the fibre acts towards the dissociated solute merely as would a thread hung in a saturated alum solution: it receives and encourages the deposition of insoluble bodies (the colour radicle or its hydrate) and rejects soluble. He is attracted to the solid solution theory of Witt (*vid. sub.*) as being the best statement of such phenomena of selection. The appearance of von Georgievics in the arena now so thoroughly stated the case for the purely mechanical deposition theorists that no further citations need be made from the researches of his disciples to bear out his theories.

Meanwhile, in the hands of C. O. Weber,[32] W. P. Dreaper,[33] Rosenstiehl, Gnehm and Rotheli,[34] A. W. Hallitt,[35] A. Reychler,[36] Prudhomme,[37]

[30] *Journ. Soc. Dyers and Col.* 1898, p. 59.
[31] *loc. cit.*
[32] *Journ. Soc Chem Ind.* 1894, p. 120.
[33] *Ibid.*, 1904, p. 111; 1905, pp. 118 and 136.
[34] *Journ. Soc. Dyers and Col.* 1898, pp. 190 and 215.
[35] *Ibid*, 1899, p. 30.
[36] *Bull. Soc. Chim. de Paris*, 1897, p. 449.
[37] *Rev. Gen. de Matt. Col.* 1900, p. 184.

and Knecht himself, the chemical theory developed, and widened its horizons until it merged into the view that any dyeing process is necessarily dualistic: that some physical cause of deposition, be it (1) purely mechanical adhesion or (2) intermolecular diffusion analogous to the interdiffusion of any two solutions, with miscible solvents, until a state of equilibrium is reached, or (3) attraction of an electrical nature due to contact-difference of potential in the presence of a solute hydrolysed or ionised, must accompany any postulated chemical combination of dye and fibre. The fundamental theories governing the chemical combination of fibre and dye are twofold: (1) All dyestuffs have either acid or basic properties or represent salts of acids or bases, (2) these dyestuffs combine with the animal fibres, especially wool, by virtue of the amphoteric nature of the latter. In the case of cotton, although the process is generally looked upon as being of a mechanical character, it is quite conceivable that a chemical action may sometimes occur.[38]

If cotton be rendered more acid, *i.e.*, by the formation of oxy-cellulose or nitro-cellulose, the fibre shows a marked affinity for basic colours. But nitrated or acetylated cotton has lost its affinity for direct colouring-matters. More evidence in favour of the Chemical Theory was advanced by Fort[39] in a series of papers in the 'Journ. Soc. Dyers and Col.' He constructed a theory to explain the taking up of acid dyes by materials which are able to effect combination with acids and supported this theory by a large number of experiments.

The first steps towards a clear and adequate explanation other than that of chemical combination of the phenomena of absorption by the fibre or a dye from its aqueous or alcoholic solution were made by A. Muller Jacobs.[40] He bases his researches upon the known facts of diffusion of gases, of one liquid through another, and of crystalloid solutions through membranes that prevent the diffusion of colloids. Researches in the last-mentioned diffusions had been first published by Thomas Graham[41] in 1861-1864. Muller Jacobs divided the 'attraction' between the phases of a disperse system into 'hygroscopy,' 'capillarity,' and 'imbibition' between solids and liquids, all based on the phenomena of endosmosis. He is aware that even colloids will diffuse if the membrane be suitable (this confirmed in 1912 with great accuracy by Zsigmondy and Siedentopf) and applies this to dyeing. Many dyestuffs, whose colloidal nature is known, will diffuse into and colour a parchment membrane, but will not stain the surrounding solvent. Some enter into the cell wall, some appear to be fixed upon it. Now, in dyeing the aim is either to fix this interpermeated colloid by a mordant which will turn it to an insoluble precipitate, still within the fibre, or to cause the endosmosis of such large molecules of the colloid dyestuff that it will not readily diffuse out. Silk and wool have small interstices in their membranous structure: an 'animalising' process is any which so closes up the large interstices of the cotton fibre that it will act in the same way. There is no need to postulate any entry into chemical combination on the part of the fibres (*e.g.*, with the colourless rosaniline solution). Heating is of value because it expands the pores of the fibres—here he reverts a century to the pure mechanicists of the infancy of the science—

[38] See Knecht, *Manual of Dyeing*, vol. 1, p. 19.
[39] 1913, p. 269; 1914, p. 5; 1915, pp. 80, 96, and 222; 1916, p. 33.
[40] *Textile Colorist*, 1884 and 1885.
[41] *Philos. Transact.* 1861–1864.

and also because it favours the combination of the dye plus mordant into insoluble lakes

O. N. Witt's[42] theory of selective solution and of solid solution was the next step. The phenomenon of solid solution was first noticed by Van 't Hoff[43] in 1890, as an explanation of the formation of alloys by the solution of one solid metal in another. Witt's application of this to dyeing was, it must be remembered, put forth as a 'working hypothesis,' which appeared to its formulator as being capable of explaining many observed facts, and which might at least serve as starting-point for a more adequate theory. His initial objection to the terminology 'substantive' and 'adjective' colours is, that the success of the dyeing process depends on the fabric as well as on the dye: one fibre will not take all dyes nor will one dye colour all fabrics. This is not, he says, explained by chemical combination, but by choice of solvent, the fibre is a better solvent for the dyestuff than is the water of the bath, and absorbs the colour in the same way as ether will take iodine from its brownish water-solution and form a violet layer, or as ether absorbs resorcin from its aqueous solution, whereas benzol will not, save in minute quantities, though resorcin is soluble in benzol. Keratin and fibroin are very good solvents, cellulose a poor solvent, for colours; but no dyestuff can be truly insoluble in the fibre, or it would wash out. He insists that the colour on the fibre is the colour of the dissolved, not the solid dye, *e.g.*, magenta dyes red, not metallic green, and fluorescein dyes fluorescent, though it only fluoresces in solution So illuminating was the theory at first glance that it found many upholders: P. Sisley, W. H Perkin, Michaelis, Cross and Bevan, and at one time Dreaper; and it was only when von Georgievics, Biltz, Freundlich, and Walker and Appleyard made exhaustive researches into the laws governing colour adsorption (*e.g.*, that Henry's law is not obeyed, unless totally unfounded assumptions are made as to the molecular constitution of the absorbed dye) that the inadequacy of the theory was demonstrated.

Cross and Bevan in 1910 still insist, from the pure transparency of the jute-fibre when dyed dark blue with a mixed solution of potassium ferricyanide and ferric chloride, that this is a case of 'solid solution'[44] and Sisley[45] in 1913 claimed that 'Berthelot's law' on the distribution of a dissolved substance between two immixable solvents holds good in dyeing silk with certain acid dyestuffs, and quoted his experiments to show the analogy between the extraction of picric acid from its aqueous solution by silk on the one hand and by organic solvents such as benzene or amyl alcohol on the other hand, the action in both cases being accelerated by the presence of a mineral acid, because it is found that fully ionised dyestuff, *i.e.*, one in very dilute aqueous solution, will not come out of its water solution on to fibre or into organic solvents, and the addition of an electrolyte diminishes the ionisation coefficient and the solubility of the dyestuff in water. C. O. Weber[46] likewise believes that benzidine colours go into solid solution in the cotton fibre, the fastness of the colour to washing being inversely proportional to the diffusion-coefficient of the dye. The then extant theories of colloidal solution were first applied

[42] 'Theory of the Dyeing Process,' in *Farbenzeitung*, 1890–1.
[43] *Zeitschr. f. phys. Chemie* (1890), **5**, 322.
[44] See also *Journ. Soc. Chem. Ind.* 1893.
[45] *loc. cit.*
[46] *Journ. Soc. Chem. Ind.* 1894, p. 120.

by F. Krafft[47] to the theory of dyeing. His summary of the facts then known is this: a colloid solution or system contains the solute in molecular form; the molecules are large in mass and volume, and tend to form systems rotating round one another. When the gel coagulates these spheroid forms become rigid—the solid is not 'amorphous' but 'globomorphous' (this is not true unless the disperse phase occupies no more than 74 per cent. of the total volume of the sol;[48] above 74 per cent. the globules become flattened to dodecahedra, with walls, of increasing tenuity, consisting of the continuous phase—but such fine walls are rare save in the soaps). Krafft goes on to state that in dilute solutions the soaps are hydrolytically dissociated, but the constant interchange of +ve and −ve ions causes the neutral reaction to persist and the solution to remain 'clear' His proof of dissociation is that the melting-point is that of stearic acid, not of sodium stearate. Hence Krafft's theory of the dyeing process is that it consists in the deposition of colloids in or on the fibre in the form of globules or membranes, very plastic, which (like the soaps) have the power of clinging to solid bodies. Dyes which have a small molecular weight must be presented to the cotton fibre in the form of colloidal compounds with a mordant, which is in itself always a colloid, to form colour lakes. Many dyes are colloids in water and not in alcohol, the substance is hydrated and forms immense molecules. Colloid solutions of iron hydroxide, aluminium chloride, *i.e.*, in water, will all form colour lakes which 'fall out of solution' (*i.e.*, coagulate) at 0° C. (see Zsigmondy's experiments in freezing sols). Their tough, plastic, clinging nature all makes for good dyeing, *e.g.*, alizarin red in presence of a fatty acid of low melting-point forms a colloidal membranous deposit, Turkey red. Direct dyes are mostly colloids of more or less slight solubility, *e.g.*, benzopurpurin. The direct cotton colours were supposed to exist in the colloidal condition to a much greater extent than the dyes of the acid and basic groups, and this would explain them being taken up direct by the cotton fibre. Wool and silk enter into combination with dyes, forming membranous colloidal salts; leather in tanning forms a similar surface. Hence his theory is that the dyer 'imitates Nature' in 'forming a protective insoluble colloid membrane on the outside of the fibre.' Biltz[49] also showed that colloidal solutions of inorganic substances like selenium, tellurium, gold or molybdenum blue would dye wool or silk, and that analogously with organic dyestuffs an electrolyte (salt) hastened, while a protective colloid retarded, the process.

Later research has confirmed much of Krafft's work, if it has also served to point out his errors, most glaring of which is of course that of the 'protective exterior membrane.' Certainly the adsorption process is by its very nature largely confined to the surfaces, but the entire structure of a sol (or gel) may be permeated by another substance, colloid or crystalloid, and then, according to McBain and Zsigmondy, the term 'sorption' is more descriptive of the phenomenon. Sisley takes exception to the use of the word 'adsorption' which is now largely used in colloid chemistry to indicate the extraction of a dissolved body by a solid. He submits that the word is no improvement on absorption and that so-called adsorption compounds are in no way distinguishable from chemical

[47] 1896–9, *Berichte*, **27, 28, 29, 30, 32.**
[48] Zsigmondy, p. 67, 157 *et seq.*
[49] *Journ. Soc. Dyers and Col.* 1904, p. 145; 1905, p. 276.

compounds. It is probable that their formation is incomplete, and this would explain their not obeying the law of multiple proportions.

Other workers besides Krafft and Biltz are of the opinion that many dyestuffs form colloidal solutions. Teague,[50] Buxton, and Vignon base their conclusions with Krafft on diffusion experiments, Pelet-Jolivet[51] and Wild on their ultramicroscopic studies. Knecht and Batey[52] and later Donnan and Harris[53] deny the colloidal nature of benzopurpurine, chrysophenine, and Congo red on grounds that their electrical conductivities are normal and that they exert osmotic pressure. The work of Donnan and Harris is important and leads to the view that measurements of the osmotic pressure are of no value unless account be taken of the presence of an electrolyte (if present). The electrolyte distributes itself unequally on the two sides of the dialysing membrane and sets up an opposing osmotic pressure. Zsigmondy, considering their experiments, also those of Bayliss,[54] Teague and Buxton,[55] Rachlmann v. Vegesack,[56] Biltz and Bredig, places Congo red and all the other azo- dyestuffs of its class among the colloids, owing to their low diffusibility and optical visibility (in the ultramicroscope). On boiling Congo red dissociates, it is extremely sensitive to the presence of carbon dioxide in diffusing, but in the matter of conductivity and osmotic stress it behaves like a crystalloid or electrolyte, the conclusion being that the salt is dissolved as molecules, but the presence of extremely minute amounts of electrolytes causes aggregation into submicrons. Dyestuffs with the alizarin group are highly colloidal, while the dyestuffs containing sulphonic groups not only form very soluble compounds in water, but their salts are very dialysable even with molecules of from 76–78 atoms, yet, according to Biltz,[57] molecules of from 70 to 95 atoms should not diffuse.

In the light of these facts, all the recent research into the properties of colloids has its direct bearing upon the theory of dyeing.

Following upon Krafft, P D. Zacharias published in 1900 a 'Farbentheorie,' of which the German translation appeared in 1908. His theory meanwhile developed in a series of essays in the 'Farbenzeitung,' 1901, **12**, 149 and 165, and 'Ber. d.d. chem. Ges.' 1905. His earlier theory is one of colloid interdiffusion plus adhesion. He discounts the chemical theory altogether, objects to the solid solution theory pure and simple, but, recognising the colloidal nature of the dyes and of the fibres, he suggests an interdiffusion plus precipitation, followed by or resulting in an adhesion, whose nature he does not particularise. His later theory, which he insists does not essentially vary from his first statements, follows upon the researches of Graham, Krafft, Justin-Mueller, Biltz and Zsigmondy (Biltz and Zacharias variously quarrelled about the originality of each other's theory and experiments, while Zacharias continuously and pugnaciously defends his theory, it is Biltz who brought forward the experimental material for such a theory—no such experimental data

[50] *Zeitschr. für Phys. Chem.* 1907, **60**, p. 419.
[51] *Zeitschr. Chem. Ind. Koll.* 1908, **3**, 174.
[52] *Journ. Soc. Dyers and Col.* 1909, **25**, 194.
[53] *Chem. Soc. Trans.* 1911, **99**, 1554.
[54] *Proc. Roy Soc.* 1909, **81B**, 269.
[55] *loc. cit.*
[56] *Zeitschr. physikal. Chem.* 1910, **73**, 481.
[57] *Ibid.*, 1911, **77**, 91; also *Gedankbook*, van Bemmelen, 1910, 108.

having been furnished by Zacharias). He now places the dyeing process in close relation to that of solution, with its phenomena of hydrolysis and ionisation, on the border-line between chemistry and physics. The cohesion between fibre and dye he now conceives to be possibly electrical in character, comparable to the combination of ions. Essentially, dyeing is the coagulation of a colloid in or upon another colloid, in such a form as to be insoluble; the electrolyte present in the bath causes such coagulation by its electrical effects on the colloid solute and its solvent. He does not now deny the possibility of subsequent chemical combination between the cohering fibre and dye, particularly in the case of animal fibres.

W. P. Dreaper also did something to bring the observed dyeing phenomena into line with the evolving colloid theory. In his earlier papers his theory is one of endosmosis, proportional to pressure and to the absolute temperature, coupled with chemical combination; he also inclines to the solid solution theory, applying Linder and Picton's idea of 'pseudo-solution' to the phenomena of dyeing. Finally he rejects both the chemical and the solid solution theories, upholding one of pure adsorption by the fibre, acting as a more or less dry gel, of the hydrosols of the various dyes. Dyeing is always carried on in the wet condition, so that the fibre may be sufficiently hydrated to act as a hydrogel of the gelatine type; the state of hydration Dreaper finds to influence the amount of any solution adsorbed. His text book (1906) 'Chemistry and Physics of Dyeing' gives a very broad and somewhat indecisive theory of 'the phenomena which take place in dyeing,' including: (1) 'A solution state of the dye, within certain limits of aggregation, determined by the laws of size'; (2) 'a fibre state corresponding to this state of aggregation, and of a permeable nature'; (3) 'effective localisation of the dye within the fibre area, due to surface concentration phenomena'; (4) 'localisation of salts, acids, &c., within the fibre area', (5) 'indirect entrance of dye aggregate by molecular migration with subsequent re-formation of aggregates within the fibre area, according to the laws of size'; (6) 'de-solution, due to secondary attraction between the fibre substance and the dye, or by reduced surface energy phenomena, or concentration effects'; (7) 'in some cases, primary or chemical action may play some part at this stage; this may even, in some cases, take the place of de-solution phenomena'; (8) 'dissociation effects in the case of basic dyes which may lead to the production of very basic salts in a high state of aggregation within the fibre area.' He is aware of the electro-positive or electro-negative nature of all colloids, but does not connect this with the coagulating (he calls it 'degrading') influence of crystalloids in the dissolved colloid.

A similar cognition of the diverse and seemingly irreconcilable nature of the dyeing processes was published by Grehm and Rotheli,[58] who, after an exhaustive criticism of all existing theories and evidence, conclude that each existent theory can find place in the final and adequate one. They were the first to show that cotton takes up direct cotton colours in an unchanged condition. Later Gnehm and Kaufler performed the following experiment: a skein of cotton dyed with benzopurpurin was boiled with two undyed skeins in a small beaker. After drying, all three skeins were alike. This observation is in direct opposition to Krafft's

[58] *Zeitschr. f. angewandte Chemie*, 1898, pp. 482, 501.

theory of colloidal precipitation, for if the colour in the dyed skein is due to the formation of a colloid precipitate, it cannot be conceived that in one case solution should ensue and in another precipitation.

Wilhelm Ostwald,[59] M. van Bemmelen,[60] H. Freundlich,[61] G. Losev,[62] L. Pelet-Jolivet,[63] and W. Biltz [64] investigated the laws governing adsorptions by solids such as charcoal, of crystalloids and colloids, and the dyeing of mineral substances by dyestuffs. The associated phenomena of contact-electrification were also studied by Perrin,[65] who formulated laws,[66] and by Pelet-Jolivet and Grand,[67] Miolati,[68] Gee and Harrison,[69] and Knecht.[70] Further work in the same fields—by Svante Arrhenius [71] (diffusion of hydrosols and adsorption isotherms), O. Bütschli [72] (structure of gels, and influence of hydration on a dried gel), Wolfgang Ostwald [73] (classification of disperse systems, conductivity of metal hydrosols, electrical coagulation of suspensions, &c.), A. Lottermoser [74] (metallic hydrosols, solid sols, freezing of metallic hydrosols, mutual precipitation), W. Pauli [75] (electric charge and coagulation of albumen, precipitation by electrolytes, internal friction of albuminous sols, structure of jellies, turgescence of the same and conditions governing its rapidity), P. P. von Weimarn[76] (emulsoids and suspensoids, the formation of jellies from crystalloid solutions and the crystallisation of colloids, laws governing surface tension in two-phase systems), Emil Hatschek [77] and Zsigmondy,[78] working with Siedentopf, Ambronn, Heyer, Kirchner, Schultz and Wilke Dorfurt—has resulted in a comprehensive theory of colloidal systems, which many of the investigators have themselves applied to the dyeing process.

The idea of 'solution' is to be widened to embrace all possible combinations of a solid, liquid or gaseous disperse phase with a solid, liquid or gaseous continuous phase.[79] The most common solutions still are those having a liquid continuous phase, and the most common solvent is water—few, if any, substances refusing to go into colloid, if not crystalloidal, solution in water. Now, the obvious method of differentiating between crystalloids and colloids is by means of dialysis, whether it be carried out by the Graham dialyser or the far more complicated and efficient ones of Kuhne, Jordis, or Zsigmondy and Heyer. But a substance may be colloid in some solvents and crystalloid in others; nor is it only crystal-

[59] *Zeitschr. f. phys Chemie*, 1890, **6**, 71-82; *Lehrbuch der allgem Chemie*, 1 Aufl. **1**, 778-791 (1885), 2 Aufl. **2**, **3**, 217 *et seq.* (1906)

[60] *Zeitschr. f. anorg. Chemie*, 1903, **23**, 238, **18**, 114-7, **13**, 350.

[61] 'Kapillar Chemie,' 1909, *Zeitschr. f. phys. Chemie*, 1909, **44**, 129.

[62] *Zeitschr. f. phys. Chemie*, 1907, **59**, 284-312, &c.

[63] 'Theorie des Farbeprozesses' (1910), *Kolloidzeitschr.* 1909, **5**, 238-243.

[64] *Berichte*, 1904, **37**, 1095-1116; van Bemmelen, *Gedankboek*, 1910, 108-20.

[65] *Annales de Chim.* 1909, **18**, 5-114; *Comptes Rendus*, 1903, **136**, 1388-1391, **137**, 513, 564.

[66] *Journal de Chim. Physique*, 1904, p. 619, and 1905, p. 100.

[67] *Rev. Gen.* 1907, p. 225; *Koll. Zeitschr.* 1907, **2**, 41.

[68] *Berichte*, 1893, **26**, 1788.

[69] 'The electrical theory of dyeing,' 1910, *Journ. Soc. Dyers and Col.* 1911, p. 279.

[70] *Journ. Soc. Dyers and Col* 1909, **25**, No. 7.

[71] *Immuno Chemie*, 1907, p. 17.

[72 73] See Zsigmondy, *Kolloid Chemie*.

[76] 'Zur Lehre von den Zustanden der Materie' in *Koll. Zeitschr.* 1907-9, 2-5. 'Grundzuge der Dispersoid Chemie' (1911), *Chemikerzeitung*, p. 725.

[77] *Introduction to the Physics and Chemistry of Colloids*, 1916.

[78] *Kolloid Chemie*, 1912.

[79] Zsigmondy, *ibid.* p. 25.

loids that form geometric crystals colloid gold, silver, albumen, globulin and hæmoglobin will all give crystals, while it is possible to obtain 'globomorphous' sodium chloride, and many crystalloid solutions pass through a jelly-like stage immediately before solidifying into crystals. It is more correct to speak of a 'colloidal state of matter' than of 'colloids' as a sharply defined class. Colloidal solutions are either 'suspensoid' (*i.e.*, having a solid disperse phase) or 'emulsoid' (having a finely divided liquid disperse phase); the particles or 'micelli' varying in size from ·1 $\mu\mu$ (crystalloid) to 1 $\mu\mu$ (hydrosols) to 100 $\mu\mu$ (turbidities) and from 100 $\mu\mu$ to 1 mm. (suspensions fine or coarse). Below 1000 $\mu\mu$ the so-called Brownian movement is visible, both in true colloid-solutions and fine suspensions; the motion is the more rapid the smaller the particles are; it does not vary on admitting or excluding the dark heat-rays; it is independent of the direction of admitted light-rays, or the length and intensity of its subjection to these, it will continue for months and even years, it does not depend on the charge upon the particles; it is affected by dilution, and the particles appear to influence one another. Various theories have been put forward to explain it. Quincke[80] considered it due to the spreading of liquid layers over the surfaces of the particles; Wiener,[81] Cantori, Renard, Boussinesq, and Gourg based it upon collisions between the particles and the molecules of the solvent, Einstein,[82] von Smoluchowski,[83] Zsigmondy,[84] The. Svedberg,[85] and Perrin[86] ascribe it to kinetic energy.

The particles migrate, under the influence of the electric current ('cataphoresis'), in a direction determined by their charge. The same colloidal solution may be positive or negative—it depends on the nature of the continuous phase ('intermicellary liquid') and the electrolytes it may contain The direction can be measured by Coehn's[87] apparatus, or that of A. Cotton and H Mouton,[88] or of The. Svedberg[89]; colloidal iron oxide, cadmium hydroxide, titanic acid, &c., and all basic dyestuffs, colloid or crystalloid, are positive and wander to the cathode; colloidal gold, silver, platinum, sulphides, mastic, starch, gums, stannic acid, molybdenum blue, &c, and all acid dyestuffs, colloid or crystalloid, are negative and wander to the anode.[90] A trace of added alkali causes a neutral colloid (*e.g.*, suspended white of egg in pure water) to become negative, added acid causes a cathodic convection.[91] The electrical

[80] *Verh. d. Ges. d. Naturf. u. Ärzte*, 1898, *Beibl. zu d Annalen d Phys.* 1899, **23**, 934–7.

[81] *Poggendorff's Annalen d. Phys. u. Chemie*, 1863, 118, 79–94.

[82] *Drude's Annalen d. Phys.* (4) 1905, **17**, 549–560; 1906, **19**, 371–381; *Zeitschr. f. Elektrochemie*, 1908, **14**, 235–239.

[83] *Drude's Annalen d. Phys.* (4) 1906, **21**, 756–780; 1908, **25**, 205–226.

[84] *Zeitschr. f. Elektrochemie*, 1902, **8**, 684–687; *Koll. Chemie*, p. 38 9; *Zur Erkenntnis der Kolloide*, 1905, S. 106–111, with tables.

[85] 'Studien zur Lehre von den kolloiden Losungen,' 1907, 125–160; *Zeitschr. f. phys. Chem.* 1910, **73**, 547–556.

[86] *Annales de Chimie et de Phys.* 1909, (8) **18**, 5–114.

[87] *Zeitschr. f. Electrochemie*, 1909, **15**, 653.

[88] *Les Ultramicroscopes*, &c., 1906, p. 144.

[89] *Loc. cit.*

[90] Zsigmondy, *Kolloid Chemie*, p. 44.

[91] Hardy, *Journal of Physiology*, 1899, **24**, 288–304; Hardy, *Zeitschr. f. p. Chemie*, 1900, **33**, 385–400; Perrin, *Comptes Rendus*, 1903, **136**, 1388–1391; 1903, **137**, 513–514, 564–6.

property of electrolytes is well known to be due to their dissociation into negative anions and positive cations; the charge on the colloid particles is not so easy to explain, as they are not generally supposed to be ionised. Yet Zsigmondy gives three various explanations,[92] and Bredig [93] and Billitzer [94] assume the same, *i.e.*, difference of dielectric constant between particle and intermicellary fluid; capture (*e g*, colloid gold with H ions) or deposition of ions. Hardy [95] has the distinction of pointing out that it is the electrification of the particles of any irreversible colloid that causes it to remain in solution; if an electrolyte of opposite charge be added till the isoelectric point be reached, the colloid will coagulate into a gel; the ions of the electrolyte bearing the opposite charge to the colloid particles also take part in the precipitation.[96] Schulze [97] has pointed out, and this has been many times corroborated, that the valency of the ion is of great influence in this coagulating process: a trivalent ion is worth 1,000 monovalent or 30 divalent ions. The curve is the same as the adsorptions curve, as Freundlich [98] has pointed out, and Pelet-Jolivet's [99] table of comparisons between the laws of contact electrification, colloid coagulation, dyeing and capillary attraction bears out in a remarkable way. Not only do crystalloids precipitate colloids, but two colloids of opposite charge will precipitate each other, unless one is in overwhelming excess of the other, there is a more or less wide zone within which mutual coagulation will take place, though there is only one point at which the charges actually neutralise each other. For dyeing, this rule is of the widest importance [100]

If the dry gel of a reversible colloid like gelatine or agar be put into water to be dissolved, it behaves in a manner quite distinct from a crystalloid. The latter gives off particles from its surface till all is dissolved, in a manner analogous to the evaporation or sublimation in a gaseous medium, and the solution obeys Boyle-Gay-Lussac's laws of gases, within certain limits. The gelatine swells up and absorbs the water into its own substance, but does not dissolve until the temperature rises to above 25° C.

Van Bemmelen and Batschli believed that jellies possessed a porous structure of microscopic dimensions, but this theory is now abandoned; such pores can be produced by irregular contraction under the action of alcohol or chromic acid, and the structure of natural jellies is molecular, and they are of the nature of solid solutions. Capillarity may cause imbibition but cannot produce swelling in itself, though it may liberate the elasticity of the imbibing substance, as water does that of a dried sponge.

Similar phenomena will explain the adsorption of liquids by charcoal, unglazed pottery, &c., though, as von Georgievics points out, not the decolorisation of liquids: this is, according to Knecht and Suida,[101] due to the activity of the nitrogen compounds of the charcoal, and to the acid nature of the silicates.

[92] *Kolloid Chemie*, p. 48.
[93] *Anorganische Fermente*, 1901, p. 16.
[94] *Zeitschr. f. Electrochemie*, 1902, **8**, 638-642, *Zeitschr. f. phys. Chemie*, 1903, **45**, 307–330.
[95] *Loc. cit.*
[96] See also Dreaper, *Chemistry and Physics of Dyeing*, p. 123.
[97] *Journ. f. praktische Chemie*, 1882 (2), 25, 431–452; 1883, **27**, 320–332.
[98] *Zeitschr. für phys. Chemie*, 1910, **73**, pp. 385–423.
[99] *Theorie des Farbeprozesses*, 1910.
[100] See Zsigmondy, *Koll. Chem*, Ch. 98, 'Kolloidfallung der Farbstoffe.'
[101] *Sitzungsber. d. Akad. d. Wiss*, Wien, 1904, 113, 11b, 725–761.

Pieces of such colourless and transparent silicic-acid-gel thrown into colloidal dye solutions Zsigmondy found to behave as 'ultra-filters,' the dispersion-medium being absorbed as by a sponge, and the dye-particles held on the surface of the gel-particles in a semiliquid state. Silk, cotton, and wool fibres show a similar hygroscopy and were described by Dreaper. as 'colloidal substances dry to the touch,' like solid gelatine. Like it, they swell up in water and other solvents but do not dissolve; they may be looked on as irreversible gels, like silicic acid. Their 'pores,' however, are not of the extreme minuteness of those of the latter substance: they do not show anything like the same optical homogeneity, and therefore they are not 'ultra-filters' to the same degree. Moreover, the fact that they show no readiness to enter into solution, in spite of their 'swelling,' causes Justin-Mueller[102] to suggest the name 'turgoids,' not 'colloids,' for them, and to call the process turgescence and not colloidal solution. He considers this turgescence of the fibre to be a necessary part of the process of adsorption of the dye; colours that rub off do so because adhesion, not adsorption, has taken place, and the dye has been 'salted out' or coagulated on the fibre. Both the deposition and the adsorption are reversible according as the adsorption-coefficient and solubility-coefficient approach each other.

Some such laws appear to be followed as were noticed by Pelet-Jolivet and his assistants in recording the capillary attraction of filter-paper on various kinds of solutions, the height to which the coloured layer, or the layer that gives a direct reaction acid or basic, appeared to rise, was found to agree in a remarkable way with the observed electrical and colloid-precipitating effects of the same solutions. Schoenbein, W Ostbald, Goppelsroder, and Fichter and Sahlbom have recorded the following results: Alkali and acid solutions give reaction up to seven-tenths of the wetted paper, calcium carbonate only about one-tenth, and barium hydrate about three-tenths. Positively-charged colloids are found to be deposited on the paper at the surface of the liquid, while negative colloids mount with the water. (Thus Fichter and Sahlbom refer to the currents set up in the capillaries of the paper: even in glass capillaries water rises much higher than basic dyestuff solutions or positive colloids in general.) Thus any influence which causes colloidal coagulation, or decreases solubility, limits the capillary rise and favours dyeing, the influences which keep the particles small and disperse act in the other direction and are against rapidity of colouring. From this the actual value of 'assistants' in the dye-bath may be deduced, without postulating a liberation of the free dye-acid, which has been diversely shown to be little, if any, more effective pure than combined to form a dye salt.

The work of Alexander[103] is of interest as showing the influence of protective colloids on dye solutions. He has previously pointed out that, after the addition of protective colloids (gelatine &c.) to solutions of benzopurpurin, dilute acids produce colour changes analogous to those adsorbed in the dyed animal fibres. In the case of a dilute solution of benzopurpurin, addition of dilute mineral acid quickly changes the bright red colour to dark blue, and stronger acid coagulates the dye which settles out of solution. If gelatine is added to the benzopurpurin solution dilute mineral acids give a claret-red solution, and stronger

[102] *Chemikerzeitung*, p. 845, 1914.
[103] *Journ. Soc. Chem. Ind.* 1911, p. 517.

acid changes the shade to chocolate-brown, without, however, causing any precipitate. Alexander has examined these colour-changes at the ordinary temperature in the ultra-microscope, and reports—dilute benzopurpurin solution shows a field full of ultra-microns which from their brilliancy and motion appear to be 50–60$\mu\mu$ in size. When a little acid is added, the ultra-microns gradually gather together into clumps, or groups, whose motion decreases as their size increases, until the whole of the dye is deposited in coagulated masses of bright ultra-microns. Stronger acid causes instant coagulation in large masses when acid is added to the gelatine dye solution; no change is produced unless the acid is strong enough to cause a more or less extensive agglutination of ultra-microns into small groups of 2 or 3, which, however, have still sufficient motion to keep afloat. The cause of the variation in the colour-changes produced by immersion in dilute acid on the different fibres dyed with benzopurpurin is due (according to author) to their difference in protecting action on the adsorbed dye. A practical application for the use of protective colloids is found in Feilmann's English patent, 10,693, 1906, where the employment of casein is made to produce colloidal solutions of various unsulphonated dyestuffs, particularly azo- dyes. But this application has not found much use up to the present.

Similarly Mohlau and Zimmermann[104] produce colloidal indigo by means of protalbumic and lysalbumic acids—also Fabrik v. Heyden produce the same substance by the use of various protein substances.[105]

The phenomenon of 'contact electrification' and its value in dyeing remains Whenever two substances solid, liquid, or gaseous are in contact, having a common surface, all kinds of forces come into play, which are difficult indeed to study when acting between solid and solid or solid and liquid or solid and gas, but between liquid and gas have been formulated. Surface tension and surface electrification are the problems which particularly concern colloidalists, the surfaces between the disperse and the continuous phase being so immense in comparison with the mass.

Gibbs[106] enunciated the theorem 'Those substances which lower the surface tension of a solution with respect to another phase must concentrate themselves upon the latter.' This can be experimentally proved with gas-liquid and liquid-liquid systems, for it is possible to measure their surface tensions, but Freundlich has lately shown that those substances which lower the surface tension between two liquids are strongly adsorbed, not only by these but also by solid bodies, hence the rule would seem to have general application. Moreover, the adsorption-isotherm (showing quantitative adsorption by solid bodies) will hold also for the gas-liquid and liquid-liquid boundary Freundlich, Schmidt[107] and Svante Arrhenius[108] have given formulae for this adsorption, which within certain limits holds for the adsorption of crystalloids by charcoal and by hydrogels.[109] Ultra-microns of one colloid likewise adsorb ultra-microns of another colloid, and even when they both bear the same charge; this can be seen in the ultra-microscope and goes

[104] *Zeitschr. f. Farben und Textil Chemie*, 1903, 25.
[105] German Patent Application, 112,051, 1903.
[106] *Thermo-Dynamische Studien*, p. 321.
[107] *Zeitschr. f. phys. Chem.* 1911, **77**, 641–660; 1912, **78**, 667–681.
[108] *Meddelanden från K. Vetenskapsakad. Nobelinstitut*, 1911, **2** *N.* 7.
[109] *Van Bemmelen.*

to show that the electrolyte-coagulation theory is not quite adequate to explain all dyeing phenomena. When one colloid so unites with the other it forms a 'protective colloid' and shows the utmost reluctance to coagulate. This is connected with P. P. von Weimarn's 'Grundgesetz der Dispersoidologie' : 'When a substance suffers physical or chemical division it strives with all possible means for a diminution of its free surface energy.' This diminution of surface energy may take place by coagulation, which, however, is impossible so long as all the particles have the same charge, and only takes place in presence of an electrolyte or under influence of a current or by deposition upon a surface whose charge is opposite to their own, giving adsorption according to Freundlich's rules. Perrin's[110] and Pelet-Jolivet's researches into the contact charges which appear on various solid substances, including textile fibres, when brought into contact with liquids show, not only a definite 'latent heat of adsorption,' but also a charge (measured by the electrosmosis of the liquid through the diaphragm) in the case of ionising solvents, but not of non-ionising solvents like chloroform, petroleum, and benzol. All solid substances take on a positive charge in an acid liquid, a negative charge in an alkaline liquid; the difference of potential is greater when the number of H ions is greater, and smaller in presence of a greater number of OH ions. These phenomena show a remarkable parallelism to the results observed in the coagulation of colloids and point to some deep-seated analogy. Wool, cotton, silk, &c., follow the general charge-law in acids and alkalies, but they all take a negative charge already in pure distilled water; this charge is increased in contact with alkaline solutions and decreased in acid solutions with silk and wool it is possible to show an actual change in sign of charge.

The work of Linder and Picton[111] may be mentioned here. They stated that dyeing is connected with the electrical charges which substances carry when existing in colloidal solution. They experimented on colloidal ferric hydroxide and basic dyes which carry positive charges and arsenious sulphide and acid dyes which are negatively charged. Hence—as two oppositely-charged colloidal solutions precipitate one another—soluble blue (acid) precipitates ferric hydroxide, but methyl violet does not Exactly the reverse process occurs with arsenious sulphide. Ammonium sulphate also precipitates colloidal ferric hydroxide, but they found a distinction between its action and that of the dye. A definite quantity only of the salt is required to precipitate the colloid, and more added remains in solution. However, with the dye, after the colloid had been precipitated the dye continued to be adsorbed by the ferric hydroxide as a whole. They explained this by assuming that the precipitated colloid still retained a portion of its original charge, and that by virtue of this it still continued to take up more dye. The same kind of action was supposed to take place in dyeing—the fibre taking the place of ferric hydroxide or arsenious sulphide.

These facts will account for the phenomena of dyeing wool with a basic dyestuff of the methylene-blue type: it is an evident case of mutual discharge and consequent precipitation by two oppositely-charged colloids,

[110] *Loc. cit.*

[111] *Journ. Chem. Soc.* 1905, pp. 1931–1935. See also *Journ. Chem. Soc.* 1892, **61**, 114, 137, 148; *ibid.*, 1895, **67**, 63; *ibid.*, 1897, **71**, 568.

and the effect of adding either acid, base, or salt to the bath can also be demonstrated. But the colloid-precipitation theory can by no means be directly applied to dyeing with acid dyes upon animal fibres in the neutral bath: the fibre charges itself negatively, the dye also has a negative charge, and no two colloids of the same sign will precipitate each other. This leads Pelet-Jolivet[112] to revert to the adsorption theory, assuming that the dyestuffs act as unhydrolysed electrolytes in their solutions, and are adsorbed according to the valency of their combining ion, *e.g.*—the sodium salt of the colour acid should dye less strongly than the calcium or magnesium salt, and this less strongly than the aluminium salt or than the free acid with its hydrogen ion, similarly the hydrochloride of a basic dyestuff should give weaker colours than the sulphate or than the phosphate, or finally than the hydrate with its OH ion. This theory Pelet was able to demonstrate clearly by experiments both with acid and basic dyes upon wool, he concludes that the dyes, as von Georgievics, Walker Appleyard, and Vignon had already stated, act as dissociable electrolytes in the bath and dye according to valency—the H and OH ions always having disproportionate action to their valency.

These results also accord with his experiments (following Goppelsroder[113]) in capillary-ascent of various dyes (in water-solution) in strips of linen, cotton, flannel, and silk cloth, as well as filter-paper. Positive dyestuffs (colloid) cease to ascend at the actual surface of the liquid; added acids cause them to ascend, and decrease the ascent of acid dyes, alkalies will not cause acid dyes to ascend further, and actually decrease the ascent of basic dyes.

The dyeing process by adsorption plus dissociation Pelet ingeniously explains by assuming an accompanying dissociation of the water, the fibre becomes covered in the case of basic dyes by a 'double layer' of H and OH ions, which, like those of the sodium, &c., base in acid dyes and the SO_4, &c., ion in basic dyes, are very small and mobile in contrast with the large organic ion, and therefore reach the fibre first and deposit themselves as a film upon it, giving it thus their charge. The organic ion of the dyestuff has an opposite charge to these, and fixes itself, by a process analogous to coagulation, upon them. The actual existence of this 'double layer,' which by selection results in a fixation of the dye accompanied by a quantitative survival of the acid in the bath, has been demonstrated by Pelet, von Helmholtz, G. Quincke, and A. Pellot to exist on the surface of solid bodies immersed in water. Similar cases of chemical action subsequent to adsorption have been noticed by H. Freundlich and W. Neumann.[114]

It would appear that in this theory—which takes account of the electrical properties of solutions colloidal and crystalloidal, of the phenomena of contact-electrification and surface-tension expressed in terms of capillary attraction, of the effect of temperature upon all these, without denying the possibility of chemical reaction between the fibre and the dye presented to it—lines are laid down upon which an adequate theory of the dyeing process may develop.

[112] *Theorie des Farbeprozesses*, p. 105, Pelet-Jolivet and N. Anderson, *Koll. Zeitschr.* 1908, **8**, 206.

[113] 'Verhandlungen der Naturforschenden Gesellschaft zu Basel,' *Koll. Zeitschr.* 1909–10, **4**, 5, 6.

[114] *Zeitschr. f. phys. Chem.* **67**, 538.

Wm. Harrison and Haldane Gee[115] proceeded now to carry out their experiments testing this electrical theory and found it to explain phenomena observed better than the adsorption theory, which Lewis[116] had discredited on the grounds that it demands a decrease in amount of dye adsorbed under increase of temperature. These authors claim that it is always an electrical phenomenon: if the dye be colloid, then coagulation results from neutralisation of charge, if not colloidal, then it is ionised in solution and deposited by contact-electrification charges acting on the ions.

They discovered a most important phenomenon, *i.e.*, that the maximum negative charge attained by wool, silk, and cotton was at 40°. This is undoubtedly strong evidence in favour of an electrical phenomenon, as Brown[117] found that wool absorbed most basic colour at about 40°.

Harrison refers to the physical constitution of the fibres, as the surface (on which the charge rests and to which the dye-particles wander to fix themselves) is greatly increased by the porosity and irregularity of the fibre. He suggests that the dye-particles, if very large, will not fix on silk so well as on wool or as on cotton (this being the order of increasing size of their pores); by this theory Harrison also explains the adsorption and fixation of the direct cotton-colours.

In his dyeing experiments various salts, &c., are added, none of which tend to retard coagulation or to decrease the size of the particles, but rather the reverse. The dye should, therefore, be fastest dyed without salts, and this Harrison finds to be the case. Also, as an increase in temperature decreases the size of the particles, it should increase the fastness of the resulting dyeings. This also he finds to be true.

Feilmann expressed his ideas of dyeing similarly to those of Gee and Harrison, *i.e.*, that the dye was attracted electrically by the oppositely-charged fibre. He also asserted that the ion of the dyestuff penetrated the fibre more or less deeply, and was retained either because the fibre acted as a protective colloid or because chemical action took place between the ion and the fibre.

COLLOID CHEMISTRY IN THE FERMENTATION INDUSTRIES.

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[115] *Trans. Faraday Society*, 1910, April (*Journ. Manic. Sch. Techn. Manchester*, vol. iv., 1911, pp. 131–154), Paper (Harrison) *Journ. Soc. Dyers and Col.*, 1911, p. 279. They append to their paper a translation of Pelet's tables of affinity between colloid-coagulation, contact-electrification, capillary ascent and dyeing, as does also Zsigmondy (*Kolloid Chemie*, p. 229).

[116] *Phil. Mag.* 1908 (6) **15**, p. 499.

[117] *Journ. Soc. Dyers and Col.* 1901, p. 92.

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'The Selective Permeability of the Coverings of the Seeds of *Hordeum vulgare*.' ADRIAN J. BROWN. ('Proc. Royal Soc. **B**. Vol. **81**, 1909,)

The seeds are furnished with a covering permeable by water and certain classes of solutes when in aqueous solution; with the majority of solutes, however, the covering behaves as a true semipermeable membrane.

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'Cause of Precipitation in Finished Pasteurised Bottled Beer.' F. EMSLANDER. ('J. Inst. Brewing,' 1912, **18**, 484.)

The 'head-retaining power' and 'palatefulness' of beer are due to ultramicroscopic particles of albumen existing in the form of an emulsion-colloid. Turbidity is occasioned by coagulation of the particles induced by physical or chemical influences. The stabilising influence of acids (*i.e.*, H ions) is discussed.

L. WALLERSTEIN. New York. (Eng. Patent 12,350, May 22, 1911.)

Object of process is the rendering of beer chill-proof by treatment previous to bottling with proteolytic enzymes (*e.g.*, pepsin or papain), to hydrolyse albumins causing turbidity. (See 'J. Inst. Brewing,' 1912, **18**, 491.)

'Colloidal Chemistry and Brewing.' EMIL HATSCHEK ('J. Inst. Brewing,' 1912, **18**, 494.)

A general survey of colloidal chemistry, with special reference to questions such as 'head' formation, haze, &c., which are of particular importance in brewing.

'Plant Colloids Gelatinisation of Starch in Presence of Crystalloids.' M. SAMEC. ('Kolloidchem. Beiheft,' 1911, **3**, 123. Abst. 'J. Inst. Brewing,' 1912, **18**, 694.)

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'Reactions of Tannin and their Importance in Brewing.' A. REICHARD. ('Zeitschr. Chem. und Ind. Kolloide,' 1912, 209. Abst. 'J. Inst. Brewing,' 1912, **18**, 695.)

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Author suggests that the selective permeability of the inner covering of barleycorn may be occasioned by the tannin present. (See A. J. BROWN, p. 1.)

'Beer Haze.' F. SCHONFELD. ('Wochenschr. Brau.' 1912, 29, 557. Abst. 'J. Inst. Brewing,' 1912, **18**, 696.)

The paper contains illustrations of different types of beer haze.

'The Influence of Temperature on the Absorption of Water by the Seeds of *Hordeum vulgare* in relation to the Temperature Coefficient of Chemical Change.' ADRIAN J. BROWN and F. P. WORLEY. ('Proc. of Royal Soc.' **B**. 1912, **85**, 546.)

The velocity with which water is adsorbed by the seeds is an exponential function of the temperature, and is comparable with the vapour pressure of water, which is also approximately an exponential function of the temperature. The velocity of adsorption of water from a solution of ethyl acetate is also an exponential function of the temperature, but the actual velocity is higher in the presence of ethyl acetate than in the presence of pure water. Probably the partial pressure of water vapour is increased by the presence of ethyl acetate.

'Use of Gelatinous Silica for the Clarification of Beer.' P. DEPRAX. ('Ann. Brass. et. Dist.' 1912, 15, 410. Abst. 'J. Inst. Brewing,' 1913, **19**, 52.)

'On the Flocculation or "Break" of Worts and Beers and its Significance in Brewing Practice.' HORACE T. BROWN. ('J. Inst. Brewing,' 1913, **19**, 84.)

The persistent turbidity produced on cooling a hopped malt wort is occasioned by a suspension of particles of a tannin-protein compound soluble in hot wort, insoluble in cold. Most of the particles are formed during cooling between the limits of 49° C. and 27° C. If the wort is strongly agitated when cooling between these limits, flocculation takes place, otherwise flocculation is rendered difficult owing to the protective influence of the dextrins of the wort. A suspension of the tannin-protein compound is injurious to the propagation and fermentative power of yeast, and adversely affects the flavour of the resulting beer owing to adsorption of hop resin on the surface of the suspended particles. A technical means of inducing flocculation during cooling of the wort is indicated.

'Practical Observations and Studies of Albumin Turbidities in Beer caused by Tin and Iron.' G. L. GOOB. ('Eighth Internat. Cong. Appl. Chemistry,' 1912. Abst. 'J. Inst. Brewing,' 1913, **19**, 147.)

'Head on Beer.' A. FERNBACH. ('Ann. Brass. et Dist.' 1913, **16**, 145. Abst. 'J. Inst. Brewing,' 1913, **19**, 400.)

The relation of the colloids of beer to the formation, nature, and retention of 'head' is discussed.

'Electrical Dialysis of Enzymes: Application of the Principle to the Purification of Malt Diastase.' M. LISBONNE and M. VULQUIN. ('Journ. de Physiol. et Pathol.' 1913, **15**, 24. Abst. 'J. Inst. Brewing,' 1914, **20**, 64.)

'Removal of Oil from Condenser Water by Electrolysis.' H. WINKELMANN. ('Zeitschr. ges. Brauw. 1913, **36**, 664. Abst. 'J. Inst. Brewing,' 1914, **20**, 78.)

'Colloids as Vehicles of Undesirable Flavour in Beer.' F. EMSLANDER. ('Wochenschr. Brau.' 1913, **30**, 387. Abst. 'J. Inst. Brewing,' 1914, **20**, 80.)

'Plant Colloids, III.—Processes of Solution and Removal of the Ash of Starch.' M. SAMEC and F. VON HOEFFT. ('Koll. Chem. Beihefte,' 1913, **5**, 141. Abst. 'J. Inst. Brewing,' 1914, **20**, 124.)

'Concentration of Hydrogen Ions in Beer, and its Relation to the Brewing Process.' F. EMSLANDER. ('Zeitschr. Ges. Brauw.' 1914, **37**, 2. Abst. 'J. Inst. Brewing,' 1914, **20**, 136.)

The colloids of beer migrate towards the cathode. The difference between the concentration of hydrogen ions and the acidity of beer as found by titration is discussed. A form of apparatus is suggested for the measurement of ion concentration for technical use.

'An Account of Some Investigations on the White Wines of South Africa an Œnological Study.' HORACE T. BROWN. ('J. Inst. Brewing,' 1914, **20**, 345.)

The white wines of the Cape are peculiarly liable to turbidity or 'casse,' accompanied by an increase in colour and a bitter flavour. 'Casse' is not due to micro-organisms, but is conditioned by purely chemical changes, and only arises in contact with air or with oxygen derived from some such source as hydrogen peroxide. The oxidising agent inducing 'casse' does not belong to the class of vegetable oxidases, but consists of a small amount of iron in the ferrous state present in the wine, which behaves as a carrier of oxygen (Fenton's reaction). The 'casse' itself consists of colloidal particles of a combination of iron with products derived from the limited oxidation of tannins and certain proteins present in the wine. The grape contains a peroxidase in the inner cells of the epidermis and in the vascular bundles of the fruit, but freshly expressed grape-juice contains no peroxidase unless the juice of the fruit has remained in contact with the skin for some time. If the amount of oxidase in the juice is considerable it has a tendency to brown on exposure to the air, but there appears to be no connection between the occurrence of oxidase and the *casse ferrique* referred to above.

'Estimation of Colloids in Beers.' R. MARC. ('Kolloid-Zeitschr.' 1914, **14**. Abst. 'J. Inst. Brewing,' 1914, **20**, 431.)

Measurements made by means of refractometer readings before and after adsorption of colloids by barium sulphate.

'Green Sickness (Verdissement) of Ciders.' WARCOLLIER. ('Comptes Rendus,' 1914, **158**, 973. Abst. 'J. Inst. Brewing,' 1914, **20**, 457.)

'Variations in the Phosphorus-content of Starch accompanying its Changes of State.' M. Samec ('Kolloidchemische Beihefte,' 1914, **6**, 23. Abst. 'J. Inst. Brewing,' 1914, **20**, 716.)

'Influence of some Colloids on Alcoholic Fermentation' N. L. Sohngen. ('Folia Microbiologica,' 1913, **2**, 94. Abst. 'J. Inst. Brewing,' 1914, **20**, 720.)

'Retention of Head on Beer.' O. Furnrohr. ('Zeitschr. Ges. Brauw.' 1913, **36**, 473. Abst. 'J. Inst. Brewing,' 1914, **20**, 596.)

'Melanoidines in Roasted Malt.' W. Ruckdischel ('American Brewers' Journal,' 1915, **39**, 107. Abst. 'J. Inst. Brewing,' 1915, **21**, 123)

The melanoidines are colloidal condensation products formed during the heating of ammo-acids and dextrose present in malted grain

'The Rate of Adsorption of Various Phenolic Solutions by Seeds of *Hordeum vulgare*, and the Factors Governing the Rate of Diffusion of Aqueous Solutions across Semipermeable Membranes.' Adrian J. Brown and F. Tinker. ('Proc. Royal Soc.' **B**. Vol. **89**, 1915.)

When the osmotic pressures, vapour pressures, and viscosities of a series of solutions of permeable solutes such as the phenols are equal, their rates of diffusion across the barley membrane are inversely proportional to their surface tensions.

'Gluten Turbidity.' E. Moufang. ('Allgem. Zeitschr. fur Bierbrau. und Malzfabr.' 1915, **43**, 275. Abst. 'J. Inst. Brewing,' 1916, **22**, 468.)

'Brewers' Filter Pulp.' W. A. J. Foster. ('J. Inst. Brewing,' 1916, **22**, 413.)

'Sensitiveness of Beer towards Cold and the Wallerstein Process.' P. Petit. ('Brasserie et Malterie,' 1916 **6**, 61. Abst. 'J. Inst. Brewing,' 1916, **22**, 468.)

'Pre-mashing and Protein Haze Concentration of Hydrogen Ions in Beer.' F. Emslander ('Wochenschr. Brauw.' 1916, **33**, 169. Abst. 'J. Inst. Brewing,' 1916, **22**, 509.)

'Selective Permeability: The Absorption of Phenol and other Solutions by the Seeds of *Hordeum vulgare*.' Adrian J. Brown and F. Tinker. ('Proc. Royal Soc.' **B**. vol. **89**, 1916.

The various solutes enter the barley seeds in an amount which is indicated by the extent to which they are adsorbed by the barley membrane and by the colloidal contents of the seeds. The solutes which are most strongly adsorbed are those which give solutions having low surface tensions and *vice versâ*.

RUBBER

By Dr. Henry P. Stevens.

Bibliography.

(1) *Composition and Properties of Latex and Raw Rubber.*

'Some Analyses of *Hevea* Latex,' C. Beadle and H. P. Stevens ('The Analyst,' 1911, **36**, 8). Gives the results of analyses of latex from the cortex of the trunks of trees of different ages and also from leaf petioles

'An Investigation into the Nature and Properties of *Hevea* Latex,' C. Beadle and H. P. Stevens ('8th Inter. Congress of Applied Chem' Vol. 9, pp. 40-43). Part 1 contains a study of the phenomena accompanying coagulation; distinctions are drawn between the microscopic and macroscopic forms in which coagulation takes place and the effect of formaline on latex. The quantities of acid required for coagulation under different conditions are given Part 2 contains the results of the chemical analyses of three samples of *Hevea* latex.

'The Carbohydrate Constituents of Pará Rubber,' Pickles and Whitfield ('Proc. Chem. Soc.' 1911, p 54). It is shown that sheet rubber from *Hevea* latex contains appreciable quantities of l-methyl inositol.

(2) *Production of Raw Rubber*

The Rubber Growers' Association, 'Revised Tables of Recommendations for the Treatment of Latex and Curing of Rubber,' 1917. The original table has been revised and split up into two tables, one dealing with sheet and the other with crêpe rubber. These tables give concise instructions for the preparation of rubber from the latex, giving proportion of coagulant, preservatives, &c., to be used, types, construction and handling of plant and machinery, instructions for straining, bulking, standard-

ising, coagulating, washing, rolling, drying and sorting, grading, curing, packing, and a list of defects commonly met with and the preventives which can be adopted.

'A Comparison of the Brazilian and Plantation Methods of Preparing Para Rubber,' G. S. WHITBY ('Journ. Soc. Chem. Ind.' 1916, p. 493). Gives the results of comparative tests on rubber prepared in the East by the Brazilian method, smoking and coagulation in thin films, and the typical plantation method of coagulation and rolling to sheets, followed by smoke-drying. Two series of samples were prepared, one from the latex from young trees (five years old) and old trees (fifteen years old). The conclusions arrived at were that the rubber prepared by the Brazilian method was a little inferior to that produced by the plantation method. It was, however, suggested in the discussion following the paper that the Brazilian method of smoking had not been exactly imitated. There was little difference between the rubber from young and old trees. The following conclusions were also arrived at:—Phenols absorbed from the smoke reduce the rate of cure, and, generally speaking, rubber is not improved by smoking, and latex crêpe may be very seriously deteriorated by this means; 'oxidation' has no ill effect on the quality, and, contrary to the generally accepted view, there is practically no difference in quality between the outer 'oxidised' portion and inner portion of a ball of fine hard Pará.

Comparative tests on rubber from groups of trees in different areas showed marked variation. Also latex allowed to stand before coagulation gave rather better results than that coagulated straight away.

'On the Coagulation of *Hevea* Latex and a New Method of Coagulation,' B. J. EATON and J. GRANTHAM ('Agric. Bull. Federated Malay States,' vol. 4, No. 2 (1915), p. 26). When latex is coagulated spontaneously by exposure to the air there is formed an alkaline scum on the surface where coagulation does not take place, while underneath the serum reacts acid and coagulation is more or less complete (G. S. WHITBY, 'Congress of Applied Chem.' 1912; 'Koll Zeit.,' 12, 153). At the same time, strong putrefactive odours develop. The authors find that the putrefactive changes are inhibited while the development of the coagulating agencies have free play if a small quantity of sugar, *e.g.*, 0·2 per cent. dextrine, be added to the latex.

Eng. Pat. 104,323 of 1916, G. M. THOMAS and M. D. MAUDE, claims the process for allowing latex to coagulate spontaneously out of contact with the air, by which the formation of the surface scum is prevented. EATON and GRANTHAM, however, state in the above communication that the coagulation is frequently incomplete when this is effected merely by exclusion of air, whereas in the presence of sugar coagulation is complete either under aerobic or anaerobic conditions. S. MORGAN, however, finds that even in the presence of sugar coagulation is often incomplete (private communication).

Other patents deal mostly with methods of evaporating latex in thin layers, as in native Brazilian Pará.

'Bull. Agric. Intell.' 1915-16, 1703-4. M. KERBOSCH states that rubber obtained by evaporation of latex is less readily oxidised under the influence of sunlight than that produced by coagulation in the ordinary manner.

(3) *The Non-Caoutchouc Constituents of Raw Rubber.*

Nitrogenous constituent.—D. SPENCE was the first to show that the insoluble constituent of rubber (*i.e.*, insoluble in organic solvents such as chloroform, benzene, &c.) was highly nitrogenous, and in fact consisted of protein matter coagulated with the caoutchouc in the latex ('Journ. Liverpool Univ. Inst. of Commercial Research in the Tropics,' No. 13, 1907). Distribution of the protein in Pará rubber.

C. BEADLE and H. P. STEVENS subsequently showed that the nitrogenous or insoluble constituent was necessary for satisfactory vulcanisation, as its removal reduced the proportion of combined sulphur, and such rubber, vulcanised under normal conditions, had poor physical properties. It was also found that the nitrogenous constituent could be satisfactorily replaced by nitrogenous matter of foreign origin, such as peptone, and less satisfactorily by casein. The choice of nitrogenous substances was limited by the difficulty of incorporating them with the rubber. ('Koll. Zeit.' 1912, 11, p. 61, 1913, 12, p. 46; 'Journ. Soc. Chem. Ind.' 1912, 31, p. 1099; H. P. Stevens, 'Koll. Zeit.' 1914, 14, p. 91.)

D. SPENCE and G. D. KRATZ ('Koll. Zeit.') employ a ·3–·5 per cent. solution of trichloracetic acid in benzene for separating the nitrogenous constituent. When the rubber is swollen in this solvent it rapidly breaks down, giving a solution of low viscosity from which the insoluble nitrogenous constituent is easily separated. Spence examined the

product thus obtained, which contains about 10 per cent. of nitrogen, and regards it as a glycoprotein.

Eaton and Grantham found that if freshly coagulated latex be allowed to remain for a few days before washing or rolling the rubber eventually obtained is rapidly-curing and possesses considerably superior physical properties after vulcanisation ('Agric. Bull. F.M.S.' 1915, **3**, p. 442, and **4**, p. 58, also 'Journ. Soc. Chem. Ind.' 1916, **35**, p. 715). This increase in rate of cure they attributed to some accelerating substance formed in the rubber by the action of micro-organisms, as they found that freezing the rubber inhibited the development of the rapid-curing properties, but these were restored on allowing the temperature to rise again. Further, formalin and other antiseptic treatment, *e.g.*, smoking, had also an inhibiting effect. They also observed that once the rapid-curing effect was produced, this was not destroyed by heating to relatively high temperatures, as in the treatment of the rubber in a hot-air drier or by washing on crêping rolls.

J. Grantham ('Agric. Bull. F.M.S.' **4**, pp. 1-4) published a number of nitrogen determinations of plantation rubber and concludes that smoking appears to fix the nitrogen. Generally speaking, matured 'slab' gave low figures, especially after crêping, in spite of the rapid-curing properties of this rubber.

H. P. Stevens confirmed Eaton and Grantham's results and succeeded in separating the accelerating substance, which was found to be an organic base or mixture of bases formed during putrefaction. The rapid-curing properties were found to be partly, but not completely, removed by washing on crêping rollers. ('Journ. Soc. Chem. Ind.' 1917, **36**, p. 365.) Larger quantities of base could be extracted from rapidly-curing rubber than from slow-curing rubber. The bases can also be obtained from the latex serum and produce acceleration of vulcanisation when added to ordinary crêpe.

Synthetic organic accelerators.—A general description of organic accelerators for vulcanisation and their characteristics have appeared at various times (Ditmar, 'Gummi Zeitung,' 1915, **29**, p. 425; Gottlob, 'Gummi Zeitung,' 1916, **30**, p. 303; A. H. King, 'India Rubber Journ.' 1916, **52**, p. 440; S. J. Peachey, 'I.R.J.' 1916, **52**, p. 603; S. J. Peachey, 'Journ. Soc. Chem. Ind.' 1917, **36**, p. 424). The first patent of importance is given as that of Bayer & Co., Elberfeld Farbenfabrik, Ger. Pat. 265,221 of Nov. 16, 1912. This was for the use of piperidene. Subsequently it was recognised that all organic bases act as accelerators, but that only those having a high dissociation constant are sufficiently powerful for technical work. This led to the patent taken out by Bayer & Co., claiming all organic bases having a dissociation constant greater than 1×10^{-8} (Ger. Pat. 280,198 of 1914). S. J. Peachey has patented the nitroso-derivatives of certain bases (Eng. Pat. 4,263 of 1914), particularly *p*-nitroso-dimethyl aniline, which differ from compounds previously referred to in that they are not strong bases and are yet very effective accelerators. Peachey has also patented condensation compounds formed by the interaction of aldehydes and amines (Eng. Pat. 7,370 of 1914), but these substances are not so powerful as the nitroso-derivatives.

D. Spence ('Journ. Soc. Chem. Ind.' 1917, **36**, p. 118) claims to dispose of the novelty of all these inventions, and states that, six months previous to the date of application of the Bayer patent of 1912 (covering the use of piperidene), he described experiments in which piperidene was used in the 'Kolloid Zeitschrift,' 1912, **10**, pp. 303-305.

Dunlop Rubber Co. and Twiss (Eng. Pat. 1916, 17,756) have patented the use of caustic soda or potash in solution in glycerol as a vulcanising accelerator. The accelerating effect of mineral bases is well known, particularly lime and magnesia. The glycerol is used as an agent for incorporating the alkali in the rubber (see also paper by D. F. Twiss ('Jour. Soc. Chem. Ind.' 1917, **36**, 782).

Resinous constituent.—L. E. Weber, 'The Action of Resins in the Vulcanising of Rubber' ('Inter. Congress of Applied Chem.' 1912, **9**, 95). The author prepared three compounds from the same mixing, containing rubber, litharge, sulphur, and whiting, as follows:—Compound A was prepared with plantation-smoked sheet, which had been cut up and extracted for fifteen hours with acetone. Compound B exactly resembled the foregoing except that the rubber was used without previous extraction. Compound C was identical with compound B except that it contained in addition the resins (acetone extract) obtained from the rubber used for compound A. On vulcanising (in water) it was found that compound A 'could not be vulcanised,' that is to say, cured for one hour at 140° C.; 'it showed a strength of less than 20 lb.,' while compounds B and C variously cured gave figures up to 800 lb. with irregular differences. The author

concludes that 'the resins play an active part in the vulcanisation and not merely the part of catalyser. Their presence is absolutely essential.'

C. BEADLE and H. P. STEVENS, 'The Nature of the Resinous Constituent and its Influence on the Quality of Rubber' ('Inter. Congress of Applied Chem.' 1912, **25**, 581). The authors made comparative vulcanising tests with *Hevea* and Rambong (*Ficus elastica*) rubbers, one compound prepared from acetone (or alcohol) extracted rubber and the other from the untreated rubber. The compound employed consisted of the rubber (treated or untreated) and sulphur without other ingredients. They noted that the compound prepared from the extracted rubber appeared undercured when compared with a control specimen of untreated rubber, but the main difference between the vulcanised samples was shown on keeping the vulcanised specimens, when those prepared from the extracted rubber rapidly hardened and deteriorated (perished).

H. P. STEVENS, 'The Function of Litharge in the Vulcanisation of Rubber,' Part II., 'The Influence of the Resinous Constituents' ('Journ. Soc. Chem. Ind.' 1916, **35**, p. 874). The author describes further comparative tests with resin-extracted rubber, using compounds with and without litharge and determining the coefficient of vulcanisation.

(4) *Vulcanisation.*

Spence and his collaborators ('Koll. Zeit.' 1911, **8**, 304, **9**, 83, 300; 1912, **10**, 299; **11**, 28, 274; 1913, **13**, 265).—The process of vulcanisation is studied in a systematic series of experiments, and the conclusions arrived at point to vulcanisation as essentially a chemical reaction between sulphur and the caoutchouc, the amount of combined sulphur being proportional to the time of heating with a temperature coefficient of approximately 2·7 for a rise of 10° C. Moreover, when the amount of sulphur is limited (*e.g.*, 10 per cent. on the caoutchouc), the whole becomes combined on prolonged heating, and with an excess of sulphur the maximum combined sulphur corresponds approximately to the formula $C_{10}H_{16}S_2$ (compare also C. O. Weber, 'The Chemistry of India Rubber,' pp. 87-91; also Hinrichsen and Kindscher, 'Gummi Zeit.' 1903, **18**, 251; 'Koll. Zeit.' 1912, **11**, 191; 'Ber.' 1913, **46**, 1291).

SKELLON, in more recent work, gives a great amount of data which confirms the above ('Koll. Zeit.' 1914, **66**, p. 96; 'The Rubber Industry papers read at the Exhibition held in London in 1914,' p. 172).

F. W. HINRICHSEN and K. MEIZENBERG ('Ch. Zeit.' 1909, **33**, p. 756). Quantitative experiments on cold vulcanisation.

E. STERN ('Ch. Zeit.' 1909, **33**, p. 256), 'Study of the Reaction between Rubber and Sulphur in Solution in Naphthalene.'

HARRIES and FONROBERT ('Ber.' 1916, **49**, 1196 and 1390). Rubber was vulcanised in sheets 6 mm. thick by heating a mix containing 10 per cent. of sulphur for thirty minutes at 145° C. After sixty days' extraction with hot acetone, only 0·25 per cent. sulphur remained, and it is concluded that this would have been removed if the extraction had proceeded long enough. It is therefore concluded that vulcanisation is a physical change. A distinction, however, is drawn between vulcanisation as carried out above, which the authors term 'primary vulcanisation,' and the more fully vulcanised product obtained by longer heating or by 'after-vulcanisation' of the primary vulcanised body.

D. F. TWISS ('Journ. Soc. Chem. Ind.' 1917, **36**, 782). This paper contains a review of the subject and a very full reference list. The original work contained in it deals particularly with the relative reactivities of $S\mu$ and $S\lambda$ as vulcanising agents. It is concluded that the modification in which the sulphur is employed is practically without influence on the course of vulcanisation. Compare also Dubosc ('Le Caoutchouc et la Gutta Percha,' Jan. 1917).

I. I. OSTROMYSLENSKI ('Journ. Russ. Physico-Chem. Soc.' 1915, **47**, 1453 *et seq.*, 1885 *et seq.*; also

Vulcanisation of caoutchouc by means of halogen compounds, and mechanism of the vulcanisation process.	'Journ Soc. Chem. Ind.'	1916,	**35**,	370
Hot vulcanisation of caoutchouc by means of nitro-compounds in absence of sulphur.	,,	,,	,,	,,	59
Hot vulcanisation of caoutchouc by means of peroxides or per-acids, in absence of sulphur.	,,	,,	,,	,,	59

Cold vulcanisation of caoutchouc by means of sulphur, trinitrobenzene, or benzoyl peroxide.	'Journ. Soc. Chem. Ind.'	1916,	**35**,		369
Mechanism of vulcanisation of caoutchouc.	,,	,,	,,	,,	59
Mechanism of action of amines and metallic oxides on the vulcanisation of caoutchouc	,,	,,	,,	,,	370
Vulcanisation of caoutchouc by molecular oxygen, ozone, or organic ozonides.	,,	,,	,,	,,	370
Vulcanisation of synthetic caoutchouc.	,,	,,	,,	,,	58
Preparation of vulcanised caoutchouc coloured by organic colouring matters.	,,	,,	,,	,,	371
Process for obtaining a substance identical with or analogous to natural vulcanised rubber.	,,	,,	,,	,,	131

I. I. Ostromyslenski and I. M. Kelbasinskaja ('Journ. Soc. Chem. Ind.' **35**, 58, "New Constants of Caoutchouc, Elasticity Point and Fatal Temperature').

The first three papers describe methods for producing a vulcanised rubber without the use of sulphur by heating the rubber (*a*) with nitro-aromatic derivatives, *e.g.*, trinitrobenzene, or (*b*) with organic peroxides, *e.g.*, benzoyl peroxides.

H. P. Stevens ('Journ. Soc. Chem. Ind.' 1917, **36**, 107) has shown that reaction (*a*) only proceeds in the presence of a base such as PbO or MgO, and that the products are inferior technically to rubber vulcanised with sulphur. (Compare also Twiss (p. 63).

H. Heilbronner and J. Bernstein ('Rubber Industry,' 1914, 156; 'Caoutchouc et Gutta Percha,' 1915, **12**, 8720) describe a method of vulcanisation in which rubber and sulphur in solution are exposed to the action of ultra-violet light from a quartz mercury vapour-lamp. Once the solvent has evaporated from this solution the rubber becomes insoluble.

(5) *Physical Testing of Vulcanised Rubber.*

P. L. Wormeley ('Rubber Industry,' 1914, 246-256). This paper brings out the great influence exerted by temperature on the results of physical tests.

P. Schidrowitz ('Rubber Industry,' 1914, 230-245), 'Outline of a Method of Physical Tests.'

H. P. Stevens ('Journ. Soc. Chem. Ind.' 1916, **35**). Criticises current methods of testing, particularly with regard to state of cure of the specimens tested and the ageing factor.

A. van Rossem ('Bijdrage tot de Kennis van het vulcanisatieproces,' Amsterdam, 1916) contains the results of tests on a very large number of vulcanised rubber samples, with mathematical treatment of same.

See also publications of the International Association for Rubber Cultivation in the Netherlands Indies, Delft, Part I., published in 1917, 'Bulletin of Imperial Institute,' 1916, **14**, 495.

(6) *Synthetic Rubber.*

I. I. Ostromyslenski ('Journ. Russ. Phys.-Chem. Soc.' 1915, **47**, 1441 *et seq.*, 1928 *et seq.*; 1916, **48**, 1071 *et seq.*

Condensation of alcohols and aldehydes in presence of dehydrating agents	'Journ. Soc. Chem. Ind.'	1916,	**35**,		69
New syntheses of caoutchouc and its homologues.	,,	,,	,,	,,	368
Mechanism of transformation of isoprene and β myrcene into caoutchouc.	,,	,,	,,	,,	369
Production of caoutchouc.	,,	,,	,,	,,	130
Constitution of caoutchoucs.	,,	,,	,,	,,	369
Definition, classification and evaluation of caoutchoucs.	,,	,,	,,	,,	57
New methods of preparation of divinyl, isoprene, piperylene, and dimethyl-erythrene.	,,	,,	,,	,,	380
Formation of erythrene	,,	,,	,,	,,	69
New methods of preparation of erythrene.	,,	,,	,,	,,	69

Transformation of cyclobutane derivatives into erythrene.	'Journ. Soc. Chem. Ind.'	1916,	**35,**		381
Synthesis of the symmetrical bromide of erythrene-caoutchouc, of caoutchouc itself and of caoprene.	,,	,,	,,	,,	368
Preparation of esters of unsaturated alcohols from aldols.	,,	,,	,,	,,	382
Polymerisation of ethylenic compounds and mechanism of transformation of vinyl bromide into bromide of erythrene-caoutchouc.	,,	,,	,,	,,	369
Analysis, purification, and reactions of isoprene.	,,	,,	,,	,,	381
Polymerisation of isoprene. divinyl and dimethylerythrene to caoutchouc or its homologues.	'Journ. Chem. Soc '	1917,	**112,**	i.	399
Preparation of substances equivalent to ebonite, celluloid or gutta percha. Synthesis of vulcanised caoutchouc.	,,	,,	,,	,,	i. 403
Synthesis of the symmetrical chloride and of the higher chloride of erythrene caoutchouc. New chlorides of natural isoprene and erythrene caoutchoucs. ('J. Russ. Phys. Chem. Soc ' 1916, **46,** 1132-1151.)	,,	,,	,,	,,	i. 404

B. D. W. Luff ('Journ. Soc. Chem. Ind.' 1916, **35,** 983). 'Some Aspects of the Synthesis of Caoutchouc.'

Kondakow ('Caoutchouc et Gutta Percha,' 1917, July 15). Deals historically with his own researches.

Note.—'Rubber,' by Dr. H. P. Stevens, forms one of the sections in the 'Annual Reports on Industrial Chemistry,' vol i., issued by the Society of Chemical Industry.

COLLOID CHEMISTRY OF STARCH, GUMS, HEMICELLULOSES, ALBUMIN, CASEIN, GLUTEN, AND GELATINE.

By H. B. Stocks, *F.I.C.*

Starch.

The application of starch in the sizing and finishing industries, for which it is used in very large quantities, depends entirely upon its colloidal properties. That is, on heating with water, it forms a plastic mass, or adhesive sol, according to the concentration and the temperature. It can therefore be readily applied to textile fibres or fabrics. In the sizing industry it is applied to the yarn—the warp—to strengthen it, render it smoother (*i.e.*, lay the individual fibres), and thus facilitates weaving, while in heavy sizing it acts as a binder to hold the weighting material, usually china clay, which is employed. For these purposes, although very useful, it is not altogether perfect, since, on drying, it does not form a continuous film. In calico-printing it is one of the mediums employed for carrying or thickening the colours, thus preventing them spreading into the surrounding tissues. For these purposes potato starch or farina, wheat-starch and wheat-flour, sago, tapioca, maize, cassava, and rice-starch are employed.

It is well known that the granules of the various starches vary in appearance under the microscope, they also vary somewhat in their properties; for instance, sago, tapioca, and cassava starches yield more

tenacious or glutinous sols than the others, and for particular purposes certain starches may be found more suitable than others.

Starch absorbs a certain amount of water from the atmosphere; this varies with the conditions, but is usually from 13 to 15 per cent.; it also contains a small proportion of mineral matter, which is, in all cases, alkaline; this amounts in potato-starch to about 0·22 per cent., sago 0·4, cassava 0·12, maize 0·11, and wheat 0·23, therefore in dealing with natural starch we have to take into account the influence the electrolytes in this mineral matter will have upon the starch molecules.

On heating with water no action whatever is apparent until a temperature of about 55° C. is reached, when it is noticed that a few granules have swollen enormously; from this point onwards there is a progressive increase in the number of swollen granules, till at a certain temperature all the granules have become fully hydrated and most, if not all, have burst, although the granules can still be observed more or less distorted. The temperature at which this occurs is the maximum thickening-point of the mixture, this occurring with wheat-starch at 65° C., maize 70°, sago 72°, rice 74°, and potato-starch 63°.

The viscosity of solutions made from different starches varies; thus, G. M. MacNider ('Journ. Ind. and Eng. Chem.' 1912, **4**, 417–422) found the viscosity of potato-starch to be 14·31, maize 2·49–2·86, cassava 3·88–3·97, wheat 1·24–1·26, and rice 1·00 for solutions containing 12 grams in 30 c.c. of water. These figures need verification, as the differences appear to be very much greater than one would suppose possible, although, no doubt, a certain amount of variation does really exist. It was noted also by the above observer that very small quantities of borax (*i.e.*, ·08 gram) and of caustic soda (·06 gram) lowered the viscosity, while larger quantities (*i.e.*, 1·0 gram) increased it, the viscosity being also lowered by boric acid.

Since writing the above, the author has found that the time factor is most important. For instance, freshly prepared and quickly cooled potato-starch solution of 2 per cent. concentration gave the following figures (water = 1):—

Fresh.	5 min. later.	40 min. later.	18 hours later.
106·7	96·3	19·3	1·3

At the last period quite a considerable quantity of the starch granules had deposited, leaving a clear liquid on the surface, which could be filtered

The viscosity of starch solution does not therefore increase, as with other colloids, with the time.

It was at one time believed that starch granules consisted of two distinct substances, an inner material or granulose (amylose), and an outer material named starch cellulose or amylopectin; but according to Harrison ('Journ. Soc. Dyers and Colourists,' 1916, **32**, 40–44) the outer portion of the starch granules does not differ in composition from the inner material although it is more resistant to hydrolytic agents. By physical means alone they are capable of being changed one into the other. Z. Gatin-Gruzewska and L. Macquenne ('Compt. Rend.' 1908, **146**, 540–545) also conclude that there is a structural relationship between amylose and amylopectin, and that probably each is composed of a series of closely related substances.

The addition of certain substances to starch and water lowers the surface tension of the granules so that the thickening-point is more or less depressed; this is especially the case with caustic soda, zinc chloride, and

hydrochloric acid, which in concentrated solutions form a tenacious white translucent gel with starch even at the ordinary temperature; other metallic chlorides behave similarly to zinc chloride, although less marked in their action, but the chlorides of the alkalies appeared to be without effect. Gels made on these lines, containing 9 to 34 per cent. of starch, 4 to 20 per cent. of zinc chloride, and 0 to 19 per cent. of magnesium chloride, are sometimes sold for sizing purposes (H. B. Stocks and H G. White, 'J.S C I,' 1903, 22, and 'Jour. Soc. Dyers and Colourists,' March 1894).

E. Fouard ('Comp Rend' 1907, **144**, 501–503 and 1366–1368) found the amount of phosphoric acid in a starch containing 0·331 per cent. of ash to be 0·1915 per cent. By treatment with acid these were reduced to 0 123 and 0·1117 per cent. respectively, and he is of opinion that the acid is absorbed by the insoluble starch granule. Acids have a coagulating effect upon starch in proportion to their hydrogen-ion concentration, very weak acids having no appreciable effect. Alkalies, on the other hand, have an exactly opposite effect, either dissolving the starch or decreasing its tendency to coagulation, the retardation being strictly in proportion to their hydroxyl-ion concentration. Salts which hydrolyse in solution act upon starch in one or other of these directions according to the predominance of the hydrogen or hydroxyl-ions respectively. This coagulating effect of the hydrogen-ions and the swelling effect of the hydroxyl-ions is general throughout the whole of the organic and some of the inorganic colloids, and is a capillary phenomenon of the greatest importance.

The mineral matter of starch can be to a certain extent removed by precipitating a dilute sol with alcohol, or, better, by addition of ammonium carbonate. Sols of starch purified by these means are very unstable, the starch reverting to the insoluble form in very minute granules on standing. W. Harrison ('Jour. Soc. Dyers and Colourists,' 1916, **32**, 40–44), also L. Macquenne ('Compt. Rend.' 1908, **146**, 317–318), G. Malfitano and A. Moschkoff ('Compt. Rend.' 1910, **150**, 710–711), by successive freezing and thawing of solutions of starch, have obtained it almost free from mineral matter which remained in solution in the water. The starch thus prepared formed a heterogeneous mixture with water even after heating, and on standing the starch settled out again. These authors believe that starch is entirely insoluble in water but that in association with electrolytes it forms colloidal solutions.

The Arabol Man. Co. (Fr. Pat. 394,167, 1908) use KCNS for preparing starch soluble in cold water, while, according to W. Lenz ('7th Int. Cong. Appl. Chem. Lond.' 1909), sodium salicylate causes some starch granules, though not all, to swell.

Starch adsorbs alkalies and alkaline earths, the adsorption compounds, although unstable in water, appear to be more stable in contact with alcohol; thus starch precipitated from a solution in caustic potash by alcohol contains potassium in proportion to the strength of the caustic potash solution (E. Fouard, 'Bull. Soc. Chim.' 1909, **5**, 828–834). Precipitation of starch in presence of barium hydroxide by means of alcohol has also been proposed by Asboth ('Analyst,' July 1887; also 'Jour. Soc. Chem. Ind.' 1888, 77) as a method of estimating this substance by volumetric means, the compound containing 19·1 per cent. of BaO, corresponding with the formula $C_{24}H_{40}O_{20}BaO$. In order to get concordant results it is necessary that certain conditions as to strength of reagents, &c. should always be complied with. According to W. Harrison ('Jour. Soc. Dyers

and Colourists,' 1916, **32**, 40–44), the composition of the precipitate varies with the concentration of the barium hydrate according to the laws of adsorption. According to Tollens, starch combines with Na or K in the proportion of 1 atom to 4 ($C_6H_{10}O_5$); on addition of alcohol amorphous precipitates with alkaline reaction are formed; these are represented as potassium starch $C_{24}H_{39}O_{20}K$ and sodium starch $C_{24}H_{39}O_{20}Na$.

On heating starch with caustic alkalies a change takes place with the scission of acetic acid, the amount of alkali neutralised when N strength of solution is employed being equal to 8·33 per cent. of KHO. A similar change takes place with all carbohydrates, but the amount of acid liberated varies very considerably, pointing to differences in structural arrangement.

The stiffening power of starch appears to depend upon the amount of swelling to which individual starches are liable on heating with water; in other words, to the extent of the dispersion; thus, by heating to a few degrees above the temperature of swelling and centrifuging the sol, W. Harrison ('Jour. Soc. Dyers and Colourists,' 1911, **27**, 84–88) found the volume of the swollen granules to be directly proportional to the stiffening power, the experiments agreeing closely with the formula

$$\text{Viscosity} = 1\ (4{\cdot}75 \times \frac{\text{Vol. of granules}}{\text{total vol. of solution}});$$

alkalies if present cause high results, as might be expected.

Starch gel on standing separates into two phases, a more solid gel and a liquid phase, the latter containing very little starch; several other colloids behave in a similar way, notably cellulose xanthate or viscose, some colloids, such as gelatine, do not behave in this manner. The phenomenon is probably due to the aggregation of the molecular complexes, the colloid becoming less dispersed. Starch shows practically no osmotic pressure (*i.e.*, only 2 m.m. at 13° for a 1 per cent. solution) in a parchment paper diaphragm (Moore and Roaf, 'Biochem. Jour.' **II.** 39), neither does it show any appreciable depression by the freezing-point method of Raoult, pointing to a very high molecular weight (E. Fouard, 'Compt. Rend.' 1908, **146**, 978–981). On the other hand, pure soluble starch, according to L. Macquenne ('Compt. Rend.' 1908, **146**, 317-318), passes through filtering material, even the Chamberland filter, and E. Fouard ('Compt. Rend.' 1908, **146**, 285–287) found that a solution containing 2·74 per cent. of pure starch could be filtered through a collodion membrane. The molecular solution volume is lower than that calculated by Taube's method ('Ber.' 1895, **28**, 410), *i.e.*, 92·6–93·3 instead of 102·6 (Cross and Bevan, 'Ber.' 1909, **42**, 2,198–2,204), which the authors regard as evidence of ring-formation. Other colloids show a similar result

With regard to the action of reagents, other than those mentioned, upon starch, it is capable of forming a xanthic derivative in the same way as cellulose by action of caustic soda and carbon bisulphide (C. F. Cross, J. F. Briggs, and Société Française de la Viscose, Fr. Pat. 370,505, 1906), while a nitro-derivative of starch has been suggested as a substitute for celluloid (G. E. Arnold, A. S. Fox, A. C. Scott, and H. E. V. Roberts, Eng. Pat. 3,450, 1906).

Oxidising agents have a marked effect upon starch (see soluble starch). F. G Perkins (U.S. Pat. 1,020, 656, 1912) proposes to prepare a glue from cassava starch by acting upon it with sodium peroxide and caustic soda.

Starch and tannic acid mutually precipitate each other, this being also

the case with soluble starch and dextrin, but in lessening degree. This fact should be borne in mind in testing a colloid for gelatine by means of tannic acid.

Ordinary wheat-flour is used very largely for sizing purposes, both in its fresh state and after long-continued fermentation. It differs from the starches in containing the nitrogenous colloid gluten, a coagulable albumen, sugar, dextrin, &c. It is doubtful if in the fresh state the gluten exerts any marked influence, but during fermentation the gluten, which suffers little in the process, becomes dispersed and forms a colloidal solution in the acids, which are generated, thus becoming available as a binding agent; other marked changes also take place (H. B. Stocks, 'Jour. Soc. Dyers and Colourists,' 1912, **28**, 148–151, also H. B. Stocks and H. G. White, 'Jour. Soc. Chem. Ind.' 1903, **22**).

Soluble Starch.

The so-called 'soluble' starch may be formed from ordinary starch in a variety of ways, the processes which have been proposed falling naturally into certain classes.

1. By heating starch at a regulated temperature but lower than that which will convert it into dextrin.

2. Heating starch with water under pressure (H. Hale, Eng. Pat. 3,311, 1866).

3. Treating starch with acids, J. Sellars (Eng. Pat. 2,810, 1865) proposed to heat the starch with a mineral or vegetable acid, then neutralise with soda. Rellmas steeps starch in a 1 to 3 per cent. solution of a mineral acid at 50° to 55°. Fols carries out the same process at 80° C. A. Schuhmann (Eng. Pat 5,160, 1887) treats starch with acid in the cold, washes out the acid, and heats with SO_2 under pressure. W. P. Thompson (A. H. J. Berge, Eng. Pat. 7,272, 1891) employs SO_2 under pressure, while W. Thompson and J. Morris (Eng Pat 21,973, 1906) claim to employ SO_2 at 200°–220° F. H. H Lake (W. Angelo, Eng. Pat. 5,617, 1893) treats starch with strong HCl and dries at a low temperature. G. Rivat (Fr. Pat. 433,726, 1910) claims the application at 100° C. of dilute solutions of H_3PO_4,HF, potassium bitartrate, acid potassium oxalate, or aromatic sulphonic acids. Reumer (Eng. Pat. 10,873, 1902) proposed the application of organic acids at 115°, while Cross and Traquair (Eng. Pat. 9,868, 1902) claimed the application of carboxylic acids, such as acetic or formic, but specially the former, together with dehydrating agents, *e.g.*, alcohol or concentrated solutions of salts. The amount of glacial acetic acid employed is from one-third to one-half the weight of the starch, and they claim that under these conditions an acetyl derivative of starch is formed. The product has been named 'feculose' (see also Traquair, 'Jour. Soc. Chem. Ind.' 1909, 288).

4. *Oxidising agents.*—Starch is treated with chlorine or calcium hypochlorite (C. H. Meyer, Eng. Pat. 1,146, 1893), with hypochlorite or chlorate of potassium or sodium (C. Brender, Eng. Pat. 17,650, 1898). A. Ashworth (Eng. Pat. 19,720, 1901) treats starch with acid and a chlorate, with or without the addition of a catalytic agent, *e.g.*, vanadium chloride, $CuSO_4$, or $CuCl_2$. Siemens and Halske (U.S. Pat. 798,509, 1905) propose the use of chlorine gas; the use of acids, such as HCl, H_2SO_4, and organic acids, is also mentioned in the specification. Chlorine is claimed by H. Kindscher (Ger. Pat. 168,980, 1902). In W. von Siemens and C. Witt's

patent (Eng. Pat. 21,455, 1895) it is proposed to treat first with $K.MnO_4$, then by HCl, and finally to remove excess of Cl, by means of SO_2, or a dilute solution of a bisulphite. The soluble starch is stated to form a clear filterable solution with dilute potash solution.

F. Fritsche (Eng Pat. 1,351, 1908) claims the application of perborates for the preparation of soluble starch; perborate of soda is also used for rendering starch, gums, algæ, lichens, &c., soluble by heating (Stolbe and Kopke, Fr. Pat. 384,704, 1907, and addition Jan. 23, 1908), F. G Perkins (U.S. Pat.—1,020, 656—1912) uses sodium peroxide for rendering starch soluble.

5. *Alkalies.*—J. Kantorowitz (Eng. Pat. 5,844, 1896) claims the preparation of soluble starch by treating ordinary starch with NaHO, neutralising with HCl, and precipitating the product with $MgSO_4$ or by keeping at a temperature of 20° C for several hours. In a later patent (Eng. Pat. 10,216, 1910) Kantorowitz claims the application of caustic soda, but to prevent the former swelling the reaction is carried on in presence of concentrated solutions of salts, *e.g.*, Na_2SO_4.

6. *Treatment with neutral salts.*—Soluble starch can be formed by heating starch with a strong solution of KCNS and alcohol, the latter probably added to prevent swelling, as in the last example. (The Arabol Man. Co., Fr. Pat. 391,167, 1908.)

C F. Cross and J. S Remington (Eng. Pat. 1,035, 1899) propose to use the fruit of the horse-chestnut as a source of starch or soluble starch.

Soluble starch does not differ in appearance from ordinary starch, except that in some cases the hilum of the granules appears to be fractured On heating with water, however, it behaves quite differently; thus 1 part of ordinary starch heated with 9 parts of water yields a stiff white paste, which on cooling becomes a white opaque gel from which after a time water separates. On the other hand, soluble starch in the same proportion forms a thin opalescent but nearly clear sol which remains fluid on cooling, for which reason it is known as thin-boiling starch. The change which has taken place is probably largely one of de-polymerisation.

M. Saurec and S. Jencic ('Koll. chem. Beihefte,' 1915, **7**, 137–171) state that the formation of soluble starch is accompanied by a reduction in the size of the molecule, but this is not always the case. Dextrin is almost always present, although it is claimed that in certain products it is absent. The soluble starches usually, although not invariably, contain a higher mineral content than ordinary starch, amounting to about 1·5 per cent., and this being alkaline will have a decided effect upon their properties; the amount of water is also higher, *i.e.*, 17 to 21 per cent. Soluble starch on heating with caustic alkali yields a higher percentage of acetic acid, *i.e.*, about 13 per cent. of KHO is neutralised, pointing to a molecular change. It is precipitated by tannic acid, but to a lesser extent than ordinary starch. Soluble starch reverts to the insoluble form when a solution is allowed to stand (E. Fouard, 'Compt. Rend.' 1908, **147**, 931–933). Soluble starch is used in sizing and finishing, but more particularly for the latter purpose; it yields a continuous film and imparts a 'fuller' feel to fabrics than does ordinary starch.

Dextrin.

The products sold under the name of dextrin or 'British gum' vary very widely in their properties, being complexes of true dextrin, soluble

starch, poasibly unaltered starch and glucose. There appear to be several modifications of dextrin, known as erythrodextrin, amylodextrin, achrodextrin, &c., which differ from each other in their molecular weights.

Pure dextrin can be prepared by dissolving starch in moderately concentrated sulphuric acid, quickly neutralising with alkali and precipitating with alcohol.

The commercial dextrins are prepared by heating dry starch either alone or after sprinkling with nitric acid to temperatures between 100° and 280° C. Nitric acid or a mixture of nitric and sulphuric acid are used (W. S. Hayward, Eng. Pat. 2,612, 1858). It is also produced by the restrained action of malt extract upon starch (B. J. B. Mills (T. Sim and E. S. Hutchinson), Eng Pat. 933, 1869). The products vary according to the method of treatment, white dextrin containing soluble starch and possibly unaltered starch,while brown dextrin contains more or less glucose.

Dextrin contains about 12 per cent. of water and about 0·2 per cent. of mineral matter. On heating with normal alkali solution the acetic acid liberated neutralises 15 to 24 per cent. of KHO. According to G. Malfitano and A. Moschkoff (' Compt. Rend.' 1912, **154**, 443–446), starch is converted into dextrins by drying over P_2O_5. When the desiccation is prolonged so that the water of constitution is removed the solubility is diminished. They regard the molecule of starch as consisting of $C_6H_{10}O_5$ aggregates linked together by OH.H molecules and that by the loss of the latter the molecule becomes disintegrated.

Dextrin is only slightly precipitated by tannic acid; it is precipitated readily by alcohol, but is not readily salted out by electrolytes, only concentrated solutions of sulphates and not those of other salts causing it to separate (S. Levites, ' Zeit. Chem. Ind. Kolloide,' 1908, 3, 145–153).

Dextrin is used to a considerable extent in finishing and calico-printing, imparting a very hard ' boardy ' feel to cloth, which for certain purposes is much desired. It is also employed as an adhesive under the name of British gum, in place of gum arabic, but the solutions have much less viscosity, and therefore stronger sols have to be employed. It has, however, two advantages, that is, it can be spread in a thinner layer and is more readily softened when moistened; for these reasons it has largely replaced the natural gum. It is remarkable that, although a profound modification must have been made by treating starch at high temperatures, the structure of the granules is in no way affected until water is added, when they entirely dissolve. It is used to some extent in painting (Church, ' Chemistry of Paints and Painting,' p. 72), but it is rarely used for emulsifying purposes.

Pfeffer, using a membrane of copper ferrocyanide, found the osmotic pressure of dextrin to be 16·6 c m. of mercury (Ostwald, ' Solutions,' p. 94); Musculus and A. Meyer (Bull. Soc. Chim., **30**, 370) found the rate of diffusion of dextrin through membranes to be for Y dextrin (achroodextrin) 7, and amylodextrin, 1; dextrose hydrate being taken as 100.

Barium oxide is adsorbed by commercial dextrins, but it has been found that the amount varies with the percentage of starch present, the following results having been obtained:

	Starch.	BaO adsorbed
Dextrin 1 . . .	1·99	1·75
,, 2 . . .	13·13	3·53
,, 3 . . .	24·72	5·64
Starch	100·0	23·61

Gum Arabic.

The commercial gum arabic is often a mixture of gums from several species of trees, and is therefore a variable product. The best gum arabic is that obtained from *Acacia Senegal*, known as Hashab gum, which comes from Kordofan and the Blue Nile District. Gums are also obtained from several other species of acacia, and, although these resemble gum arabic in appearance, they differ from it more or less in constitution and also notably in yielding solutions which are less viscous and much less adhesive. They therefore rarely appear in commerce except in admixture as above stated.

Gum arabic contains normally about 15 per cent. of water and 3½ per cent. of mineral matter, which consists largely of the carbonates of potash and lime. It has long been regarded as an acid—arabic acid—in combination with bases. The same acid is supposed to be present in beet-root juice. More recently the researches of O'Sullivan and others have, according to H. H. Robinson ('Report on the Chemistry of Gums,' British Association, 1906), appeared to prove that the gums are composed of complex acids built up of a nucleus acid associated with the sugars galactose, arabinose, and xylose. Arabic acid is the nucleus acid in gum arabic and geddic acid in gedda-gum. Without subscribing to this decision, it may be stated that gum arabic functions as an acid, and either combines with or adsorbs metallic bases, it is a complex of the two carbohydrates galactan and araban.

Gum arabic is employed more for its adhesiveness than for any other property, but closely allied to adhesiveness is viscosity, the gums which yield the most viscous solutions being the most valuable. It is employed in painting (Church, 'Chemistry of Paints and Painting') as a glaze or varnish, in the manufacture of sweets, and for emulsifying oils, for which purposes it is eminently fitted.

Gum arabic is usually entirely soluble in water. The gum from the earliest exudation is, however, not entirely soluble, yielding a glairy mucus-like fluid, from which a perfect solution separates after a time. After storage for two to three months a change has taken place in the product, probably due to enzymes, so that it dissolves entirely (F. Reinitzer, 'Zeitschr. f. Physiolog. Chem.' 1909, 352–392, also '3rd Report of the Wellcome Research Laboratories, Khartoum'). Dr. Beam ('2nd Report of the Wellcome Research Laboratories') notes the fact, which, however, was previously well known, that the viscosity of a solution prepared in the cold is greater than when heat is employed. It may be mentioned that gum arabic contains at least three enzymes, an oxidase, a peroxidase, and a diastase (F. Reinitzer, 'J. Physiol. Chem.' 1909, **61**, 352-392), the functions of which have not yet been determined, but these render the gum incompatible for use with several medicinal preparations; incidentally they also serve for detecting gum arabic in admixture with other gums, *e.g.*, tragacanth, which are free from these enzymes.

Hashab gum was found to be composed of two gums, a hard and a soft one. On exposure to the sun the hard gum remains glassy, but the soft kind becomes white and opaque, owing to the development of innumerable tiny fissures. By this treatment it appears to be bleached, although this is really not the case. There is a marked difference in the

viscosities of the two varieties in the torsion viscosimeter, a 20 per cent. solution of the hard gum indicating a retardation of 60 to 70 deg., whereas the soft gum showed a retardation of only 28 to 33 deg. The difference in these two varieties has not yet been determined, the amount of mineral matter and the acidity being practically the same. It was found, however, that gum from tapped trees had a higher viscosity than that which exuded naturally ('4th Report Wellcome Research Laboratories, Khartoum'). A solution of gum arabic yields an opaque white gel with basic lead acetate—no doubt, due to the adsorption of PbH_2O_2. It becomes more glutinous on addition of borax and is not precipitated by tannic acid. It is insoluble in liquid phenol and in pyridine, in which gelatine is readily soluble.

On adding alcohol to a solution of the gum, it is precipitated, but more readily in presence of hydrochloric acid. The precipitate has been regarded as 'arabic acid,' but this cannot be the case, since the mineral matter adheres very strongly to the carbohydrates, and, unless the solution is dilute, the gum is precipitated almost unaltered.

Thus a solution precipitated once by alcohol in presence of dilute hydrochloric acid yielded a product containing 2·73 per cent. of mineral matter, while after three precipitations it still contained 2·21 per cent. In presence of sulphuric acid the precipitate contained 2·30 per cent. of mineral matter, while, in presence of ammonium oxalate, the precipitate contained 1·29 per cent. The proportion of galactan and araban did not appear to differ markedly from the original gum. After precipitating in this way, however, the gum does not dissolve to a clear sol, but is more or less turbid, and after about three precipitations with alcohol it ceases to be precipitated, but remains as a turbid sol, from which it deposits on addition of acids or electrolytes. On the other hand, Rideal and Youle ('Jour. Soc. Chem. Ind.' 1891, 60) found a difference in the optical rotation between the gum precipitated (amounting to about half the original) and that which remained in solution, from which they concluded that at least two substances were present. O'Sullivan obtained a similar result with 'pure arabin.'

Attempts have been made to utilise this reaction for estimating the gum in syrups (as also the amount of precipitate obtained with lead acetate in alcoholic solution), gum arabic yielding 85 per cent. of 'pure gum' calculated free from ash (A. C. Chauvin, 'Ann. Falsif.' 1912, **5**, 27–30, also X. Roques and G. Sellier, 'Ann. Chim. Analyt.' 1911, **16**, 218–220).

An interesting case of the mutual precipitation of two colloids is afforded by the interaction of gum arabic and gelatin, under certain conditions, which have been closely studied by F. W. Tiebackx ('Z. Chem. Ind. Kolloide,' 1911, **8**, 198–201, and 1911, **9**, 61–65). The precipitation takes place in acid solution only within certain limits depending upon the strength of the solutions. Thus, with 2 c.c. of a 0·5 per cent. gelatin solution and 2 c.c. of a 2 per cent. solution of gum, coagulation takes place with 2 c.c. of N/40 HCl, whereas with 2 c.c. of N/25 or N/125 acid, the solution, after becoming turbid, clears again. With a solution containing 0·5 per cent. of gelatin and 0·5 per cent. of gum arabic, a turbidity is produced when the acidity = ·002 N.HCl; on further addition of acid a precipitate occurs which passes again to a turbidity and at a concentration of 0·01 N the liquid becomes clear again. Increasing the percentage of gelatin and gum, or raising the temperature, restricts the action, until at a

concentration of 2 per cent. each of gelatin and gum, at a temperature of 80° C., there is no sign of flocculation. If, however, the proportion of gum is increased, a turbidity appears which again disappears on increasing the proportion of gelatin and gum. Strong solutions of gelatin and gum, *e.g.*, 50 c.c. of 50 per cent. solutions of each, yielded no precipitate with N/10 HCl, or stronger solutions of the acid. When sulphuric acid is added to a solution containing 0·5 per cent. of gelatin and 0·7 per cent of gum, a turbidity occurs when the acidity of the solution is ±0 003N. A solution of 100 c.c. of a 0·1 per cent. solution of gelatin and 100 c.c. of a 2 per cent. solution of gum is coagulated by the addition of 500 c c. of 6 per cent. acetic acid. The coagulum consists of an adsorption compound containing gelatin, gum, and acid, the gelatin being enclosed by the gum, which latter adsorbs the acid. On washing or drying at 100° C. the acid is removed. Two layers are formed, the lower one behaving in a similar way to globulin or casein in presence of electrolytes, the view being expressed that casein and other proteids may also be adsorption compounds, the constituents resembling one another both in properties and in composition. In the above reaction the acid may be replaced by salts, the most active being tartrates, citrates, phosphates, and acetates, followed by sulphates, chlorides, bromides, and iodides, the activity of the cations being in the following order, Na)K)NH_4)Mg)Zn). Salts cause the coagulum produced by acids to swell, the activity of the anions in this respect being in the order I)Br)Cl)SO_4)CO_3) and the cations K)Na) alkalies) alkaline earths). When, however, concentrated solutions of salts or those of $\frac{1}{8}$ gram molecule strength or less are employed, the already swollen transparent gel becomes again opaque. The tendency of a saline solution is to remove the acid, while in presence of salts greater concentration of acid is required to produce a given effect.

Gum arabic solutions show a very high osmotic pressure, which remains constant over a long period Thus Pfeffer, using a copper ferrocyanide membrane, records a pressure of 7·2 c.m of mercury with a 1 per cent. solution and 120 4 c.m. with an 18 per cent. solution (Ostwald, 'Solutions,' p. 91), while Moore and Roaf (Biochem. Jour.' **2**, 39) and Edie ('4th Report Wellcome Research Laboratories, Khartoum'), using a parchment paper diaphragm, found for 6 per cent. solutions pressures of 114–170 m.m , and for a 10 per cent. solution 276 m.m. The reason for these high pressures, which remain almost constant after reaching a maximum, has not yet been explained , it may be due to the slow diffusion of the electrolytes associated with the carbohydrates, or it may be a swelling or imbibition pressure (pseudo-osmotic).

In testing gum arabic for commercial purposes the viscosity is the most important property (R. Hefelmann, 'Zeitschr. Offentl. Chem.' **7**, 195–198). C. Fromm ('Zeitschr. Annal. Chem.' 1901, **40**, 143-168) soaks strips of paper in solutions of the gums to be tested and notes the increase in weight and tensile strength of the paper which serves as a measure of the value of the gums for adhesive purposes. The latter author also states that on keeping gums a gradual change takes place in them which in the trade is known as 'ripening'; this change leads to a decrease in strength, viscosity, and acidity, at the same time there is an increase in the proportion of gelatinised insoluble gum.

The problem of the effect of colloids upon the precipitation of mineral matter is a very interesting one, which would well repay further study, not

only because of the remarkable results which have been obtained, but also in view of the difficulties which are encountered in many industries because of their presence. Generally speaking, colloids are more or less protective in their effect; that is to say, in the case of two solutions which in the ordinary way react to form an insoluble precipitate which settles easily, in presence of a colloid either no precipitate is formed or the precipitate is much more finely divided, and refuses to settle, or it settles much more slowly. Problems of this kind often occur in chemical works, sewage works, and in water filtration, &c., the remedies being either application of heat or addition of some chemical which in itself is colloidal, or which forms a colloidal precipitate of opposite sign, as, for instance, alum, ferrous sulphate, potassium permanganate, &c., in the case of sewage also the colloidal matter may be destroyed or flocculated by bacterial action. On the other hand, it may be advantageous to form a highly flocculent precipitate instead of a crystalline one, as, for instance, in steam boilers, the deposit then being easier to deal with—a result which is brought about by the addition of colloids, *e.g.*, tannin and soda, infusion of straw, &c. The precipitation of mineral matter by slow diffusion of salts through colloidal jellies leads to the production either of spheroidal or nodular aggregates (Rainey, 'On the Mode of Formation of Shells of Animals, Bone, &c.,' published in 1858, also H. B. Stocks, 'Precipitation of Carbonate of Lime under Varying Conditions,' 'Jour. Soc. Chem. Ind.' 1912, **21**, 527) or to banded structure, which appears to explain the formation of mineral lodes (Hatschek, 'Jour Soc. Chem. Ind' 1911, 256, F. S. Shannon, 'Jour. Ind. and Eng. Chem.' 1912, 526–528, and E Marriage, 'Z Chem. Ind. Kolloide,' 1912, **11**, 1–5).

Other Soluble Gums.

There are two other types of soluble gums differing from gum arabic in their properties which are worth considering, the one the ghatti-gums, because of their high viscosity, the other the wattle-gums, because of their abundance.

Ghatti-gum is the product of *Anogeissus latifolia*, but the commercial varieties are mixed products containing the gums from several species, and therefore are very variable. The solutions of ghatti-gums are very much more viscous than those of gum arabic, and also contain more or less of a product which swells to a gel in water, but does not pass into the state of solution (metarabin). ('Colonial Reports,' No. 63, Imperial Institute, 'Report, Gums and Resins,' p. 160.)

The moisture in these gums ranges from 4 to 7 per cent., mineral matter 2 to 3 per cent., and potash neutralised on heating 0·22 to 3·99 per cent. (Rideal and Youle, 'Jour. Soc. Chem. Ind.' 1891, 160). Ghatti-gum contains more araban and less galactan than arabic gums.

The wattle-gums of Australia and South Africa are of two types—although there are many gradations—the one entirely soluble in water, the other leaving more or less swollen but insoluble gum. To the former group belong the gums of *Acacia farnesiana, A. ferruginea, A. leucophlœa*, &c., and to the latter gums from *A. decurrens, A. mollissima, A. vestita*, &c. For a full account of the wattle-gums see J. H. Maiden ('Pharm. Jour **20**, 869–980). Several of the wattle-gums contain a low mineral content, *i.e.*, 1 per cent. or less, and they are all very low in viscosity. The wattle-gums are distinguished by containing a much greater proportion of galactan

and less araban than gum arabics. If the viscosity of these gums could be improved there would be a great demand for them; they are very plentiful, and exude freely in large tears or masses, often very fine.

A very large number of trees of other species and genera yield soluble gums, but none of these have ever come into extended use.

Tragacanth.

Tragacanth is employed in calico-printing, for painting on linen (A. H. Church, 'Chemistry of Paints and Paintings,' p. 70), in the preparation of lozenges, for cosmetic purposes, and in the manufacture of oil emulsions. This gum is the product of various species of *Astragalus* (Imperial Institute, 'Report on Gums and Resins,' p. 161), and it differs from gum arabic in that it is almost always the product of incisions. It shows distinct evidence of metamorphosed or swollen vegetable tissue, the cells containing a few granules which have the character of starch, which, however, appear to resist hot water to a considerable extent. The content of water varies according to the state of the atmosphere; normally this is about 17 per cent., but in moist air it may be as much as 26 per cent. (H. B. Stocks and H. G. White, 'Jour. Soc. Chem. Ind.' 1903, 4); it contains 3 to 5 per cent. of mineral matter, which is largely composed of carbonates (Rideal and Youle, 'Jour Soc. Chem. Ind.' 1891, 610), that produced by incision containing the larger quantity (Hilger and Dreyfus, 'Ber.' 1891, **33**, 610). The amount of acetic acid formed on heating with potash is much higher than gum arabic, corresponding to 15 to 26·61 per cent. of alkali neutralised (Rideal and Youle, Stocks), showing a different constitution. The carbon and hydrogen in this gum approximate to the formula $C_6H_{10}O_5$, but both galactan and araban are present, even more of the latter than in gum arabic; there is also a methylpentosan present, as fucose is found in the products of hydrolysis (A. Widtsoe and B. Tollens, 'Ber.' 1900, **133**, 132–143).

On heating tragacanth with water it swells very considerably, forming a stiff paste, even at 5 per cent. concentration, which by straining can be separated into a white translucent sol and an opaque insoluble gel, known as tragacanthine or bassorin. O'Sullivan ('Proc. Chem. Soc.' 1901, **17**, 156–157) states that the gum contains a series of gum acids similar to geddic acid, which he termed polyarabin-galactan geddic acids, and bassorin, which yields tragacanthan-xylan-bassoric acid by action of alkalies and xylan-bassoric acids on partial hydrolysis with acids. Xylan-bassoric acid is nearly insoluble in water, and bassoric acid insoluble, but the alkali salts are soluble.

According to Hilger and Dreyfus, on treating bassorin with 35 per cent. caustic potash and acidifying with acetic acid, oxybassorin $(C_{11}H_{20}O_{10})_2O$ is formed. If the alkaline solution is neutralised with acetic acid and precipitated by alcohol, the potassium derivative of oxybassorin is produced; this is soluble in water and yields insoluble calcium and silver derivatives by double decomposition. These salts do not respond to the usual tests for the metals, and therefore do not appear to be true salts. These are probably adsorption compounds of the bases. Tragacanth is not precipitated by ferric chloride, it is precipitated by alcohol and also by basic lead acetate. Dilute solutions of bassoric acid are precipitated by alcohol and also by electrolytes; it can be titrated, using

phenol-phthalein as indicator (T. von Fellenberg, 'Mitt. Lebensmittel, unters. Hyg.' 1914, **5**, 56–259).

Tragacanth gives with borax a slightly more viscous mass, a reaction which is sometimes made use of in detecting adulteration (W. L. Scoville, 'Drugg. Cir' 1909, **53**, 116–117; also H. C. Fuller, 'Amer. Jour. Pharm.' 1912, **84**, 155–158). It can be distinguished by not containing oxydates.

Tragacanth yields a much more viscous solution than gum arabic, but does not form a continuous film on drying, breaking up into large curved flakes. The viscosity is lowered by heating under pressure. Tragacanth more nearly resembles starch than gum arabic in its properties. It shows only a slight osmotic pressure, *i.e.*, a 0·72 per cent. solution gave a pressure of 5 m.m. at 17° C with a parchment paper membrane (Moore and Roaf, 'Biochem. Jour.' **2**, 39).

The commoner qualities of gum tragacanth, known in the market as 'gum trag' or 'hog gum,' is in larger and thicker pieces, white or yellow in colour, and often quite opaque. It yields a solution which is more pasty than real tragacanth and also contains more insoluble matter. The moisture in this gum is about 11 to 12 per cent., mineral matter 3·16, and potash neutralised after heating 8·14 per cent.

For certain purposes mixtures of two or more colloids are sometimes preferable to a single one (F. Beckmann, Ger. Pats. 219,651 and 223,709, 1908.)

In a general paper on thickenings for calico-printing from a colloid point of view, E. Austin-Muller ('Chem. Zeit.' 1910, **34**, 598–599) divides them into three classes:

(1) Homogeneous, *i.e.*, those which dissolve to a clear sol which can be filtered through paper—examples, gum arabic and better qualities of gum senegal.

(2) Heterogeneous. Those which form two phases, a sol and a gel, the latter retained by a filter, *e.g.*, tragacanth.

(3) Heterogeneous. Those forming micella-sols, which are entirely retained by a filter, *e.g.*, starch paste. The latter can be rendered more homogeneous by acetic acid. The products obtained from starch by roasting, *i.e.*, soluble starches and dextrins, fall between classes 2 and 3 or 1 and 2, according to their properties. By addition of NaHO they form homogeneous sols.

Insoluble Gums.

The gums which are insoluble in water exude naturally from cherry and peach trees, &c.; there are also certain gums found in India, known as Indian gum or Bombay gum, the products of species of *Sterculia*, and the gum of *Cochlospermum gossypium*, which have the remarkable property of spontaneously evolving acetic acid. H. H. Robinson ('Jour. Chem. Soc.' 1906, **89**, 1496) regards the latter as an acetyl derivative, and found that on distillation it yielded 14 per cent. of acetic acid.

Bombay gum and the gum of *Cochlospermum gossypium* are very similar in composition. They lose 19 to 21½ per cent. on heating at 100° C. (water and acetic acid), and contain 7 to 9 per cent. of mineral matter. On heating with alkali, the amount of KHO neutralised equals 13 to 16 per cent. They contain galactan and araban, but less of the former than in gum arabic; there is probably a third carbohydrate present.

On treatment with water they swell up very quickly to form nearly

transparent gels, which, however, are so brittle that they can be pulverised between the fingers into innumerable minute angular particles which do not coalesce.

These insoluble gums are not at present of any value, the chief interest in them commercially centring round the possibility of converting them into soluble products. Several patents have been taken out with the view of converting such gums into colloid sols, other colloidal products being also mentioned. Thus L. Kern (Eng. Pat. 21,370, 1891) purposes to render cherry, peach, and other gums soluble by heating with water under pressure, F. Fritsche (Eng. Pat. 1,353, 1908) prepares soluble gums by acting upon the products obtained from algæ and lichens—carrageen moss, agar, Iceland moss, &c.—East India gum, bassorine, &c., with sodium perborate after boiling with water under pressure; A. Boidin (Eng. Pat. 16,589, 1905) proposes to render starch, inulin, glycogen, gelose from agar-agar, gums and mucilages more readily soluble, by converting the phosphates which they contain into insoluble phosphates by addition of metallic salts or into monobasic acid salts by acidifying.

Vegetable Mucilages.

A variety of vegetable mucilages can be prepared by treating seeds, roots, &c., of various plants with water. These products, which were investigated many years ago by Fremy, Mulder, Chodnew, &c., were known as pectins or pectinous substances. Our knowledge of these materials needs revision. They are more nearly related to gum arabic than to the hemicelluloses. Pectose was the soluble colloidal material contained in beetroot; this was converted by means of an enzyme or ferment called pectase into pectin and subsequently into pectic acid, coagulation not occurring except in presence of CaO or a salt of Ca, Ba, or Sr. The coagulated mass is not pectic acid but a pectate of one of the alkaline earths (A. Mallevre, 'Bull. Soc. Chem.' 1895, **13**, 77–82). This looks like adsorption compounds.

The gelatinous material pectose is present in the pulp of ripe fruits, such as apples or pears, and in roots, *e.g.*, carrots and beetroot, in association with cellulose. It is insoluble in water (Fremy). By the action of the ferment pectase, or acids, alkalies, or milk of lime, pectose is converted into pectin or pectic acid, in other words, it is converted into a sol. Pectin is contained in the juice of ripe fruits, from which it is precipitated by alcohol in presence of HCl. It is soluble in water and is precipitated from the solution by basic lead acetate, also by $Ba(OH)_2$ and $Ca(OH)_2$ in excess, but not by NH_4HO, NaHO, HCl, H_3BO_3 or borax. On boiling an aqueous solution of pectin it becomes insoluble, being converted into parapectin (Fremy, Sidersky), parapectic acid ('Watts' Dict.,' vol. **4**, p. 365), metapectic acid (J. Weisberg, 'Chem. Zeit.' **13**, 2). Parapectin is converted by dilute acids and bases into metapectin, and with concentrated solutions of the same into parapectic acid. Metapectic acid has an acid reaction; it is completely precipitated by lime and basic lead acetate. On prolonged heating it is converted into metapectic acid (J. Weisberg, 'Chem. Zeit.' **13**, 2). Pectous or pectosic acid is obtained by the action of pectase upon a solution of pectin, also produced by the action of cold solutions of the alkalies upon the same substances. It is a gelatinous substance, slightly soluble

in cold water, but quite soluble in dilute acids. On boiling with water it dissolves, but reverts to a gel on cooling. It is very quickly converted into pectic acid by boiling with water, by pectase, and by alkalies in excess. The pectosates form amorphous gels (Pelouze et Fremy). Pectic acid is formed by the action of alkalies upon pectin, also by the action of HCl upon beetroot pulp; it dissolves in boiling water, but reverts to a gel on cooling (Pelouze et Fremy). By long-continued boiling with water or by acids it is converted into parapectic acid; alkalies convert it into metapectic acid. Parapectic acid dissolves in cold water, and the solution on evaporation leaves a residue which resembles gum or gelatin. The solution reddens litmus and is precipitated on addition of a mineral acid, acetic acid, or $Ba(OH)_2$. It yields a gelatinous precipitate with alcohol. Metapectic acid is stated to be identical with arabic acid. It is soluble in water, forming turbid or heterogeneous sols, yields a barium salt and is precipitated by alcohol, but not completely by basic lead acetate in excess (J. Weisberg, 'Chem. Zeit.' **13**, 2).

We have therefore the following series of products:

Pectose	Metapectin	Parapectic acid
Pectin	Pectosic acid	Metapectic acid
Parapectin	Pectic acid	

The ultimate analyses of these products by various observers do not agree among themselves, therefore we do not know how many individual members really exist, one fact, however, is clear, that is, that they contain more oxygen and less hydrogen than the true carbohydrates and that they have for the most part acid functions which become more marked by partial hydrolysis, showing that they contain one or more COOH groupings. According to later investigations (E. Bourquelot, 'Comptes Rend.' **128**, 1211–1244, and Bourquelot and Herissy, 'Jour. Pharm. Chem.' 1899, **9**, 281–286), the pectens so far examined yield galactose and arabinose on hydrolysis, so that they probably contain galactan and araban. Cross and Bevan ('Cellulose,' p. 217) state that 'the pectic group of compounds may be regarded as compounds of carbohydrates of varied constitution with acid groups of undetermined constitution associated to form molecular complexes, more or less homogeneous, but entirely resolved by the continued action of simple hydrolytic agency.' According to S. B. Schryver and D. Haynes ('Biochem. Jour.' 1906, **10**, 539–547), 'pectinogen' is obtained by treating turnips with a solution of ammonium oxalate and precipitating with alcohol. It has acid functions, and when kept in alkaline solutions it readily reverts to pectin, which also has acid characters. It is soluble in alkalies and is precipitated as a gel on addition of acids. Analysis shows it to have the composition $C_{17}H_{24}O_{16}$. It yields furfural equivalent to one atom of carbon in each complex of C_{17}. Pectin would therefore appear to be an acid and not a carbohydrate.

Pectins are more particularly interesting since they form the basis of fruit-jellies, such fruits as currants, gooseberries, and apples being especially rich in these constituents. The mucilages of linseed, marshmallows, orchids, and other plants are also worth attention.

Several colloidal products from plants have been proposed for use from time to time, but very few have been found sufficiently valuable to

be retained in industry. A list of the more interesting patents in this connection is given below:

Preparation of a sizing material from the juice of linseed, hemp-seed, plantain-seed, &c. (F. C. Calvert, Eng. Pat. 164, 1857).

Obtaining fecula from bulbs of the lily type (R. I. C. Dubus, Eng. Pat. 2,801, 1857).

Preparation of a mucilage from quince-seeds (G. Norris, Eng. Pat. 2,240, 1861).

Preparation of a substance named 'parapectin' from the juice of the fruit of the arbutus tree by precipitating with alcohol. This substance resembles pectin but has greater consistency and strength (P. Mingaud, Eng. Pat. 1,619, 1865).

Obtaining a mucilaginous substance from flax, China grass, sorghum, *Phormium tenax*, and other fibre-yielding material by boiling with alkali (T. Gray, Eng. Pat. 1,058, 1866).

Preparing size from the fruit of the augustus palm (S. C. Dhondy, Eng. Pat. 7,458, 1891).

Preparation of a gum from plants of the Mesembryanthaceae family (R. Haddon (R. My Glyvares), Eng. Pat. 23,555, 1898).

Preparation of vegetable glue or sizing material from the palmetto palm and similar plants (F. Hepburn, Eng. Pat. 10,814, 1898).

Obtaining a glutinous substance from beetroot by treatment with SO_2 and neutralising with chalk. The acid calcium salt which is obtained is evaporated *in vacuo*. The product is rendered gelatinous by an alkali or ammonia, but this property is obviated by previous treatment with H_2O_2 (G. B. Ellis (F. Hornung), Eng. Pat. 22,788, 1898).

Using mucilage from linseed for sizing yarn (J. Pate, Eng. Pat. 2,645, 1901).

Obtaining 'viscine' from plants of the Ilex class (W. Loebell, Eng. Pat. 26,383, 1904).

Obtaining gum for sizing purposes from flax, hemp, and other textile fibres (H. Sefton Jones, Eng. Pat. 18,337, 1907).

Bacterial Gums.

The bacterial gums are of interest in connection with the mode of genesis of exudation gums and also as to their influence in certain industries such as sugar manufacture and brewing. A. Greig Smith appears to have been the first to connect the formation of gum, or gum flux, with bacterial action. In researches into the mode of formation of the gum from *Acacia perennis* (wattle-gum) he isolated from the twigs of the tree two kinds of bacteria, one of which, the most prevalent, named by him *Bacterium acaciæ*, when grown upon suitable media produced a slime of the araban-galactan class ('Proc. Linn. Soc. N.S.W.' 1902, Pt. III. Sept. 24). The view that a specific organism is responsible for the formation of gum is also held by Bean and Edie ('4th Report Wellcome Tropical Research Laboratories, Khartoum') as a result of their researches. Attempts to inoculate gum-bearing trees with this organism, however, led only to a decreased product of gum. Ruhland ('Ber. Deutsch. botan. Ges.,' 1906, **XXIV**. 393) holds the contrary opinion, although he was able to isolate a bacterium—*Bacillus spongiosus*—from diseased cherry-trees which formed a gum yielding only arabinose on hydrolysis. R. Greig Smith

('Centr. Bakt.' Par. II. 698–703) also discovered a bacterium—*Bacterium acaciæ*—in the gum of plum, cedar, peach, almond, and date trees. *B. persicæ*, found on peach and almond trees and *Cedrela Australis*, also probably influences the formation of gum. In a medium containing sucrose it forms a mucus or gummy matter which yields galactose and arabinose on hydrolysis. The gum of the fruit of *Sterculia diversiola* contains arabin and par-arabin (insoluble gum); these are stated to be produced by two organisms, *B. acaciæ* and *B. par-arabinium* respectively. Several varieties of the latter have been isolated and they produce par-arabin (*i.e.*, insoluble mucus) when grown under suitable conditions.

In the manufacture of sugar the juice sometimes becomes extremely viscous and very difficult to filter. This has been found to be due to an organism, *Bacillus levaniformis*, which forms a viscous or gummy product known as levan; this yields only lævulose on hydrolysis (Greig Smith and Thomas Steel, 'Jour. Soc. Chem. Ind.' 1902, 1381, 1904, 105). The product differs from that formed during the 'gummosis' disease or 'gumming' which takes place within the sugar-cane, the fibro-vascular bundles becoming filled with a viscous gum to which the name 'vasculin' has been applied by Cobb ('Agric. Gaz. N.S.W.' 1893, 777). Levan dissolves in cold water, but on dilution the sol becomes turbid and opaque, although no separation takes place either on standing or on centrifuging. It is not precipitated by basic lead acetate, but it forms an adsorption product with BaO containing 19·85 per cent. of the latter, similarly to starch.

Gum appears, however, to be present normally in unripe cane-juice, as this after evaporation thickens with acetic acid and on cooling sets to a solid mass. The amount of gum in the molasses was found to be 8 per cent. (Hazewinkel, 'Archiv Suikerind. Nederl. Ind.' 1910, **18**, 44–45).

Beet-juice sometimes becomes mucilaginous owing to a peculiar fermentation which is induced by an organism, *Leucostocus mesenteroides*, resulting in the conversion of the sugar into a carbohydrate known as dextran or fermentation gum. Two varieties of this carbohydrate appear to be formed, one of which is soluble, the other insoluble in water. *Bacillus gummosis* also develops in sugar solution, forming a gum having the composition represented by the formula $C_6H_{10}O_5$ (Happ). It is remarkable that in both these cases at a certain period in the growth of the organism it swells up enormously, diffusing itself through the liquid, thus forming a mucilaginous fluid.

Ropiness also occurs in beer, milk, wine, infusions of Ipecacuanha, Radix Althæa, Senegæ, Folia Farfaræ, Folia Digitalis, &c., from time to time; in all cases the cause has been traced to the action of micro-organisms. (For further information on this subject see Lafar, 'Micro-organisms and Fermentation,' pp. 270–278.)

Hemicelluloses.

The hemicelluloses constitute a group of closely related substances contained in the seeds, roots, &c., of various plants, the cellular tissues of certain plants consisting largely of these products intimately associated with cellulose, to which they are also allied.

On heating with water, some of the hemicelluloses swell up enormously and pass into the state of colloidal sols, which are extremely viscous and which revert to non-rigid gels after keeping for a few days.

Hemicelluloses from seeds are employed in the manufacture of sizing materials (P. C. D. Castle, Eng. Pat. 10,822, 1905, C. V. Greenwood, Eng. Pat. 564, 1912). The hemicelluloses, no doubt, vary in composition, but that from the locust-bean (*Ceretonia siliqua*) consists of a complex of mannan and galactan in the proportion of about 2 : 1, mannose and galactose in these proportions being the products of hydrolysis (Bourquelot and Herissy, ' Compt. Rend.' 1889, **129**, 228, 231, also 1889, **129**, 391–393). Solutions of hemicelluloses of this type yield, on evaporation, clear transparent continuous films which have considerable tensile strength and are much tougher than films of nitrocellulose. In composition they approximate to the formula $C_6H_{10}O_5$ (H. B. Stocks and H. G. White, ' Jour. Soc. Chem. Ind.' 1903, 4, also C. F. Cross, ' Lectures on Cellulose, Inst. of Chem.' 1912). They contain but little mineral matter and are not acidic in character. Sols of the hemicelluloses show a very high viscosity, increasing enormously with the concentration, but heat has only a slight effect in decreasing it. Dilute acids lower the viscosity very considerably, especially the mineral acids; alkalies increase the viscosity, especially of strong sols, which become glutinous or tenacious. Salts generally have very little effect except in strong solutions, in which case the complex is in many cases precipitated. Iron and copper salts, hydrogen peroxide, sodium peroxide, and potassium persulphate all lower the viscosity of the product. Heating under pressure and with organic acids renders the material quite fluid (C. V. Greenwood, Eng. Pat. 569, 1908), but partial reversion takes place after a time.

Hemicelluloses form adsorption compounds with bases such as $Ba(OH)_2$ and $Ca(OH)_2$ becoming more or less solidified and in diluted sol precipitated. Basic lead acetate forms a heavy solid white opaque gel, $KMnO_4$ and Fehling's solution also forms solid gels. Boric acid renders the gel more viscous, while the action is still more marked with borax, a solution of the complex being solidified to a brittle gel, while even in very dilute solution the material becomes so viscous that it ceases to flow and also does not wet the containing vessel. The mixing of viscous gels of this type with water is an interesting proposition ; the surface tension is so high that water will not penetrate. On stirring, the gel breaks up into small particles, which by long-continued stirring gradually absorb the water and coalesce, the mixture becoming homogeneous again. Friction is a considerable factor in the mixing, but, as dilution proceeds, the surface tension being progressively lowered, mixing becomes more and more easy. If the material is added to a large volume of water it is practically impossible to obtain a homogeneous solution. Mixtures of hemicelluloses with starch paste, some soluble starches, dextrin, if not too concentrated, Irish moss mucilage, and agar mucilage are easy to prepare, and homogeneous probably because the surface tensions are equal or nearly so ; but with hemicelluloses and gum arabic, gelatin, and strong solutions of dextrin the interfacial pressure must be considerable as there is no interpenetration, and although vigorously agitated they form granular or frothy heterogeneous mixtures which sooner or later separate into two layers of the different materials. The reason for this difference is not very apparent.

The hemicelluloses, consisting of mannan and galactan, react with tannic acid to form complexes, which in presence of excess of tannic acid appear as an opaque turbid sol with considerable reduction in

viscosity, immediately after mixing; upon standing, however, the viscosity progressively increases until after a few hours the product forms a soft gel which takes the form of the containing vessel; after a still further period the material separates into a stiffer gel and a clear supernatant liquid, about equal parts. On removing from the liquid, the gel progressively dehydrates until it forms a tough material like leather, and on fully drying it forms a hard solid. This product is an adsorption compound containing $C_{14}H_{10}O_9$ and $C_6H_{10}O_5$ molecules in the proportion 1 : 2. Owing to the special properties of this material, it is employed for the purpose of tanning, the colloidal carbohydrate having a restraining influence on the tannic acid, so that concentrated tanning liquors can be employed at the commencement and tanning completed in a few days (C. V. Greenwood, Eng. Pat. 5,018, 1910, and 7,635, 1915; also C. F. Cross, 'Lectures on Cellulose,' p. 38). On treating the material with water, tannic acid first dissolves, but on further dilution the complex becomes dispersed. Alcohol dissolves the whole of the tannic acid, precipitating the carbohydrate in the form of a flocculent gel. Some salts such as alum, Fe_2Cl_6, $FeSO_4$, and $ZnCl_2$, which yield precipitates with tannic acid, do not coagulate the hexosan-tannin complex, while others such as lead acetate, tartar emetic, $SnCl_2$, Na_2WO_4, and ammoniacal copper solution coagulate it.

The turbid complex becomes clear and much more viscous, *i.e.*, more dispersed at a temperature of about 12° C., reverting to the original condition on cooling; this change is strictly reversible. Alkalies and certain salts, *e.g.*, sodium benzoate and KCNS, also strong formaldehyde, sugar, glucose, and glycerine, cause a similar dispersion, the effect of hydroxyl, ions and groups, being most marked in this respect Acids appear to have very little action.

The nuts of vegetable ivory (*Phytelephas macrocarpa*) and also probably of the dum dum palm ('Bull. Imp. Inst.' 1911, 105-109), coffee, date stones, &c., contain the carbohydrate mannan, which on hydrolysis with acid yields mannose. Vegetable ivory consists of almost pure mannan, which has been carefully studied by S. W. Johnson ('J. Amer. Soc.' 1896, 214–222). The nuts at present used in turnery work in place of real ivory are very large, extremely hard and tough white seeds. On treatment with water it is not dissolved, but it is readily soluble in 70 per cent. sulphuric acid, from which it is precipitated unchanged by addition of alcohol and ether. The mannan thus formed swells in water and partially dissolves; it is more readily soluble in alkalies. This would be a very useful product if a colloidal solution in water could be prepared.

There is also contained in woods generally a gummy product known as xylan, which yields xylose on hydrolysis. This dissolves in solutions of the alkalies, but is insoluble in water. It is contained in large quantity in the alkaline liquors of paper-pulp manufactories, but has not yet been utilised for technical purposes.

Seaweed Jellies.

Several algæ yield colloidal products when boiled with water, but only a few have been utilised for technical purposes. They differ in composition and properties from the colloids previously described, containing less carbon and more oxygen, and in addition 0·15 to 1·0 per cent. of nitrogen, but in what state of combination is not known. They contain galactan and

a methyl pentosan—fucosan—which hydrolyses to form the methyl pentose —fucose.

Irish moss grows extensively on the coasts of Ireland and Scotland, and was at one time largely used for sizing linen; it is still used to a limited extent. On soaking in water the plant breaks down to form a gelatinous mass, and on boiling with water it forms a colloidal sol which is quite fluid while hot, but sets to a gel on cooling. This material contains a considerable amount of finely divided cellular tissue and usually has a high mineral content, *i.e.*, about 18 per cent. (H. B. Stocks and H. G. White, 'Jour. Soc. Chem. Ind.' 1903, 4). Irish moss gel becomes less viscous with caustic soda; $Ba(OH)_2$ and Fe_2Cl_6 both yield precipitates and alcohol partly precipitates it.

Agar-agar is a Japanese product derived from a seaweed; it occurs in thin crinkled ribbons, and is extremely bulky. On heating with water it does not swell very appreciably or easily dissolve, but when solution is complete the liquid is very thin while hot, but on cooling it very quickly sets at about 50° C. to a solid brittle gel, which does not readily melt below the temperature of boiling water. These properties render it extremely useful for bacteriological investigations and other purposes. A solution containing only 1 per cent. of agar is quite solid at the ordinary temperature.

Agar contains about 20 per cent. of moisture and only about 1 per cent. of mineral matter. It has no acid characters. It is only slightly acted upon when heated with caustic soda solution. Alcohol yields a white curdy precipitate, and it is also precipitated by basic lead acetate, and tannic acid, which latter does not affect Irish moss jelly. It mixes readily with gum arabic and hemicellulose solutions.

Japanese isinglass is very similar to agar, sometimes being sold in the ribbon form and sometimes in rods about 1 in. square, which, however, consist merely of membranes filled with air bubbles, so that in this form it is equally bulky.

It contains about 23 per cent. of moisture and 2·9 per cent. of mineral matter, but likewise has a similar composition to agar (see also C. F. Cross, 'Lectures on Cellulose'). It dissolves more easily and more completely in water than does agar, and on cooling forms even a stiffer gel. The gel is clear at first, but after a time it becomes opaque. It yields a white cloudy precipitate with alcohol and is precipitated by basic lead acetate. It mixes readily with gum arabic solution.

Evaporated seaweed products in the form of scales are sold for sizing and finishing purposes under the names of 'Algin,' 'Blandola,' 'Norgine,' &c. Norgine is stated by E. Schmidt ('Chem. Zeit.' 1910, 1,149–1,150) to be the sodium salt of laminaria acid. It is probably an adsorption compound, as are several of the products mentioned in the patents below.

E. C. C. Stanford (Eng. Pat. 142, 1881, also 8,075, 1899; see also 'Journ. Soc. Chem. Ind.' 1886, 218) prepared a product (which he named 'algin') by heating marine algæ with caustic soda or sodium carbonate. The material was regarded by him as an acid, which he named 'alginic acid'; this combined with alkalies to form soluble compounds—algenoids—which could be used for a variety of purposes, notably for sizing. By adding metallic salts such as those of iron, mercury, silver, &c., to the alkaline solutions, precipitates were obtained which he regarded as insoluble alginates, proposed to be used for medicinal and other purposes. Most of these were soluble in ammonia. The British Algin Co., T. Ingham

and H. Bunzyl, took out patents for the preparation and application of such double alginates for waterproofing purposes (Eng. Pats. 25,187 and 25,537, 1905).

Preparation of a size for raw silk consisting of Japanese isinglass, gelatin, alum, spermaceti, and glycerine (J. F. Girard, Eng. Pat. 8,402, 1885).

Preparation of Irish moss for sizing paper (C. Morfitt, Eng. Pat. 8,148, 1886).

Preparation of mucilage or size (G. Laurean, Eng. Pat. 6,988, 1894), removing the saline ingredients preliminary to treatment with alkali; also S. Pitt (Laurean, Son & Co.), Eng. Pat. 28,356, 1898.

A solution of kelp is fixed with an alumina or other metallic salt for waterproofing purposes (Laurance & Co., Eng. Pat., 20,356, 1898).

Mixtures of starch and seaweed are used (M. Cerf, Fr. Pat. 317,942, 1902). A. Krefting (Eng. Pat. 7,913, 1903) precipitates the jelly as 'tangate' of lime and mixes the product with carbonate of soda. P. Jensen (Eng. Pat. 11,625, 1903) claims the use of agar, after treating with citric acid and filtration, for films for photographic purposes. W. F. Cooper (Eng. Pat. 2,156, 1907) also claims the use of agar for the same purpose. W. F. Cooper and W. H. Nuttall ('Phot. Jour.' 1908, **48**, 11–25) state that agar has certain advantages over gelatine for photographic purposes, it sets at a higher temperature, the viscosity is eight times greater; 1 per cent. solutions can be employed which enables thinner films to be obtained.

Preparation of mucilages (J. H. Laurean, Eng. Pat. 5,169, 1906, and F. F. Figgis, Eng. Pat. 22,247, 1906).

H. Bruhn and C. Timpke (Fr. Pat. 381,323, 1907) propose seaweed jelly as a size for use in paints.

Chem. Fabrik, Gruman, Landshoff und Meyer, A. G. and R. May (Ger. Pat. 240,832, 1911) claim the preparation of 'Norgine' insoluble in water and alkalies, formed by action of formaldehyde, also use of 'Norgine' as a protective colloid (Ger. Pat. 248,526, 1911). M. P. Gloess (Fr. Pat. 445,771, 1912) proposes to use sodium peroxide in preparing gums from seaweeds.

T. Ingham (Eng. Pat. 13,777, 1913) employs double alginates of alkali and heavy metal as sizing and dressing materials.

E. Hastaden ('Farber Zeitung,' 1909, **20**, 107–109) describes the use of carrageen moss in finishing.

Albuminous Substances.

The group of albuminous compounds have a similar percentage composition, containing a high percentage of nitrogen, but differ very considerably in their properties. They are all typical colloids, and several are exceedingly useful for technical purposes.

Albumin.

Albumin is not only valuable as a food product, but it is employed in calico-printing, leather-dressing, bookbinding, for clarifying liquids, &c. It is derived either from white of egg or from blood serum after purification with animal charcoal. Both forms are met with in commerce in the form of scales. Egg albumin is pale yellow and is used for fine purposes; blood albumin is red or brown and has an odour of meat. The latter can be distinguished also by containing an oxidase.

White of egg contains 10 to 12 per cent. of albumin, about 88 per cent. of water, rather less than 1 per cent. of mineral matter, and also about 1 per cent. of a carbohydrate. In dealing with white of egg, usually the hen's egg is implied There are differences in the properties of the whites of eggs from different birds. For instance, the white of the duck egg has a bluish-cast and on heating coagulates to a stiffer gel.

Egg white consists of a glairy liquid portion and a glutinous portion; the latter, equal to about one-fifth of the whole, does not mix with the former but can be separated by means of a sieve. In what respect these two portions differ from one another we do not know, but there is certainly a difference in their alkalinity, the alkalinity of the glutinous portion being = to 0·473 per cent of NaHO, and the more fluid portion, alkalinity = 0·585 per cent. NaHO. White of egg when fresh shows a distinct alkalinity to phenol-phthalein, showing the presence of HO ions, this being = to 0·026 to 0·159 per cent NaHO; after keeping for a time, which may vary according to the quality of the egg, this reaction is not observed. The white is, however, always alkaline to methyl orange = to about 0·5 per cent. of NaHO. Addition of alkali to albumin results in a considerable increase in viscosity; with 20 c.c. white of egg and 3 c.c. N.NaHO the mixture sets to a solid gel after standing for a few hours; on further addition of alkali the albumin again becomes liquid, forming a thin fluid (alkali-albumin). Acids reduce the viscosity and finally coagulate the albumin, or, in solution, cause a flocculent precipitate. (For the effect of electrolytes on the viscosity, coagulation, and osmotic pressure of albumin see 'Colloids and their Viscosity,' Faraday Soc., March 12, 1913.) Acids, especially mineral acids, readily coagulate albumin; potassium ferrocyanide in acid solution is a powerful coagulant, being used as a test for traces of albumin. It is also coagulated by phenol, cresol, tannic acid, and by formaldehyde. It gradually yields a precipitate when shaken with ether or turpentine.

Egg white is purified for use in painting by adding dilute acetic acid till neutral and straining; this removes the glutinous portion and renders the material much more fluid. The painting can be rendered insoluble either by heat or by tannic acid (A. H. Church, 'Chemistry of Paints and Painting,' p. 63).

Dialysed albumin yields a clear gel with acetic acid; on heating, the mixture forms a clear fluid which gelatinises again on cooling. The viscosity of sols of albumin and acetic acid increases by keeping up to 18 to 20 days; the viscosity of albumen is also increased by addition of acetic acid up to 7·01 per cent.; further addition decreases the viscosity up to 11·22 per cent., when there is again a rise. Salts cause a rise in the rapidity of the reaction but not in the intensity (L. Zoja, 'Zeitschr. Chem. Ind. Kolloide,' 1908, **3**, 249, 269).

Albumin is readily salted out, salts of alkaline earths acting in this respect more powerfully than the alkalies, salts of zinc aluminium, and the heavy metals powerfully coagulate albumin.

Slaked lime and white of egg set to a solid; this mixture has been used as a cement for a very long time (D. C. Söuef (J. Schuberth), Eng. Pat. 1,225, 1862). A mixture of blood and slaked lime is a variant. White of egg in contact with iron or iron rust adsorbs $Fe_2(HO)_6$, becoming blood-red in colour (iron albuminate), at the same time losing its viscosity.

Albumin in solution is coagulated at temperatures above 54°; at that

temperature it commences to coagulate and at 70° it is converted into a solid white gel. If, however, it is evaporated at temperatures below 40° it dries to form a pale yellow, transparent, brilliant film which is easily broken up into scales, in which form it is sold.

Salts, *e.g.* $(NH_4)_2SO_4$, lower the coagulation point of albumin. The effect is not so marked with egg albumin as with serum albumin, while milk albumin is much more sensitive (K. Micho, ' Zeitschr. Unters. Nahr. Genussm.' 1911, 646–654).

Dried albumin contains about 12 per cent. of moisture and 5 to 6 per cent. of mineral matter; the alkalinity equals about 2·4 per cent. of NaHO, but on boiling with water the alkalinity is increased to 4·13 per cent.; it would appear, therefore, that on coagulating a chemical change takes place. The alkalinity is probably due to phosphates.

Albumin forms homogeneous systems with gum arabic and with agar. The specific gravity of egg-white is 1·045. Harriette Chick and C. J. Martin (' Zeitschr. Chem. Ind. Kolloide,' 1913, **12**, 69-71) found that the densities of egg albumin, crystalline serum albumin, serum globulin, &c., compared with the densities of the same products in the solid state, show that on dissolution there is a contraction amounting to from 5 to 8 per cent. It was also found that with serum albumin and serum globulin the solution volume was independent of the concentration, but that with casein the contraction which takes place diminishes with increasing concentration.

Albumin adsorbs Ag_2O from a solution of the nitrate, forming silver albuminate; and it was found that in photography the whole of the silver was not removed from this compound after fixing with sodium thiosulphate (Luppo Cramer, ' Zeitschr. Chem. Ind. Kolloide,' 1907, **2**, 171–172). A compound of albumin and copper is also formed by adding $CuSO_4$ to a solution of albumen, with or without the addition of KHO. In the absence of alkali the product had an almost constant composition, the Cu and SO_4 being present in equivalent amounts, the product containing albumin 86·67, Cu 5·26, and SO_4 8·07. In presence of alkali the proportion of SO_4 in the compound decreased as the alkali was increased, until the product had the composition albumin 68·75, Cu 31·25 (G. Bonamartin and M. Lombardi, ' Zeitschr. Physiol. Chem.' 1908, **58**, 165–174).

When aqueous sols of albumin, tannic acid, and a metallic salt, &c., are mixed, a precipitate is obtained which contains albumin, tannic acid, and the metal. Using 20 per cent. sols in all cases the precipitates had the following molecular composition calculating tannic acid as a dibasic acid.

	Metal.	Albumin	Tannin.
Ag salt . . .	18	32	50
Bi ,, . . .	14	40	46
Hg ,, . . .	15	50	35
Zn ,, . .	10	48	42
Cu ,,	9	50	41
Pb ,, . . .	16	45	39
Fe ,, . . .	5	60	35
Br ,, .	15	21	64
I ,, . . .	23	21	56

G. Grasser, ' Collegium,' 1911, 185-192 and 199-200.

A compound or combination of chloroform with an albumin has, according to C. S. Schleich (' Therapie der Gegenwart,' 1909, 138), been prepared. This preparation, which has been named ' desalgin,' contains 25 per cent. of chloroform in a solid colloidal form.

Both egg albumin and blood albumin are used for clarifying or 'fining' liquids. They owe their special functions to the fact that on heating, or by action of acids or tannin, the coagulum forms upon and around finely divided suspended matter; at the same time impurities may be adsorbed so that the liquids after settlement or filtration remain quite clear and bright.

Albumin or white of egg is used in baking for the preparation of light pastry, in which its film-producing properties are of great service.

Albumin is also very useful for glazing purposes and in the manufacture of leather finishes. (For the composition of leather finishes and the materials used in their manufacture see 'Leather Dressing,' by M. C. Lamb, pp. 263–282, also M. C. Lamb and A. Harvey, 'Jour. Soc. Dyers and Colourists,' 1917, 19.)

Egg-yolk, although it contains 33 per cent. of fatty matter, is also an albuminous product, seeing that it contains more albumin than egg-white, *e.g.*, about 15 per cent. It also contains about 1 per cent. of a carbohydrate and 1 per cent. of mineral matter. It is probably one of the most perfect emulsions known, since, however long it is kept, it shows no sign of separation or even on centrifuging or after considerable dilution. The albumin in egg-yolk, however, is not the same as that in the white, but consists, according to Gobley, of vitellin, nuclein, and cerebrin.

Egg-yolk is always slightly acid to phenol-phthalein, although alkaline to methyl orange, the alkalinity equalling about 0·87 per cent. of NaHO.

Egg-yolk is a very efficient emulsifying agent, being often used for this purpose. This property is, no doubt, due, partially at any rate, to the presence of lecithin in the fatty material; the amount of lecithin in the yolk equals about 10 per cent. Egg-yolk is employed in the preparation of 'fat liquors' for treating leather ('Leather Dressing,' by M. C. Lamb, pp. 214–228, also H. R. Procter, 'Leather Industries Laboratory Book,' 1908, p. 353), also in the manufacture of embrocations, being capable of emulsifying such incompatibles as acetic acid and olive oil or turpentine.

Certain salts, *e.g.*, NaCl, KCl, and KNO_3, cause a dispersion of the albumin in egg-yolk, the material becoming almost transparent. The same effect is produced with HCl, only that after a time the material sets to a gel and subsequently becomes opaque. 'Salted yolks,' that is, yolks containing about 10 per cent. of common salt, are an article of commerce.

Yolk of egg was one of the earliest mediums used in painting, being employed in ancient times as a medium for laying on the pigments in tempera painting. A. H. Church ('Chemistry of Paints and Painting,' 1892, p. 65) states that after a time the yolk becomes insoluble, the change being hastened by exposing the painting to sunlight, a practice which was quite common. Desiccated egg and yolk dried at a temperature of 100° F. also become gradually insoluble on keeping, this change being accelerated by heating at 100° F. or over, light not being necessary.

Casein.

Casein is the albuminoid of milk, which contains about 4 per cent., and in which it plays the part of an emulsifier, although in this respect it is not a perfect agent, seeing that milk separates on standing into two phases, the cream and skimmed milk. Cream separated by the centrifugal machine, however, is a perfect emulsion in which both the fat and casein

are more concentrated than in milk; in ordinary cream the two phases oil-casein and casein-water tend to progressive separation up to a limit. Milk also contains about 0·8 per cent. of a coagulable albumen which is stated to be identical with serum albumen.

Milk has an amphoteric reaction, *i.e.*, when fresh, it reacts feebly both acid and alkaline according to the indicator used; on keeping, it develops lactic acid by bacterial action, and at a certain acidity the whole solidifies to a gel, which after a time or with pressure separates into a solid 'curd' (casein or cheese) and a liquid 'whey.'

With hydrochloric acid the amount required to produce clotting was 20 c.c. of N/10 HCl for 20 c.c. of milk.

An investigation has been made into the influence of the hydrogen ion in milk clotting by C. Allemann ('Biochem. Zeitschr.' 1912, **45**, 346–358), who found that when different acids were added to milk together with rennet the time of clotting depended, not upon the acidity, but upon the hydrogen ion concentration. The clotting time diminishing up to a concentration of H ions of $1·3 \times 10^{-5}$ the point at which acid alone caused coagulation. The effect of salts, *e.g.*, mixtures of phosphates and of sodium acetate and acetic acid, was also studied. It was found that the clotting points of whole milk, skimmed milk, and caseinogenate solutions showed certain differences.

When the precipitation of casein is brought about by acid in presence of a protective colloid, *e.g.*, gelatin or isinglass, the coagulum is much more diffuse, not separating in curds; hence these additions are useful for milk foods. The coagulum is also more finely divided when produced by kephir, koumiss, or youghout (*i.e.*, ferments producing lactic acid), the proteids being probably to some extent peptonised.

When albumin is added to milk and the mixture heated, the albumin and casein separate together as a complex in the form of a gel.

Commercial casein is prepared from skimmed milk by addition of rennet or acids (acetic, hydrochloric), in the case of rennet a certain amount of peptone may be formed by the digestive ferment. There is a difference in the behaviour of caseins according to the method of preparation. They contain about 11 per cent. of water and 7 per cent. of mineral matter, mostly calcium phosphate; usually also a small quantity of fat is present which has an influence on its properties.

On treatment with water, casein swells to a certain extent but does not dissolve; with NH_4HO there is a considerable increase in the swelling, but the mixture is heterogeneous; with caustic alkalies, alkaline carbonates, alkaline earths, and alkaline salts, *e.g.*, borax, sodium phosphate, &c., it forms various states of solution, those with alkalies showing the least viscosity. On heating with alkali there is a slight decomposition, ammonia being evolved and the liquid becoming extremely thin. Casein is also soluble in hydrochloric acid.

The amount of hydrochloric acid required for solution of 1 gram of casein at 1·25 per cent. concentration was found to be 32×10^{-5} equivalent gram mols of HCl, and the amount of caustic soda at 2 per cent. concentration $11·4 \times 10^{-5}$ equivalent gram mols of NaHO (J. B. Robertson, 'Jour. Phys. Chem.' 1909, **13**, 469–489); casein is dissolved much less readily by solutions of alkaline earths (J. B. Robertson, 'Jour. Phys. Chem.' 1910, **14**, 377–392). On boiling casein with acids the rate of solution is directly in proportion to the strength and concentration of

the acid (*i.e.*, the H ion conc.). Acids are adsorbed by casein; thus from 100 c.c. of N/100 HCl nearly 50 per cent. was adsorbed in 3 hours; the amount varies almost directly with the concentration of the acid. With 1 gram of casein the equilibrium ratios at 0° C. with N/500 solutions were H_2SO_4 675, HCl 147, lactic acid 80, acetic 30. The affinity of casein for acids is, however, less than that for bases; 1 gram of casein combines with 9 c.c. of N/10 solutions of the hydroxides of Na,K,Li and NH_4 (F. Tangl, 'Pflüger's Archiv d. Physiol.' 1908, **121**, 534–549, 'Chem. Zeit.' 1908, 1, 1288).

Casein forms, with certain electrolytes, *e.g.*, KI, NaCNS, Na_2HPO_4, and KNO_3, fairly stable opalescent sols, which can be filtered; these are precipitated on addition of acids. It is insoluble in pyridine, but in a solution of pyridine it dissolves up to a maximum with increase of pyridine to $C_5H_5N.H_2O$. It is almost insoluble in formamide (S. Levites, 'Zeitschr. Chem. Ind. Kolloide,' 1910, 8, 4–8). Casein is rendered insoluble by formaldehyde. Tannic acid is absorbed by casein and can be quantitatively estimated, although the results are 1 to 1·5 per cent. too high (M. Nierenstein, 'Chem. Zeit.' 1911, **35**, 31).

Casein is utilised in many different ways in industry. It is employed along with lime, with or without pigments, as a washable distemper: as the lime carbonates it becomes insoluble. It is also used as a sizing material for textiles and paper (E. Sutermeister, 'Paper Making,' 1914, **33**, 140–143), being dissolved by ammonia (T. J. Denne and A. Hentschel, Eng. Pat. 2,429, 1872) or borax (H. V. Dunham, U.S. Pat. 897,885, 1908; see also F. W. Richardson, 'Jour. Soc. Dyers and Colourists,' 1909, 25, 4–3). Casein may be used as a cement along with sodium phosphate (W. A. Hall, Eng. Pat. 2,949, 1903), water glass (C. Wittkowsky, Eng. Pat. 9,070, 1905), slaked lime (C. W. Luther, Eng. Pat. 6,104, 1892), casein, rosin, and an alkali (C. and A. Bernstein, Ger. Pat. 270,200, 1913), sodium silicate and a strong solution of a salt of Ca, Ba, or Mg (A. Bernstein, Fr. Pat. 370,940, 1906).

Casein is a useful material for the manufacture of plastic masses, which can be readily moulded and set hard after a time. 'Galalith,' a combination of casein and formaldehyde, is a material of this kind which closely resembles bone or ivory and can be turned or carved (G. Bonitt, 'Zeitschr. angew. Chem.' 1914, **27**, 2).

Plastic masses can be formed by precipitating alkali-albuminate with acids and mixing the coagulum with a carbohydrate formed by the action of alkali solution on cellulose hydrate or starch. The mixture first liquefies and then progressively hardens (J. G. Jurgens and H. Timpke, Fr. Pat. 420,164, 1890). Combinations of casein and amines, amides or their derivatives (*e.g.*, aniline, acetanilide) are also employed (Soc. anon. L'Oyonnaxienne, Fr. Pat. 472,192, 1914). A substitute for horn or ivory is made from albumin or casein or alkali-albuminates by treating with the neutral esters of higher alcohols or amino-fatty acids which harden and coagulate them (W. Plinatus, Fr. Pat. 465,048, 1913). A mixture of casein and gelatin is treated with Na_2SiO_3 and then hardened with alum (F. von Kagenek, Ger. Pat. 281,541, 1913). Hydrochloric acid forms a gel with casein which is plastic (Eborit. Ges.m.b.H., Ger. Pat. 191,125, 1902). Casein is heated with water under pressure and the mass hardened with formaldehyde (Soc. anon. franç. de Chim. Ind., Fr. Pat. 425,204, 1910). A combination of casein, gum, glue, and rosin oil is also similarly

hardened with formaldehyde (Soc. anon. franç. de Chim. Ind., Fr. Pat. 425,204, 1910).

Casein is also used for waterproofing fabrics and for calico-printing, being rendered insoluble by vapours of formaldehyde (J. E. Bousfield (F. Cautin, G. Miglioretti, and G. Maffei), Eng. Pat. 1,160, 1901) or aluminium acetate.

Albuminous substances, particularly casein, are converted into sols by alkali sulphocarbonates, the same being coagulated by $(NH_4)_2SO_4$ and the product drawn into threads, films, &c. (Fr. Pat. 395,402, 1907, and addition of July 31, 1909).

For the preparation, properties, and applications of casein see also 'Casein and its Technical Utilisation,' by Robert Scherer, 1906 (Scott, Greenwood & Son).

Gluten.

Gluten is one of the proteids of flour, wheat-flour containing a coagulable albumin, gluten, and gliadin, the total being about 10 per cent. in the soft wheats and about 15 per cent. in the hard. When flour is first mixed with water it forms a very sticky tenacious mass, but after kneading for a little while it becomes quite plastic and may be freely handled. The baking properties of flour, *i.e.*, its capacity for imbibing water and retaining the gases generated during the fermentation, are very largely dependent upon the quantity and quality of the gluten present. Flour which has become deteriorated by storage or damaged by water has a weak gluten (*i.e.*, bacterial activity has lowered its viscosity); in such cases it forms very heavy and dark-coloured bread.

The baking properties of the flours from different cereals vary considerably; this is due not so much to the quantity of gluten present as to its quality, and also to the physical characters of the flour. Everyone is familiar, for instance, with the differences between wheat and oat bread.

Gluten is obtained from wheat-flour by washing it in a muslin bag in a stream of water, and kneading it till all the starch has passed through the cloth; this is the basis of the manufacture of macaroni and vermicelli and also of some of the American chewing gums. The gluten prepared in this way is crude, since it contains the cellular tissue of the flour. This method is employed in testing flour for sizing purposes. If the flour is fresh, the gluten is cream-coloured, stiff, and tenacious, but with deteriorated flour it is grey, soft, and pulpy, even sometimes passing along with the starch through the muslin. Gluten absorbs water to form a plastic mass, but after fully drying it does not again swell to the original extent. It is readily swollen by alkalies and by dilute acids, eventually passing into the state of a colloidal solution. The gluten of wheat-flour is rendered soluble by acetic and lactic acids formed during fermentation for sizing purposes, but it appears in other respects to be but slightly affected (H. B. Stocks and H. G. White, 'Jour. Soc. Chem. Ind.' 1903, 4). This is also the reason for the deterioration of baking-flour, and at one time it was corrected for by addition of alum, or copper sulphate, which rendered the gluten insoluble again and the bread whiter; the addition of these substances to flour is now illegal.

Fermented gluten dissolved in ammonia was proposed to be used in place of albumin for calico-printing, also for clarifying liquids and for photographic purposes (R. A. Brooman (C. Kestner), Eng. Pat. 2,428, 1864).

According to J. B. Wood ('Jour. Agric. Science,' 1907, **2**, 267–277), the properties of gluten are influenced by acids, by alkalies, and by salts. For instance, with HCl of N/100 strength it loses its coherence and commences to disintegrate, this effect increases with the concentration up to N/30, above which the opposite effect is noted, until with N/12 acid it becomes permanently coherent, less sticky, harder, and more elastic. Similar effects are noted with H_2SO_4, H_3PO_4 and $H_2C_2O_4$, but acetic, lactic, citric, and tartaric acids, irrespective of concentration, produce only loss of coherence with no subsequent recovery of strength. Soluble salts induce greater coherence with weak solutions of HCl, sodium sulphate acting more strongly than NaCl and Mg and Al sulphates still more so. Alkalies cause the gluten to become negatively charged, while acids have the opposite effect. Long-continued washing with water causes the dispersion of the gluten, owing to the CO_2 which it contains (J. B. Wood and W. B. Hardy, 'Proc. Roy. Soc.' 1909, **B. 81**, 38–43).

When moist gluten is placed in a solution of a salt, the salt is adsorbed by the gluten and at the same time water passes into the solution, the result being partial dehydration. The most active in this respect are the sulphates; chlorides and nitrates being apparently equal. Salts of the alkalies are more active than those of the alkaline earths. The 'partition constants' of $MgSO_4$ and $(NH_4)_2SO_4$, both of which are used as protein precipitants, are stated to be considerable (A. J. J. Vandervelde and L. Bosmans, 'Bull. Soc. Chim. Belg.' 1912, **26**, 249–254).

When gluten is bleached by SO_2 its elasticity is destroyed (M. G. Carteret, 'Bull. Soc. Chim.' 1909, 5, 270–272). SO_2 gas has been proposed as a solvent for gluten in the preparation of an adhesive (E. Donath, Ger. Pat. 172,610, 1905). Gluten is also brought into solution by means of a per- salt of an alkali (Erste Triester Reisschäl-Fabriks Aktien-Ges. Trieste, Eng. Pat. 8,203, 1910).

A patent has been granted to G. von Riegler (Fr. Pat. 461,131, 1913) for the preparation of artificial milk by dissolving gluten in KHO, salts, &c.

Soya beans (*Soya hispida*) contain about 38 per cent. of a proteid which resembles casein or gluten in its properties. In Japan and China it is the basis of several kinds of food, and it is also interesting, because it has been used more or less successfully in the manufacture of artificial milk, being converted into a colloidal solution by means of the phosphates of potash or soda and water and then emulsified with oil and lactose (F. Gässel, Fr. Pat. 451,447, 1912, Eng. Pat. 27,860, 1912, also J. Monahan and C. J. Pope, U.S. Pat. 1,104, 376, 1914); it has also been proposed as a plastic material, for the manufacture of artificial horn, bone, &c., for which purpose it is boiled with water and then coagulated with $Al_2(SO_4)_3$, or formaldehyde (R. Dodd and H. B. P. Humphries, Eng. Pat. 15,316, 1913).

Gelatin or Glutin.

Gelatin is the most typical of the reversible colloids, a solution containing it being very fluid when hot, but setting to a clear stiff gel on cooling, which again becomes fluid at a temperature of about 25°C. Dry gelatin imbibes a certain amount of water in the cold, the quantity depending upon, and is used a test for, the quality of the material, but it retains its shape and does not dissolve unless it is very impure. In the case of glue

which is moderately impure, a portion may diffuse from the swollen gel into the water.

Gelatin is used for food purposes, as an adhesive, in sizing paper and cloth, in the manufacture of photographic plates, printers' rollers and similar compositions, and as a size for painters' use.

In addition to having considerable viscosity, gelatin or glue solutions show in the most marked manner the properties of adhesiveness or 'stickiness,' which renders it so useful in many different trades. It also forms continuous films on drying, these being perfectly transparent when the material is pure, and having considerable toughness, except when the natural moisture is dried out, when it becomes brittle.

On long-continued heating, gelatin solutions lose viscosity; heating with acids and alkalies has a more pronounced effect, in some cases the product remaining fluid even at the ordinary temperature (basis of liquid glues); these products, however, have less viscosity and adhesiveness than the original material. Impurities, both organic and inorganic, tend to produce a similar effect, thus fish glue is often quite fluid and does not set to a gel, even when concentrated.

Moore and Roaf ('Biochem. Jour.' vol. 2, 39) found the osmotic pressure of a 10 per cent. gelatin, using a parchment paper membrane, to be 90 mm. at 40°, and 158 mm. at 91°. When injected into the blood, gelatin has the remarkable property of increasing its coagulability (H. Grau, 'Deutsche medizinische Wochenschrift,' 1910, 27, also Schultz, as quoted by Umber, 'Zeitschr. für arztliche Fortbildung,' 1912, No. 20). Gelatin swells in glacial acetic acid and on heating forms a fluid sol, used as a liquid glue; it is readily dissolved by crude carbolic and cresylic acids. It dissolves to the extent of 40 per cent. in a saturated solution of urea, the sol reverting to a gel on dialysing.

Gelatin is powerfully affected by even weak solutions of NaHO, KHO, and LiHO, which cause solution even in the cold; in presence of ammonia it swells considerably but does not pass beyond this stage. Alkaline carbonates and tribasic phosphates have the opposite effect, retarding solution, and with concentrated solutions entirely preventing solution even at 100° (A. L. Lumière and A. Seyewetz, 'Bull. Soc. Franç. Photo.' 1912, **3**, 159–163).

The effect of dilute acids, alkalies and salts upon gelatin has been closely studied by H. R. Procter ('Kolloidchem. Beihefte,' 1911, 2, 243–284), who found that the swelling of gelatin in highly ionised acids is considerably greater than in water, but weak acids, *e.g.*, H_3BO_3, CO_3 and SH_2, have not the same effect. Some of the acid is fixed either as a salt or by adsorption, the whole reacting to phenolphthalein but not to methyl orange. The swelling is partly due to the hydrogen-ion concentration. Swelling is retarded by salts, especially when concentrated. Alkalies also cause the swelling of gelatin, but in this case the swelling is not inhibited by neutral salts, and therefore appears to be due to the H-O ions and not to the cation. See also M. H. Fischer and A. Sykes ('Les Matières Grasses,' 1914, 4202–4204). The last-named authors state that with non-electrolytes the maximum dehydrating effect is observed only with high concentration, whereas, with electrolytes it is attained at a lower concentration, there being only slight increase in action for each successive increase in concentration.

According to J. L. de Bancels ('Compt. Rend.' 1908, **146**, 290–291), gelatin dissolves in water in presence of certain salts at the ordinary

temperature, the bivalent metals acting more strongly than univalent metals in equal concentrations.

The nitrates of the metals have a greater influence than the chlorides. The addition of electrolytes also causes the gelatin to dissolve in mixtures of non-electrolytes and water, *e.g.*, alcohol or acetone. On removing the salt by dialysis or by precipitation the gelatin separates.

The effect on gelatin of a large number of reagents, including acids, salts, phenols, &c., is described by A. L. Lumière and A. Seyewetz ('Bull. Soc. Chim.' 1908, 3, 713–750).

Certain salts, *e.g.*, those of Va, Ni, Co, and Cr, render gelatin insoluble (Luppo-Cramer, 'Zeitschr. Chem. Ind. Kolloide,' 1909, 4, 21–23). Salts of Al and especially Fe_2Cl_6 have a similar effect (C. E. Millar, 'Jour. Soc. Chem. Ind.' 1900, 326).

With regard to the effect of chromium salts on gelatin, the action depends upon the constitution of the chromium compound employed. Thus when a small quantity of bichromate of potash is added to gelatin it has no sensible effect except after exposure to light, when the organic colloid becomes insoluble in hot water. The action of the bichromate is not well understood, although it is regarded as an oxidation process. The reaction, however, is made use of to a very large extent in photography, especially in the photomechanical processes. Dealing with gelatin from this point of view, C. W. Gamble ('Jour. Soc. Chem. Ind.' 1910, 65) states that it is a complex, the parent substance being 'collagen.' After heating for some time, gelatin passes into 'gelatose' which does not gel, this change being also brought about by bacterial action and by proteolytic enzymes, especially trypsin. Bone gelatin and fish glue are classed as gelatoses. Gelatin and gelatose are precipitated by bromine in acid solution (A. H. Allen, 'Analyst,' 1897, 258) and also by chromic acid. Gelatin peptone is not precipitated by chromic acid, nor is it rendered insoluble after addition of bichromate and exposure to light, it also passes freely through a membrane. Gelatin peptone has a marked effect upon gelatin causing a greater tendency to dispersion. Glucose has a similar effect. Both these substances counteract the effect of bichromates after action of light, the film tending to dissolve on washing.

Gelatin has now almost entirely replaced albumin and collodion in the manufacture of photographic plates and papers. It is more reliable and more easily penetrated by the solutions employed, the introduction of this colloid for these purposes entirely revolutionised the photographic trade, and is largely responsible for the enormous developments which have taken place.

The preparation of photographic emulsions is based on the knowledge gained after years of practical work, and may be regarded as an industry founded upon the application of capillary phenomena.

There are many interesting points in connection with photography; for instance, Lüppo-Cramer ('Zeitschr. Chem. Ind. Kolloide,' 1907, 2, 171–172) found that silver oxide formed in a gelatin film by the action of NaHO caused the gelatin to become opalescent and insoluble in boiling water.

It is proposed to purify gelatin for photographic purposes by means of electro-osmosis, the fat and electrolytes passing through the membrane while the albuminoid substances are precipitated (Ges. für Elektro-Osmose, Eng. Pat. 21,418, and 21,481, 1914).

Electro-osmosis is likely to play an important part in industry in the

future, and several patents have been taken out in this connection for separating ions from colloids, for removal of water from peat, for removal of impurities from clay, &c.

Reverting again to the action of chromium compounds on gelatin, the effect of chromic compounds is also important since it has developed into an industry, that of 'chrome tannage.' According to Lumière and Seyewetz ('Bull. Soc. Chim.' 1903, 1077), 100 grams of gelatin fix from 3·2 to 3·5 grams Cr_2O_3 irrespective of the chromium salt employed. On the other hand, J. T. Wood ('Jour. Soc. Chem. Ind.' 1908, 384) found that the amount of chromic oxide taken up varied with the concentration of the salt; in dilute solution it amounted to 5 per cent. and in a strong solution 13·6 per cent., showing that it is an adsorption phenomenon.

Formaldehyde added to a gelatin sol raises the viscosity and finally solidifies it to an irreversible gel. This reaction is made use of in waterproofing, preparation of artificial silk, &c.

The maximum amount of formalin absorbed by gelatin is between 4·0 and 4·8 grams per 100 grams of dry gelatin (A. L. Lumière and A. Seyewetz, 'Bull. Soc. Chim.' 1906, 35, 872–879).

Compositions containing gelatin and glucose, invert sugar (treacle), or glycerine are employed in the manufacture of printers' rollers, 'jelly-graphs,' and for moulding purposes.

The permanent softening effect which these products have upon gelatin is probably due to their OH groups.

The gelatinising temperature or setting-point of gelatin is raised by partial purification by washing out some of the salts with water (K. Wenkiblech, 'Zeitschr. angew. Chem.' 1906, **19**, 1260–1262).

Alum and aluminium salts also raise the setting-point or 'harden' gelatin; in this respect the alkali aluminates have no action. In the case of alum or aluminium sulphate, the salt is first adsorbed, then by washing with water the SO_4 is removed, finally leaving Al_2O_3. The amount of Al_2O_3 adsorbed increases with increase in concentration up to a maximum of 3·6 per cent. Al_2O_3 (A. L. Lumière, 'Brit. Jour. Phot.' 1906, **53**, 573–4).

The most important reaction of gelatin especially in connection with tanning is that with tannic acid, the two being mutually precipitated in neutral or acid solutions, the gelatin then having a positive charge and the tannic acid a negative one. In a paper by J. T. Wood ('Jour. Soc. Chem. Ind.' 1908, 384) it is mentioned that Humphry Davy ('Proc. Roy. Soc.' Feb. 4, 1803) found the amount of precipitate to increase with the concentration, 100 parts of the coagulum containing 54 of gelatin and 16 of tannin. Lipovitz ('Jahres. Forts. Chemie,' 1861, p. 624) states that 100 parts of dry isinglass precipitates 65 of tannin. Rideal ('Glue and Glue Testing,' 1900, p. 111) found 42·7 gelatin and 57·3 tannin, Mulder (Allen, 'Com. Org. An.' iv. 463) says that 100 parts of dry gelatin precipitates 135 of gallotannic acid. R. Williams (Allen, p. 484), using 1 per cent. solutions of glue and tannic acid, and estimating the excess of tannic acid in the filtrate, arrived at the figures 77·5, 77·9, and 78·6 parts of tannin for 100 of gelatin. Böttinger, quoted by Procter ('Principles,' p. 63) found 66 per cent. of gelatin in the precipitate, which equals 50 parts of tannin to 100 parts of gelatin. These figures vary to such a degree as to prove that the reaction is not truly a chemical one. J. T. Wood (*ibid.*) found the amount of tannin precipitated by 1 part of gelatin to vary from 0·91

to 3·25 according to the concentration of the solutions and the time, and gives the following figures showing the composition of the precipitate :

	Unwashed.	Washed.
Gelatin . . .	25	32
Tannin . . .	75	68

According to Trunkel (' Biochem. Zeitschr.' 1910, **26**, 458–492), the reaction between tannin and gelatin is an adsorption phenomenon. Under certain conditions the whole of the gelatin and tannic acid can be precipitated quantitatively, the product then being insoluble and resistant to water. With excess of tannin the amount of tannin may be three times that of the gelatin, but the precipitate is then unstable and affected by water. By continued treatment with alcohol, 97 per cent. of the tannin can be removed, the remainder being retained. From the residue only about 6 per cent. of gelatin could be obtained in an unaltered condition. Trunkel also states that, with a freshly prepared solution of tannin, 1 part of gelatin required 0·7 part of tannin for complete precipitation, whereas with a solution 24 hours old only 0·4 part was required

H. R. Procter (' Jour. Soc. Chem. Ind.' 1910, 329) also states that the precipitate is a colloidal combination, not a truly chemical (ionic) reaction, the precipitate is not definitely quantitative, and that the tannin can be removed to an almost unlimited extent by washing with water.

Gelatin in dilute solution, mixed with Japanese isinglass and also with agar, gives a somewhat similar reaction to that with gum arabic, a turbidity appearing which is increased on acidifying with HCl.

Chondrin from cartilage, although similar in its properties to gelatin, does not form such a stiff gel on cooling, it is also precipitated by alum and other salts which do not precipitate gelatin (Church, ' The Chemistry of Paints and Painting,' 1892, p. 65). Isinglass is somewhat similar to gelatin in its properties although it is not so easily soluble ; it is used in ' fining ' wine in which case it is coagulated, and carries down with it the finely divided suspended matter which rendered the liquid turbid.

The properties of gelatin are very considerably affected by impurities (decomposition products = gelatin peptone, &c.) and according to C. Dhéré and M. Gorgolewski (' Compt. Rend.' 1910, **150**, 934–936) the latter can be almost entirely removed by dialysis over a long period, *i.e.*, 1½ to 3 months, or by freezing a weak solution, when flocks of demineralised gelatin separate. Commercial gelatin carries a positive charge while demineralised gelatin is negative, therefore pure gelatin will be electrically neutral. Gelatin purified by these methods yields opalescent sols within certain limits of concentration. At 2 per cent. the sol is turbid, at 8 per cent. nearly clear, and at 10 per cent. quite so. Addition of alkali either partially or entirely removes the turbidity, but acids have not such a strong effect. A solution of such purified gelatin does not form such a strong gel as the original, a flocculent product settling out. Traces of electrolytes, *i.e.*, acids, alkalies, and salts, cause gelatinisation to take place ; this is the case with salts like KI which have an opposite effect upon ordinary gelatin.

According to J. T. Wood (' Collegium,' 1908, **12**, 494–5), the removal of the salts or the precipitation of lime by ammonium oxalate affects the tannin precipitate, rendering it less in amount. He is therefore of opinion that the predominant ions are those of calcium. Meunier states that a

small quantity of borax entirely inhibits the precipitation of gelatin by tannin, but boric acid does not influence it. Gelatin which has been precipitated by alcohol contains the whole of the mineral matter, and is, in fact, practically unaltered by the treatment.

In addition to the patents in connection with gelatin mentioned in the text the following are of interest :—

J. A. Swan (Eng. Pat 3,303, 1866) claimed the use of chrome alum and other salts of chromium for rendering gelatin insoluble.

E. M. Knight and A. H. Hobson (Eng. Pat. 13,168, 1887) prepare a cement or gum by heating glue or gelatin with soda.

A. Zimmermann (Chem. Fabrik auf Actien vorm E. Schering, Eng. Pat. 2,036, 1894) patented the application of formaldehyde for rendering gelatin and isinglass insoluble. The same firm claimed that the addition of a very small quantity of formaldehyde to glue materially increased its strength without rendering it insoluble (Eng. Pat 4,696, 1894). J. Hofert (Eng. Pat. 4,697, 1894) uses gelatin as a waterproofing agent, rendering it insoluble with formaldehyde. An artificial silk (Vandaura silk) is manufactured from gelatin threads rendered insoluble by formaldehyde (A. Millar, Eng. Pat. 6,700, 1898 ; see also A. Millar, ' Jour. Soc. Chem. Ind.' 1899, 17, and C. E. Millar, *ibid.*, 1900, 326).

E. J. Mills (Eng Pat. 8,847, 1895) proposed to use alkali and microbes, such as *Bacillus liquefaciens*, and liquid glue. Plastic substances are obtained by digesting ' ossein ' in NaHO solution (A. Heilbronner and E. A. Vallee, Eng. Pat. 20,548, 1906).

A mixture of gelatin, glycerine, formaldehyde (trioxymethylene), and an oxidising material, is employed for moulding purposes (B. Sauton, Eng. Pat. 27,616, 1906).

W. H. Perkin and Whipp Bros. & Tod (Eng. Pat. 23,030, 1907) claim the use of coal-tar creosote for dissolving gelatin.

The coagulation of colloids, *e.g.*, gelatin, glue, agar, casein, starch (commercial dextrin), is prevented by treatment with a salt of an organic sulphonic acid or derivative (The Arabol Man. Co., Fr. Pat. 394,173, 1908).

Use of lævulose for softening gelatin and glue (F. Evers, Eng. Pat. 25,145, 1909). See also A. H. Church, ' Chemistry of Paints and Painting,' p. 72.

COLLOIDS IN THE SETTING AND HARDENING OF CEMENTS.

By Dr. C. H. Desch, *Metallurgical Laboratory, University of Glasgow.*

The most important chemical investigation of the setting and hardening of calcareous cements is that which was submitted by Henry Le Chatelier in 1887 as a thesis for the Doctorate in the University of Paris. The setting of plaster of Paris was there shown to be due to the formation of an unstable solution of the hemihydrate in water, soon followed by the crystallisation of the less soluble dihydrate in spherulitic forms, the strength of the plaster after setting being due to the interlacing of crystals from neighbouring centres. Later investigations have only confirmed the truth of this explanation. In the case of Portland cement, it was shown that the basic silicates and aluminates of calcium contained in the cement clinker were hydrolysed by water, forming less basic salts and free calcium hydroxide. The most stable of these salts were determined

to be CaO, SiO_2, $2{\cdot}5H_2O$ and $4CaO$, Al_2O_3, $12H_2O$, and microscopical examination showed that all the products formed more or less spherulitic groups of crystals when the hydration took place in presence of an excess of water.[1] Le Chatelier's explanation was generally accepted. The alternative hypothesis, that 'the calcareous hydraulic cements owe their hardening mainly to the formation of colloidal calcium hydrosilicate,' was proposed by W. Michaelis in 1893,[2] but attracted little attention until much later, when it was expanded into a detailed memoir,[3] at a time when the interest in colloidal substances had become much more general.

According to the hypothesis proposed by Michaelis, the first effect of the action of water on the ground cement is the hydrolysis of aluminates. An unstable solution is rapidly formed, from which calcium sulphoaluminate, $3CaO$, Al_2O_3, $3CaSO_3$, xH_2O (due to the action of the calcium sulphate which is present in all commercial cements), and calcium aluminate separate as stable phases. The former compound is soluble, and crystallises readily in needles. The aluminate is less soluble, but is also crystalline under normal conditions, forming hexagonal plates. At this stage the silicates of the clinker are scarcely attacked. When the hydrolysis of the di- and tri-calcium silicates sets in, the only stable products are the hydrated metasilicate and calcium hydroxide, of which the latter crystallises in large plates, as observed by Le Chatelier. The case of the very insoluble metasilicate is different. The investigations of von Weimarn[4] have shown that a solid phase separating slowly from a moderately supersaturated solution forms well-defined crystals, that separation from a highly supersaturated solution favours the formation of crystal skeletons or spherulitic groups of needles, and that the formation of a highly insoluble product in a strongly supersaturated solution gives rise to the formation of gels. Michaelis found that the hydrated calcium metasilicate almost invariably took the form of a gel, and that even the aluminate assumed that form if the solution were sufficiently supersaturated. The coating of the particles of ground clinker with a gelatinous sheath is readily observed under the microscope. The particles increase in size by the swelling of the gel, a fact which is very obvious in photographs taken at different intervals after the addition of water.[5]

This hypothesis has been challenged on the ground that if swelling actually took place, as in the absorption of water by starch grains or gelatin, the volume of the cement during setting must increase, and that no such increase does in fact occur.[6] This objection is based on a misunderstanding.[7] The individual particles increase in size, but

[1] *Thèse de Doctorat*, 1887, 'Recherches expérimentales sur la Constitution des Mortiers Hydrauliques,' Paris, 1904.

[2] *Chem. Zeit.*, 1893, **17**, 982.

[3] 'Der Erhartungsprozess der kalkhaltigen hydraulischen Bindemittel,' Dresden, 1909. Partly in *Kolloid Zeitschr.* 1909, **5**, 9. An account of the hypothesis is given by C. H. Desch, *The Chemistry and Testing of Cement*, London, Arnold, 1911.

[4] The papers of P. P. von Weimarn in the *Kolloid Zeitschr.* for 1908-9 were collected in book form, *Zur Lehre von den Zustanden der Materie*, 2 vols., Dresden, 1914.

[5] H. Ambronn, *Tonind. Zeit.* 1909, **33**, 270.

[6] C. Schumann, *Tonind. Zeit.*, 1909, **33**, 465. See also A. Martens, *Mitt. k. Material-Prüf. Amt.*, 1897, **15**, 109.

[7] A. G. Larsson, *Tonind. Zeit.*, 1909, **33**, 785; W. Michaëlis, *ibid.*, 615. See also H. Kuhl, *ibid.*, 556.

the total volume of cement and water diminishes during setting, a similar statement being true of the swelling of starch grains in water.[8]

A gelatinous coating having once been formed around the particles of clinker, which are thus protected from direct contact with the solution, a further series of changes sets in. Water is withdrawn from the gel by the unchanged core of clinker, which thus becomes progressively more hydrated, although even after many years the proportion of cement which has escaped hydration is always considerable. At the same time, according to Michaelis, lime is adsorbed from the solution by the outer layers of the gel, which thus become harder and less permeable. On this view, the 'initial set' of cement corresponds with the hydration of the aluminates, forming crystalline masses comparable with plaster of Paris. The 'final set' is due to the formation of a silicate gel, traversed by crystals of calcium hydroxide, whilst the subsequent processes of desiccation and adsorption account for the progressive hardening of cement, which continues over a period of years

A modification of this hypothesis was proposed by G Becker,[9] according to whom the gelatinous membranes become stretched by the osmotic pressure, and then, through adsorption, undergo a change similar to that involved in the lignification of plant fibres Becker also assigns a somewhat greater share in the process to the crystalline products of hydration.

Further evidence in favour of the colloidal hypothesis was adduced by Michaelis If the calcium compounds in Portland cement be replaced by barium, a similar series of changes takes place, but the product is not hydraulic, owing to the much greater solubility of the barium metasilicate, and the resulting compounds are entirely crystalline, so that the process of setting resembles that of plaster rather than of Portland cement. The presence of gelatinous material in briquettes of Portland cement after setting and hardening was observed by E. Stern,[10] opaque sections being examined by reflected light. Stern considered the gelatinous constituents to be alumina and calcium metasilicate, fine fibro-crystalline calcium alumimate also playing a part in the binding together of the mass, whilst the presence of calcium metasilicate in a crystalline form was doubtful

The interest shown in the chemistry of hydraulic cements shortly after the appearance of Michaelis's paper was such as to justify the publication of a special periodical devoted to the subject, which however only survived for eighteen months.[11]

An attempt was made to distinguish the various products of hydration by the application of organic dyes, which stain colloidal and zeolitic mineral substances selectively. By examining the behaviour of different substances, such as silica, alumina, calcium silicate, and calcium aluminate, when immersed in acid, neutral and alkaline solutions of such dyes as patent blue, anthrapurpurin, and methylene blue, and then testing hydrated cements with the same reagents, conclusions may be drawn as to the nature of the products contained in the cement.[12] The result

[8] H. Rodewald, *Zeitschr. physikal. Chem.*, 1897, **24**, 193.

[9] *Tonind. Zeit.*, 1909, **33**, 1493.

[10] *Ber.*, 1908, **41**, 1472; *Zeitschr. anorg. Chem.*, 1909, **63**, 160; *Mitt. k. Material-Prüf. Amt.*, 1910, **28**, 173.

[11] *Zentralblatt für Chemie und Analyse der Hydraulischen Zemente*, ed. F. R. v. Arlt, Halle a. S., 1910-11.

[12] S. Keisermann, *Kolloidchemische Beihefte*, 1910, **1**, 423.

of these observations is to show that calcium metasilicate is present both in the crystalline and the gelatinous forms, but that the tricalcium aluminate is entirely crystalline. The effect of stains varies considerably with the conditions of the experiment, and the present writer has been in many instances unable to confirm the observations of Keisermann. It should be added that so experienced an observer as Le Chatelier still considers that the process of setting of hydraulic cements is entirely one of crystallisation, and denies the influence of colloidal substances.[13] In repeating experiments on this point, it is important to remember that the process is not necessarily the same when a small quantity of cement is mixed with a relatively large proportion of water on a microscope slide and when, as in the practical use of cement or the making of test briquettes, the cement and water are mixed to a stiff paste; and neglect of this fact, no doubt, accounts for some of the divergences between the conclusions of different investigators. The influence of the size of grain was pointed out by Wetzel in a criticism of the work of Keisermann.[14] An explanation of the hardening of cement in air, based on the assumption of the presence of colloids, which then absorb water vapour from the air, was given by L. Jesser.[15]

Experiments in which stains were used led F. Blumenthal[16] to the conclusion that crystalline monocalcium silicate was among the first products of hydration, together with the aluminate, and that the formation of the gelatinous silicate took place subsequently. The setting of the cement was then due to crystallisation alone, the later hardening being due to the binding together of the crystals by means of a gel, and the filling of the pores in the same manner.

The chemistry of Portland cement was set on an entirely new basis by the splendid investigations of the lime-silica-alumina system in the Geophysical Laboratory of the Carnegie Institution, Washington. As the result of these investigations, the constitution of cement clinker became known in detail, and it was then possible to consider the process of hydration as one of a definite series of chemical reactions. The study of the setting and hardening processes was taken up by the staff of the U.S. Bureau of Standards, whose results have been published in the form of monographs.[17] The general conclusions may be summarised as follows.

Tricalcium aluminate sets so rapidly that it is practically impossible to form it into test pieces, but it develops little strength. The hydrated product is mostly crystalline. The aluminate $5CaO,Al_3O_3$ also hydrates rapidly, forming an amorphous mass, which partly crystallises, the product being apparently the hydrate of tricalcium aluminate. Dicalcium silicate hydrates exceedingly slowly, and the product is entirely amorphous, except for the crystals of calcium hydroxide which make their appearance after a time. It is not believed that this amorphous or colloidal mass corresponds with any definite calcium silicate, but rather that it is an

[13] Private communication.

[14] *Zentr. hydraul. Zemente*, 1911, 2, 34

[15] *Ibid.*, 51.

[16] Dissertation, Jena, 1912; *Silikat Zeitschr.*, 1914, 2, 43.

[17] A. A. Klein and A. J. Phillips, *U.S. Bureau of Standards, Technological Paper* 43 (1914); P. H. Bates and A. A. Klein, *Technol. Paper* 78 (1916). See also G. A. Rankin, *J. Franklin Inst.* 1916, 747.

indefinite colloid, which undergoes further hydrolysis in contact with an excess of water, progressively losing lime, until a residue of gelatinous silica remains. Dicalcium silicate is rendered more soluble by the presence of the soluble aluminate. Tricalcium silicate hydrolyses fairly rapidly, the product being of the same general character as in the last-mentioned case. A strong mass is obtained, and there is little doubt that pure tricalcium silicate would form a satisfactory Portland cement, as was in fact observed in the early experiments of Newberry.

According to the experiments of the Bureau of Standards, then, the initial set of Portland cement is due to the hydration of tricalcium aluminate, the product being amorphous. At the same time any sulpho-aluminate which may be present crystallises, and any excess of free lime becomes hydrated. Within twenty-four hours, the hydration of tricalcium silicate begins, usually becoming complete within seven days. Between seven and twenty-eight days, the hydration of the dicalcium silicate, which is present in considerable proportion in most cements, and the passage of the aluminate to the crystalline condition, are the chief stages in the process. Of these, the increase in strength is attributed to the formation of colloidal material, whilst the change from the colloidal to the crystalline state is regarded as involving an actual diminution of strength, the net effect being a gain. These results stand in conflict with many previous observations, but they have not yet been directly challenged.

Lastly, reference should be made to the influence of salts and other soluble substances on the rate of setting of cements. The addition of calcium sulphate to Portland cement for the purpose of retarding the setting has long been practised on the large scale, and the action of a number of 'catalysts,' both positive and negative, was studied by Rohland.[18] Michaelis regarded the action as dependent on the change of solubility of the aluminates and silicates due to the presence of foreign salts, but Rohland, in more recent papers, has attributed it rather to their influence on the rate of coagulation of colloids.[19] The action of colloidal additions, such as tannin, straw infusion, &c., is very irregular, and no connection between the accelerating or retarding influence and the chemical composition has been found.[20] The changes in setting time which many cements undergo on storage, even out of contact with moisture, are probably of the same character, and the subject calls for much closer investigation than it has yet received.

NITRO-CELLULOSE EXPLOSIVES FROM THE STANDPOINT OF COLLOIDAL CHEMISTRY.

By E. R. CHRYSTALL, *B.Sc.* (*Lond.*), *F.I.C.*

General Review.

The work which has been done on this subject from a scientific point of view is meagre in the extreme. The text-books on colloids barely mention the fact that nitro-cellulose forms colloidal solutions with organic solvents. The papers published for the most part deal with isolated cases investigated for the purpose of elucidating troubles in manufacture.

[18] P. Rohland, *Der Portland-Zement vom physikalisch-chemischen Standpunkte*, Leipzig, 1903.

[19] *Kolloid Zeitschr.* 1911, **8**, 251; **9**, 21.

[20] H. K. Benson, C. A. Newhall, and B. Tremper, *J. Ind. Eng. Chem.*, 1914, **6**, 795.

The reason for the neglect of this branch of work is undoubtedly due in large measure to the nature of the raw material cellulose. This substance, not occurring naturally in a pure state, has to undergo drastic treatment in the way of bleaching, cleaning, and so forth before it is suitable for the manufacture of nitro-cellulose, and all treatment of the cellulose has a large influence on the character of the finished product Furthermore the material largely employed in the explosive nitro-cellulose industry, namely cotton waste, is in itself waste product from the spinning mills. As most of the investigations are carried out by the chemists of the manufacturing firms, much of the work probably the most valuable part, is never published

The colloidal solutions which have been investigated fall roughly into two classes, those made with volatile solvents such as ether-alcohol, acetone, ethyl acetate, &c., and those made with comparatively non-volatile solvents, of which nitro-glycerin and camphor are the chief.

The principal work in the former class is that of Baker, who has investigated the viscosity of three important manufactured varieties of nitro-cellulose in various solvents, namely, acetone, ethyl formate, methyl, ethyl, propyl and amyl acetates, ethyl butyrate, aceto-ethyl-toluidide, ethyl tolyl ethyl carbamate, ethyl phthalate, ether-alcohol, ether-methyl alcohol, &c. He finds that the viscosity follows the law $N=N_0(1+AC)^R$, where N and N_0 are the viscosities of solution and solvent respectively, C is the concentration, and A and R are constants depending both on solvent and solute.

In general the viscosities of nitro-cellulose solutions are diminished by all treatment which the substance or its raw material undergoes, such as bleaching and cleaning the cellulose, stabilising the nitro-cellulose by boiling, heating the nitrating mixture or the finished product, and heating or exposing to light the solutions under investigation The presence of traces of impurities in all stages of the work also adversely affects the viscosity. These causes, as well as fundamental differences in the cellulose itself, account for the varying and discordant results obtained by different workers.

In the system nitro-cellulose-nitro-glycerin, *i.e.*, blasting gelatine, the problem is to obtain a stiff gelatinous colloid which will not exude nitro-glycerin and will transmit the explosive wave with certainty. The preparation of a suitable nitro-cellulose, which in practice forms about 7–8 per cent. of the mixture, is a matter of great delicacy both in selection of raw material and method of procedure, and practically no information is available on the subject.

Hargreaves explains the behaviour of blasting gelatine by assuming a webbed structure of nitro-glycerin and nitro-cellulose, through the meshes of which free nitro-glycerin passes. As the colloid ages, more and more of the free liquid is absorbed into the gel, thus producing the state of insensitiveness to detonation which is one of the great troubles of the manufacturer. Comey ('Seventh Int. Cong. App. Ch.') has, however, shown that liquid nitro-glycerin when confined in narrow tubes is but a poor transmitter of the detonating wave. Experiments by G. W. MacDonald and the writer have shown that the problem is still more complicated, and that, although the colloidal condition of the system has a large influence on the detonation of the explosive, its behaviour can be totally altered in a few hours merely by exhausting the air which

is mechanically entangled in it during the process of incorporation. Aubert and Nauckoff have patented the addition of cork dust for the purpose of retaining air in the explosive. Colloids can be made with nitro-cellulose and liquid aromatic nitro-hydrocarbons These are used both with and without nitro-glycerin. When used with the latter the purpose is to prevent the freezing of the explosive, since on thawing dangerous exudation of nitro-glycerin is apt to occur by the liquid not being completely re-absorbed into the colloid. Modern propellant explosives all consist of a colloided nitro-cellulose with or without admixture of nitro-glycerin. Investigations into their micro-structure and other properties have been carried out, but have not been published.

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CELLULOID FROM THE STANDPOINT OF COLLOIDAL CHEMISTRY.

By E. R. CHRYSTALL, *B.Sc.* (*Lond.*), *F.I.C.*

1. Celluloid Viscosity and its importance for the Chemistry of Celluloid in theory and practice H. SCHWARZ, 'Zeitschr. Chem. Ind. Koll.' 1913 (**12**), 32–42.
2. Celluloid The Absorption of Gases, by V. LEEBURN, 'J. Chem. Soc.' 1914 (**105**), 328–337.
3. Celluloid Chemistry Problems of, and the necessity of colloid chemical views in this industry. H. SCHWARZ, 'Kolloidchem. Beihefte,' 1914 (**6**), 90–126.

General Review.

The literature on the celluloid branch of the nitro-cellulose industry, as far as colloidal chemistry is concerned, is as meagre as that on the explosive branch. Three papers have been found bearing on this subject:

(1) The author deals with the viscosity of alcohol celluloid solutions

in connection with ageing, percentage of camphor, temperature, and brittleness of the finished product.

(2) The absorption, diffusion, and equilibrium curves of carbon-di-oxide are determined and discussed.

(3) The stability of the colloid against latent acidity is considered, together with the so-called antacid treatment. The efficiency of the latter the author considers to be dependent on the size of the molecular aggregates suspended in the colloid.

COLLOIDAL AND CAPILLARY PHENOMENA IN THEIR BEARINGS ON PHYSIOLOGY AND BIO-CHEMISTRY.

By Prof. W. RAMSDEN, *Bio-Chemical Laboratory, University of Liverpool.*

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In the two books cited will be found full references to literature and an admirable treatment of the following subjects —

Adsorption. The Ultramicroscope. Dialysis. Ultra-filtration. Gels. Imbibition. Salting-out. Permeability-changes in cell-membranes during excitation or narcosis; Hæmolysis; Secretion; the Nerve Synapse. Osmotic pressure in its relations to—volume-changes of cells; effects of drugs; root-pressure; lymph-production. Enzyme action as a surface-phenomenon.

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Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere.—Report of the Committee consisting of Professor T. W. EDGEWORTH DAVID (*Chairman*), Professor E. W. SKEATS (*Secretary*), Mr. W. S. DUN, Professors J. W. GREGORY *and* Sir T. H. HOLLAND, Mr. W. HOWCHIN, Mr. A. E. KITSON, Mr. G. W. LAMPLUGH, Dr. A. W. ROGERS, Professor A. C. SEWARD, Mr. D. M. S. WATSON, *and* Professor W. G. WOOLNOUGH, *appointed to consider the above.*

AFTER the publication of the First Report the Secretary of the Committee sent requests for further communications on the subject under consideration to members of the enlarged Committee and to other geologists and palæontologists likely to contribute usefully to the discussion.

In spite of the continuance of untoward conditions due to the war, several replies have been received as mentioned in the Interim Report of last year, and are printed below. Five of these relate more particularly to the Australasian deposits and the other two to the equivalent formations in South Africa. The series of questions sent out by the Secretary and answered in the communications were printed in the First Report,[1] to which reference should be made in reading the replies.

It is still desirable to secure the opinion of geologists who have worked in India on the classification of the rocks of the same age in that region. The Committee therefore asks for reapportionment without grant.

Notes on Report of Committee on Carboniferous and Permo-Carboniferous and Permian Rocks of Southern Hemisphere

By F. CHAPMAN, *A.L.S., Palæontologist to National Museum, Melbourne.*

In points for discussion raised by Prof. Skeats:

1. It is advisable to retain the local terms, since they may represent slightly different horizons in different areas; but they should be included under a general systematic term.

2. A general name is to be preferred for the system, since no local terms may exactly agree with terrains elsewhere. For example, Jurassic in Cainozoic strata cannot be restricted to strata as developed in the Torquay cliffs.

3. I would favour Carbopermian, (*a*) because the sequence of the beds is a gradual one, and it is therefore impossible to define its limits above or below, (*b*) because this order of the word-particles is correct according to the time-sequence, unless it is held to be a Carboniferous deposit qualified by a Permian admixture, which is hardly the case. The term Carbopermian was strongly favoured by the late Prof. Rupert Jones.

4. The evidence *re* glaciation points to a recurrence of the phenomenon in some places but not in others. The plants (*e.g. Gangamopteris*) and Foraminifera (in N.S. Wales and W. Australia) should be studied for notions of general horizons (as, for example, *Nubecularia*

[1] *Rep. British Assoc.* for 1915, pp. 263–266.

stephensi occurs at Pokolbin in the Lower foraminiferal band, and is also found at the Irwin River in W.A., where Foord regarded the beds as Carboniferous).

5. Vredenburg correlates the Middle Gondwana with the New Red Sandstone. This would make our *Glossopteris* flora much younger than generally believed.

6. They are often so conformable as to be indefinable as separate systems at their junction.

Notes on Prof. Skeats' Table of Correlation.

In the Indian column should not the 'Panchet' series read 'Raniganj'? The Panchet series equals New Red Sandstone. Between the Damuda and the Talchir comes the sub-stage of the Karharbari beds.

In the Victorian column the upper plant-bearing sandstones of Bacchus Marsh are probably Triassic.

In the Queensland column I would place the Star series low down in the Carboniferous, since *Lepidodendron* is so abundant, and there also occurs *Receptaculites australis* (at Mt. Wyatt), which in Victoria and N S. Wales is found in the Middle Devonian.

The Permo-Carboniferous System in Tasmania.

By W. H Twelvetrees, *F.G.S., Government Geologist of Tasmania.*

The stratigraphical development of this system in Tasmania is, in descending order, as follows:

5. Coal measures at Mt. Cygnet and on Bruny Island, which are perhaps the uppermost beds of the system.

4. Upper marine series of mudstones, sandstones, and limestones.

3. Coal measures and Tasmanite beds in the Mersey basin. Coal measures at Preolenna.

2. Lower marine series of mudstones, limestones, and mudstone conglomerates, frequently carrying glacial erratics.

1 Basal beds of glacial conglomerate and till.

The beds nowhere rest on Carboniferous strata, but on Devonian granite or on Silurian or older rocks.

The coal measures of the system are characterised by a Gangamopteris and Glossopteris flora.

The only correlation with other countries suggesting itself as practicable and reasonable (and that a partial one) is with the Gondwana and Salt Range deposits in India, the Karroo in South Africa, the Orleans conglomerate in Brazil, and the San Luis conglomerate in Argentina.

The glacial conglomerates and tills at the base of the system in Tasmania are with great probability homotaxial with the basal conglomerates in New South Wales, the Bacchus Marsh conglomerates in Victoria, the Dwyka conglomerate in South Africa, the Indian Talchir conglomerate, and the Boulder bed of the Salt Range in the Punjab. In all these continents the overlying beds contain the remains of a common flora (*Gangamopteris* and *Glossopteris*) and pass upwards into strata with plants of a Triasso-Rhætic type.

The peculiar types of marine fossils met with in the basal beds of Tasmania, such as *Conularia*, *Martinopsis darwini*, *Aviculopecten*

(*Deltopecten*) *limæformis*, &c., are repeated in the Salt Range Boulder bed, which lies there also at the base of the system. Moreover the same fossils, as well as *Productus brachythærus*, *Spirifera vespertilio*, *Furydesma globosum*, *E. cordatum*, &c., contained in the Speckled Sandstone and Lower Limestones which succeed the Boulder bed in the Salt Range, are also common forms in the Tasmanian Lower Marine beds.

The Indian Gondwana beds of the Talchir division which succeed the Talchir Boulder bed, and the succeeding Karharbari beds, contain a flora identical with that of the Mersey Coal measures in Tasmania; and the same may be said of the Ecca series which succeeds the Dwyka basal conglomerate of the Karroo system in South Africa.

In Tasmania the Lower Marine strata are overlain by the Mersey Coal measures with the Glossopteris and Gangamopteris flora, and these are succeeded by the Upper Marine beds containing organic remains for the most part similar to those of the Lower Marine, but less abundant, and some familiar species of the lower division appear to be absent.

The thickness of the maximum development of the beds belonging to this system is estimated at nearly 3,000 feet. The strata are horizontal or gently inclined. They have not been deformed by crustal folding, but have been greatly depressed or raised by block-faulting.

The whole assemblage of the Permo-Carboniferous and Trias-Jura sediments in Tasmania may in a broad sense be conceived as belonging to a Gondwana Land system if we extend the meaning of the latter term so as to include both continental formations and the marine deposits fringing the shores of the ancient continent. It would seem desirable to devise some name which would express this relationship and at the same time put an end to the controversies which rage round the use of the terms Permian and Permo-Carboniferous, besides avoiding the unnatural and confused employment of European nomenclature.

Provisionally, however, the term Permo-Carboniferous is in common use, gives expression to the facts, and ought not to be exchanged for any other which implies homotaxial correspondence or contemporaneity with European systems.

There seems to be no stratigraphical reason why the Permo-Carboniferous of this island should not share any common name which may be decided on for the same system as a whole as developed in Australia.

Permo-Carboniferous Rocks in New Zealand.

By Professor P. MARSHALL, *M.A., D.Sc., The University, Dunedin, S. Island, New Zealand.*

The fossils originally recorded by McKay from the Wairoa Gorge, Nelson, viz. *Productus brachythærus*, *Spirifera bisulcata*, *S. glabra*, *Cyathocrinus* and *Cyathophyllum*, have recently been unpacked at the Dominion Museum, Wellington, and are now available for study. They are quite different from any fossils that have been found elsewhere in New Zealand. Additional specimens have lately been found in the same place by Mr. C. T. Trechmann. These fossils quite possibly indicate a Permo-Carboniferous age, but accurate identifi-

cation and description are still required. In the same formation and also in quite a different horizon a series of imperfect remains of a bivalve always referred to *Inoceramus* have been long known. It appears that these may be the remains of a species of *Pinna* or allied genus. The limestone in which the fossils named occur is in contact with strata that contain Triassic fossils (the so-called *Mytilus problematicus*, Zittel). If the fossils in the limestone are truly Permo-Carboniferous a disconformity of some sort must be present. A thrust plane has been described by McKay at this point. Elsewhere no Permo-Carboniferous fossils have been found anywhere in New Zealand. Park's Aorangi series is based upon no exact information of any kind. The Mount Potts beds often referred to the Carboniferous or to the Permian are now known to be of Rhætic age, for the plant remains have been identified by Arber. *Halobia* is common amongst the marine shells at Mount Potts.

Fossils have been collected from the Kaihiku formation both in the Kaihiku Gorge and in the Hokanui Hills by C. T. Trechmann and P. Marshall. They will shortly be described by the former. It may be stated provisionally that they appear to indicate a middle Triassic age. The Kaihiku formation has often been classed as Permian. The Mount St. Mary fossils at one time referred by Park to the Permo-Carboniferous are also known to be of Triassic age. It thus appears that at the Wairoa Gorge alone definite Permo-Carboniferous fossils have been found. The occurrence of red shales with the series in which these fossils occur suggests that much of the Maitai series which contains such shales in many parts of the mountain ranges of New Zealand should also be classed in the Permo-Carboniferous. This problem, which is difficult because of the absence of fossiliferous beds, remains to be solved by future study.

To sum up, it can be definitely stated that Permo-Carboniferous beds are known to occur at the Wairoa Gorge only and this opinion is based on the expectation that the fossils are of the nature described. Fossils of Middle and Upper Triassic age occur at several places in the rocks of the mountain ranges of New Zealand. The strata at the Wairoa Gorge show no indications of glacial erosion or of glacial deposition in any of the horizons.

The Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere

By A. E. Kitson, *F.G.S., Principal of the Mineral Survey of the Gold Coast.*

Questions 1, 2, *and* 3.—I prefer a single name for all the Australian late-Palæozoic glacial deposits, but think that the local names, such as Hunter, Lochinvar, Wynyard, Inman series should be retained. Inman is, I think, preferable to Ramínyere. For the Bacchus Marsh area I think the name might be changed with advantage, since the typical deposits are some miles away from that place, on the Werribee River and Korkuperrimul Creek. Moreover, the double name is a drawback. I would suggest the name Werribee (or Werribi, the geographical spelling of the sound). It is an aboriginal name, and is as

intimately connected with the literature of the deposits as is Bacchus Marsh, and it is certainly more appropriate, since the Werribee River has cut the famous gorge through these glacial deposits, and thus enabled the series to be so well exposed.

Though the term Permo-Carboniferous has priority and was made by such an eminent palæontologist as Mr. Robert Etheridge, jun., I prefer the term Carbo-Permian, for—

(1) it would be uniform with the other Australian linked system names, such as Siluro-Devonian and Trias-Jura instituted by the same author;

(2) it is a simpler term; and

(3) it is I think equally expressive.

I do not favour a single Australian name such as Hunterian for the whole of the deposits with glacial beds, having the same objection to that as Professor Skeats has. Neither Victoria nor South Australia has any known equivalents of the marine portion of the Hunter series. I may add that I think the Victorian glacials are lacustrine, as well as fluvio-glacial and land-ice deposits.

Question 4.—I regard all the lower main glacial beds as contemporaneous, and the differences in their upper portions as due to local glaciations of varying character, intensity, and extent.

Question 5.—It appears desirable at present to accept the classification suggested by Professor Skeats with the additions and modifications made by Professor David and Professor Woolnough, excepting—

(*a*) the Lower Maitai of New Zealand, and the Schizoneura Sandstone of Victoria, about which I hold the same opinion as Professor Skeats;

(*b*) the separation anywhere by a definite line of the division between Permo-Carboniferous and Permian.

In the light of our present knowledge it seems to me impossible to divide them. If the upper limit of *Glossopteris* marks the upper limit of the Permo-Carboniferous—and this seems doubtful—the deposits in New South Wales, Queensland, Western Australia, South Africa, South America, Antarctica, the Falkland Islands, and India can scarcely be called Permian, and consequently the lines of division between the Permo-Carboniferous and Permian should be excised therefrom. The Beaufort and Ecca series are conformable according to Hatch and Corstorphine.[2]

Question 6.—The Devonian and Carboniferous are conformable in Victoria. I offer no opinion regarding the other countries.

Question 7.—The Carboniferous and Permo-Carboniferous appear to be conformable in parts of New South Wales, and certainly unconformable in other parts of that State, as proved by Professor David.

There is no known contact of these in Victoria. The uppermost beds of the Grampians sandstones, however, when carefully examined may yield some useful information on the point.

Question 8.—It seems to me that there is no definite evidence to separate the Permo-Carboniferous from the Permian in the Southern

[2] *Geology of South Africa*, p. 244.

Hemisphere if *Glossopteris* is to be taken as the upper limit of the Permo-Carboniferous. Further, since *Glossopteris* has such an extended range upward it appears unsafe to regard it as a strictly zonal fossil.

Nomenclature of the Permo-Carboniferous Rocks in South Africa
By A. W. ROGERS, *D.Sc., F.G.S.*,
Director of the Geological Survey of the Union of South Africa.

In South Africa there is an apparently conformable succession from the base of the Cape system, which includes beds with marine fossils of Devonian affinities, up to beds at the top of the Karroo system for which a Jurassic age has been claimed on account of a crocodile found in them.

This great thickness of rocks has been divided mainly on lithological grounds, and at the present time it is impossible to point out horizons definitely corresponding to the bases of the Carboniferous, Permian, and Trias. An attempt to fix such horizons for the purpose of applying these widely used terms to South African maps, &c., instead of local names would be a mistake.

The Karroo system is generally understood to include all the strata above the Witteberg series up to and including the volcanic beds of the Drakensberg. The base of the Karroo system in the south, where there is an apparently conformable passage from the Witteberg series, is arbitrarily chosen as lying at the top of the highest band of quartzites, above which are shales passing into tillite. Further north the base is defined by an unconformity which increases in importance northwards.

The main sub-divisions of the system are as follows:

Stormberg series.
Beaufort series.
Ecca series.
Dwyka series.

One South African geologist[3] separates a 'Stormberg formation' from the Karroo, drawing the line at the base of the Molteno beds. This suggestion has not been adopted generally because there is not a sufficiently marked break at the horizon in question, and certain plant species occur both above and below it. There seems to be no need to make a separate 'formation' of what are conveniently regarded as the uppermost strata of the Karroo system. Whether this horizon is one which marks an extensive overlap northwards from the Stormberg region across the Orange Free State and the Transvaal remains to be proved by mapping; at present the known facts do not favour that view, but important overlaps exist at some horizon within the Ecca or Beaufort series and at another horizon above the Molteno beds.

The Dwyka Series.

There is no difficulty in defining this group in the Cape Province and Natal and the South-West Protectorate, but in the Transvaal the term has not been used in official publications because of the uncertainty whether the 'glacial conglomerate' there is really the correlative of the Dwyka or whether it was formed at a slightly later time when the

[3] Schwarz, *S.A. Geology*, 1912.

southern Ecca beds were being laid down. At present the north-eastern limit of the Upper Dwyka shales is not known, but some beds characteristic of those shales in the Cape and S.W. Protectorate are missing in the areas yet mapped in the Transvaal and Natal.

It is likely that the term 'Dwyka' will be found suitable for the glacial conglomerate' in the Transvaal also, and it is already used there by several geologists.

There are different opinions held as to whether the Dwyka series is of Upper Carboniferous or of Lower Permian age, but the few fossils found in it are not in conflict with the former view.

The Ecca Series.

The Ecca series is best known in the Cape and Natal, and the information as to its distribution in the Orange Free State and Transvaal is not sufficient to decide disputed points such as whether the Vereeniging coal-beds belong to the Ecca or Beaufort.

The fossils from undoubted Ecca beds, *i e*, beds above the Upper Dwyka shales and below those in which there are many genera of Dinocephalians and Therocephalians, are but few in number. The thickness of the series at its maximum is 6,000 feet, and the fossils are chiefly fragments of *Gangamopteris*, *Glossopteris*, *Phyllotheca* and wood, all of which, except perhaps the first named, occur in the Beaufort beds also. The reptiles are very little known, *Archæosuchus* and *Eccasaurus* are fragmentary specimens. Whether the so-called Ecca beds of Worcester with *Gangamopteris* really belong to this group is uncertain, for superficial deposits conceal the passage down into the Dwyka, outcrops of which lie four miles away.

It thus happens that in the absence of reptilian-bearing Beaufort beds the determination of the Ecca is practically impossible in an area which has not been connected by mapping with a better-known district.

The Beaufort Beds.

The Beaufort beds contain many reptilian fossils in certain areas, but there appears to be a lack of them elsewhere, and the few plants found in the lower portion of the series are not known to be characteristic. The Beaufort beds have been divided into three sub-groups which are again sub-divided:—

Upper or Burghersdorp beds.	*Cynognathus* zone. *Procolophon* zone.
Middle Beaufort beds.	*Lystrosaurus* zone.
Lower Beaufort beds.	*Cistecephalus* zone. *Endothiodon* zone. *Tapinocephaloid* zone [4]

Owing to the comparative rarity of the fossil reptiles and the difficulty of determinations of individual bones other than parts of the skull, these fossils are not well suited for the purpose of the field

[4] This term is substituted for *Pareiasaurus* zone on account of the revision of the genus *Pareiasaurus* by Mr. Watson, according to which no species of it are left in the beds concerned.

geologist. The recurrence of similar types of sandstone, mudstone, and shale makes lithological distinction between the two lower zones impossible, but their demarcation is being carried out; at present their distribution is only known in a general way in the Cape and a part of the O.F.S. and Natal. The coal-bearing Karroo beds of the Transvaal of Ecca or Beaufort age cannot yet be correlated more closely with any horizons in the Cape.

The plants of the Upper Beaufort beds include genera which are not yet known above or below, as well as species which occur in the overlying Molteno beds, and the genera *Schizoneura* and *Glossopteris*, which have great vertical distribution. These plants have been collected in a few localities only.

The Stormberg Series.

The Stormberg series is generally considered to begin at a certain horizon which is convenient for mapping, and above which the reptilian genera found in the Upper Beaufort beds do not occur. The characteristic plants of the lowest group (Molteno beds) of this series are known from the Cape, Orange Free State, and Natal only, and in Natal they are accompanied, according to recent observations of Dr. Du Toit, by the long-lived genus *Glossopteris*. The sub-divisions of the Stormberg series into Molteno beds, Red beds, Cave Sandstone, and the Drakensberg or Volcanic beds depend on lithological characters which are remarkably persistent, but the Dinosaurian genera found in the Red beds and Cave Sandstone of the Cape have representatives further north in areas where the Molteno beds have not yet been identified

The following table gives a possible correlation with systems adopted in Europe. The position of the Rhætic horizon has been shifted upwards in consequence of a recent examination of the question by Dr. Du Toit and Mr. S. H. Haughton:

Cave Sandstone	Rhætic.	
Red beds	Upper	Triassic.
Molteno beds		
Upper Beaufort beds . . .	Lower	
Middle Beaufort beds . .		
Lower Beaufort beds . . .	Upper	Permian.
Ecca beds	Lower	
Dwyka (Upper shales and Tillite)	Upper Carboniferous (Uralian).	

Notes on the Nomenclature of the Carboniferous, Permo-Carboniferous, and Permian Rocks of the Southern Hemisphere. *By* D. M. S. WATSON, *M.Sc., Lecturer on Vertebrate Palæontology, University College, London.*

These notes are written mainly from the standpoint of South African stratigraphy, and deal with points raised by the views of the Australian members of the Committee.

(A.) *Question* 4.—Judging from the evidence which exists to show that the Northern and Southern Pleistocene glaciations are approximately, at any rate, contemporaneous, it seems certain that the Dwyka

beds of South Africa are contemporaneous (in a geological sense) with those of Bacchus Marsh. The fact that there is a glacial horizon in the Upper Marine series in New South Wales some distance above the main Lochinvar glacials shows that it is not possible to use the occurrence of boulder beds for a very close correlation. From personal observation I fancy that there is a more considerable faunal difference between the Lower and Upper Marine series in the Hunter Valley than is usually recognised.

(B.) *Questions* 1 and 2.—Mr. Etheridge's first use of the term Permo-Carboniferous was for the Gympie of Queensland (=Lower Marine) with an admixture of Star (Carboniferous) forms. According to Prof. T. W. Edgeworth David, Mr. Etheridge now extends this term to include all Australian formations from the bottom of the glacial series to the uppermost beds which contain *Glossopteris*.

The term Permo-Carboniferous has, however, been incorrectly used by many authors to imply a restricted series of beds of either lowest Permian or Upper Carboniferous age, such as the reptile-bearing Wichita and Clear Fork of Texas, the Artinsk stuffe of Russia, and certain parts of the Salt Range succession. In most of these cases it has been made use of to escape the difficulty of deciding on a definite Permo-Carboniferous boundary in a consecutive series of rocks, a difficulty which is really exactly doubled by such action.

In South Africa the series of rocks to which the term could be applied are all of land origin, partly lacustrine, partly æolian, and partly river deposits, and hence very considerable discontinuities of deposition may occur in an apparently conformable series. Bearing this caution in mind, the following represents the apparent conditions:

The Witteberg beds are directly and apparently conformably succeeded along the whole southern margin of the Karroo by the Dwyka shales, in which are included the glacial beds. Further north the Dwyka conglomerates rest on older beds, partly, no doubt, as a result of overlap of land deposits from the area of deposition of the Witteberg, but apparently also partly owing to real unconformity. The Upper Dwyka shales pass into the Ecca, which is directly continued by the Beaufort series, which is again conformable to the overlying Stormberg beds.

This statement is founded on the conditions in the area south of the Orange River. In the Orange Free State there seem to be very large gaps in the series, the Stormberg series resting on the Beaufort series some distance below its top, and this in turn directly on the Dwyka, or at most separated from it by a very thin Ecca.

The Beaufort series is divided into the following zones:

Stormberg series . . .	Upper Trias—Rhætic.
Cynognathus beds . . .	Middle (? Lower in part) Trias.
Procolophon beds . . .	No direct evidence of age.
Lystrosaurus beds . . .	,, ,, ,,
Cisticephalus beds . . .	Upper Zechstein (=Dwina beds).
Endothiodon beds . . .	No direct evidence of age.
Tapinocephalus beds. . . (*olim Pareiasaurus* zone)	? Lower Zechstein. Evidence from comparison with copper-bearing beds of Orenburg.

According to Du Toit, *Glossopteris* occurs in the *Cynognathus* beds of Aliwal North. Permo-Carboniferous in Mr. Etheridge's latest sense would therefore include nearly all the Trias and Permian.

The age of the Witteberg is uncertain; the few fossil plants found in it suggest an Upper Devonian or at latest Lower Carboniferous age, which on the evidence for its conformity would suggest a Carboniferous age for the Dwyka. The occurrence of *Bothrodendron*, which is not known above the Carboniferous, and is exceedingly rare in the Upper Coal Measures, if indeed it occurs in them, above the Dwyka at Vereeniging, supports this view. The lower end of the Permo-Carboniferous would therefore be in the Carboniferous, and it would have no stratigraphical break either above or below.

I am therefore inclined to abandon the term Permo-Carboniferous and use Prof. David's suggested term Palæo-Permian for the Dwyka and Ecca.

(C.) *Question* 8.—In connection with the conformable passage of the *Glossopteris* beds into the Mesozoic in New South Wales and in South Africa, it is perhaps interesting to note that the large labyrinthodont collected by Mr. Dunston from the Wianamatta beds at St. Peter's is, so far as can be seen from a short inspection, a typical *Cyclotosaurus* which marks a definite evolutionary stage of the *Stereospondyli*, always of Upper Triassic age in Europe.

The Australian Permian and Carboniferous.
By Professor J. W. GREGORY, *D.Sc., F.R.S., The University of Glasgow.*

1. In time the term Permo-Carboniferous may, it is hoped, be rendered unnecessary by more precise correlation of the Australian deposits. Correlation of distant formations rests ultimately on their fossils, and mainly on their marine fossils; and with increased knowledge of the Australian Upper Palæozoic faunas and floras the term Permo-Carboniferous, which was introduced provisionally owing to imperfect stratigraphical evidence, may suffer the fate that has already overtaken such compounds as Devono-Silurian, Cambro-Silurian, Cretaceo-Tertiary, &c., which have been of temporary service elsewhere. Mr. Etheridge's introduction of the term was the soundest course then available, but its permanent retention may be unnecessary.

The Permian and Carboniferous systems are divided into five or six series. The Carboniferous system includes three series:

Upper Carboniferous	. .	Uralian (or Stephanian, &c.).
Middle ,,	. .	Moscovian (or Westphalian, &c.).
Lower ,,	. .	Dinantian (or Culm, &c.).

The Permian system is divided into two or three series. Many authorities adopt three series, for which well-accepted names are as follows:

Upper Permian	. . . . .	Thuringian.
Middle ,,	. . . . .	Punjaubian.
Lower ,,	. . . . .	Artinskian.

The Artinskian fauna is strikingly similar to the Uralian. The

geography of the Artinskian was also very similar to that of the Uralian. Lithologically the predominance in the Artinskian of gray sandstones and bituminous beds over red beds (which occur occasionally, as at Brives in S.W. France) indicates formation under Carboniferous rather than Permian climatic conditions. The Artinskian Brachiopods include *P. cora*, *P. punctatus*, *P. semireticulatus*, &c., which are Carboniferous species. De Lapparent has stated the general affinity of the Artinskian ammonites in his remark that they have intimate relations with those of the Uralian. The Artinskian does not seem entitled to rank as a distinct geological series. It may be merged in the Uralian. If so, the Permian consists of two series, which is consistent with its old name of Dyas.

Taking, then, the Permian and Carboniferous systems of Europe as divisible into five series, the question is, Can the Australian deposits be correlated with them?

The Australian Carboniferous-Permian sequence begins with the Lepidodendron beds, which are admittedly Lower Carboniferous. Above them is a great unconformity, above which in New South Wales occurs the following succession:

Upper Coal Measures.
Dempsey series.
Middle or Tomago Coal Measures.
Upper Marine series.
Lower Coal Measures.
Lower Marine series.

The fauna of the two Marine series seems essentially Uralian. Thus Cephalopoda usually give very reliable evidence as to correlation. Unfortunately the New South Wales Marine series are very poor in Cephalopods, but they have yielded two. The *Actinoceras* has been identified as *A. striatum*, a British Lower Carboniferous species; the specific identification is, however, doubtful, but Foord and Crick accept it as an *Actinoceras*, a genus which has a wide Palæozoic range but does not occur in the Permian. This fossil is in favour of an age not later than Carboniferous. The other Cephalopod, *Agathiceras microphyllum*, comes from the Upper Marine series; it is recognised as closely related to *Agathiceras uralicum*, which, according to Tschernichef, is a Uralian but not a Permian species. Mr. Crick has kindly looked up *A. microphyllum* again and regards it as of Uralian affinities.

The Brachiopods of the two Marine series are abundant. They also appear of Carboniferous affinities. Two of the most characteristic of the *Productus*, *P. cora* and *P. brachythærus*, are both typical Uralian species. Many of the Brachiopods have been identified as Carboniferous, and some of them as Lower Carboniferous species. Amongst them are *P. longispinus*, *P. punctatus*, *P. pustulosus*, *P. scabriculus*, *P. semireticulatus*, *P. undatus*, *Rhynchonella pleurodon*, *R. pugnus*, *Spirifera striata*, *S. rotundata*, *S. trigonalis*, &c. It is, no doubt, probable that the Australian species may ultimately be separated from the European, but any such change will not set aside the fact that a whole series of fossils from the Upper and Lower Marine series of New South Wales are so similar to European Carboniferous species

that they have been long regarded as identical. In spite of the many Lower Carboniferous species, the Brachiopods, owing to the absence of the *P. giganteus* group and the presence of *Martiniæ* (*Stropholasia*), indicate that the fauna is later than Lower Carboniferous.

The evidence of the Bryozoa agrees with that of the Brachiopods. The fauna is distinctively Carboniferous and not Permian. The Trilobites, *Griffithides*, *Brachymetopus*, and *Phillipsia* indicate the same.

Prof. Frech, however, although admitting the Carboniferous affinities of many of the fossils, is in favour of assigning the whole fauna to the Permian, mainly on the ground that some of the Spirifers and the genus *Martinia* (which includes *S. Darwini* and *S. horrescens* from Tasmania) are of Permian affinities.

The bulk of the palæontological evidence seems, however, to favour the Carboniferous age of the Marine series, and it appears that, in spite of the survival of some species which in Europe are Lower Carboniferous, the fauna may be regarded as Uralian and that any later age is improbable.

The stratigraphical evidence appears consistent with this conclusion. According to Prof. David, there is a great stratigraphical break just above the Upper Marine series, for the two next members of the sequence, viz. the Middle Coal Measures and Dempsey beds, are often absent. Proceeding from the central part of the Carboniferous area, these two members disappear southward towards Illawarra, westward at Lithgow, and northward along the Macleay River, where the Upper Coal Measures also are absent.

There is accordingly both stratigraphical and palæontological evidence that the line between the Upper Marine series and the Middle Coal Measures is an important stratigraphical horizon. Of the beds above it the most widespread is the Upper Coal Measures; and both its flora and fauna mark an important advance upon that of the Lower Coal Measures, which are interstratified with the two Marine series. In the Upper Coal Measures one of the most significant fossils is the Labyrinthodont, *Bothriceps*, which can hardly be pre-Permian, and Huxley indeed assigned it to the Trias. The fossil plants of the Upper Coal Measures, *Baiera*, *Schizoneura*, *Alethopteris*, mark the incoming of the newer flora, for these genera are absent from the Lower Coal Measures of New South Wales. They are Permian and Triassic types. Hence I am disposed to regard the upper limit of the Carboniferous in New South Wales as at the top of the Upper Marine series, and to assign the Middle and Upper Coal Measures to the Permian.

As regards the other Australian States the question is simpler. In Queensland the Bowen River beds, with their *Productus brachythærus*, *Glossopteris* and *Gangamopteris*, may be correlated with the Marine series of New South Wales, and therefore as Uralian. Above the Bowen Coal Measures are the Burrum Coal Measures, and from their flora, with *Tæniopteris Daintreei*, they are probably not earlier than Rhætic.

In Victoria some difficulty has been introduced by M'Coy's description of a fossil plant from Bacchus Marsh as *Tæniopteris Sweeti*, as on this ground the upper part of the Bacchus Marsh Sandstones have

been regarded as much later than the lower part. But, according to Arber, the specimen on which *T. Sweeti* was founded is so imperfect that the genus is indeterminable. The Bacchus Marsh Sandstones with *Gangamopteris* are generally correlated with the Lower Coal Measures of New South Wales, through Kitson's proof that the glacial beds on the northern coast of Tasmania are of that age.

The correlation suggested for the beds of Eastern Australia may be tabulated as on next page.

If this correlation be correct, the use of the term Permo-Carboniferous is one of definition and there are four available courses:

(1) To retain Permo-Carboniferous for some undefined parts of both the Carboniferous and Permian.

(2) To retain it for the combined Uralian-Artinskian as a passage series.

(3) To abandon it by referring all the beds above the unconformity at the top of the Lepidodendron beds to the Permian—the course followed by Frech.

(4) To abandon it by referring the beds above that unconformity and the top of the Upper Marine series (with the exception perhaps of the *Aneimites* beds) to the Upper Carboniferous (Uralian), and by assigning all the beds above the Upper Marine series to the Permian (Punjaubian).

Of these four courses the last seems to me the best, for the first doubles the difficulty of definition and retains a provisional term after it has served its purpose; according to the second, the term is unnecessary; and the palæontological evidence is against the third

The correlation suggested is open to one objection, based on geo-tectonic grounds. According to it, the Middle Carboniferous in Australia was a great period of earth movement and non-deposition. In N.W. Europe the corresponding disturbances were in the Upper Carboniferous. If the earth movements in Europe and Australia were necessarily synchronous, then the Australian beds here assigned to the Uralian must be referred to the Moscovian. The palæontological evidence appears entitled to more weight than the geo-tectonic.

While there is so much difference of opinion as to the system to which these beds belong, it may seem premature to attempt to determine their series. But the system can only be settled by agreeing which of the beds are Upper Carboniferous and which are Lower Permian. The problem appears easier in Australia than in South Africa, where there is continuous sequence from the Carboniferous to the Jurassic and there are no Marine beds to help the correlation.

The main argument against attempting a definite correlation with the European horizons is based on the doctrine of homotaxis. That principle seemed so reasonable that it required careful consideration. According to the present trend of opinion, the importance once attached to homotaxis was exaggerated. Huxley raised the question whether the Carboniferous fauna in Europe might have been contemporaneous with the Devonian fauna in Australia. That question has now been generally answered in the negative, since the geological time was so vast that the length required for the spread of a marine fauna from one sea

Series	Characteristic Fossils	New South Wales	Queensland	Victoria	Tasmania
Lower Jurassic—Probably Rhætic	*TæniopterisDaintreei Thinnfeldia odontopteroides Leptolepis.*	Upper Clarence River Coal Measures and Wianamatta Clays. Lower Clarence River Coal Measures. Talbragan Beds.	Ipswich Beds and Barrum Coal Measures.	Gippsland Coal Measures, &c.	Upper Coal Measures.
Upper Trias—Keuper . . .	*Semionotus. Phyllotheca.* Absence of *Tæniopteris.*	Hawkesbury Sandstones.	—	—	—
Middle Trias . . .	—	—	—	—	—
Lower Trias . . .	—	—	—	—	—
Upper Permian—Thuringian .	—	—	—	—	—
Lower Permian—Punjaubian .	Last appearance of *Glossopteris. Ganganopteris. Nœggerathia. Bothriceps.*	Upper Coal Measures. Dempsey series. Lower Coal Measures.	Bowen River Coal Measures.	—	Upper Marine with *Gangamopteris* in Mersey series.
Upper Carboniferous—Uralian .	*P. brachythærus. Spirifera vespertilio, Agathiceras sp., Actinoceras sp., Glossopteris browniana, Gangamopteris.*	Upper Marine series. Lower Coal Measures. Lower Marine series.	Bowen River Marine Beds. Unfossiliferous White and Red Sandstone of Bowen River and Gympie series.	Bacchus Marsh Sandstones, &c.	Sandstones, Marine Limestones, Glacial beds.
Middle Carboniferous—Moscovian	—	? *Aneimites* beds.	—	—	—
Lower Carboniferous—Dinantian.	*Lepidodendron.*	*Lepidodendron* beds.	—	Avon River Sandstones.	*Lepidodendron* beds.

through all the suitable seas open to it is relatively insignificant. Zonal palæontology has answered Huxley's question and shown that nomotaxis concerns only the smaller divisions of geological time.

It follows from the foregoing that I reply as follows:

1A. No; and that covers also 2, 3.

1B. No. Retain them for sub-divisions.

4. No: the Glacial beds may be on somewhat different horizons.

5. The basis for correlation is reliable.

7. Generally conformable.

8. The view suggested in this paragraph is not yet established.

Engineering Problems affecting the Future Prosperity of the Country.—Report of the Committee, consisting of Dr. H. S. HELE-SHAW (*Chairman*), Professor G. W. HOWE (*Secretary*), Professor E. G. COKER, Sir ROBERT HADFIELD, Sir W. MATHER, Mr. W. MAW, *and* Mr. C. E. STROMEYER.

THIS Committee was formed as a result of suggestions of the Chairman in his presidential address at Manchester.

The chief object in view was to prepare a report dealing with various problems which would affect the future of engineering of our country. At that time, two years ago, the war was comparatively young, and it seemed to many that we were as a nation not alive to the importance of certain far-reaching questions which confronted us at the time, and of others which would require all our energy to prepare for the conditions which would arise after the war was over.

The Committee held a number of meetings in London, and considered carefully what problems should be dealt with as being of immediate importance. It was decided at once to form sub-committees to draw up reports on the four following subjects:—

1. Scientific research in relation to engineering.
2. Patent laws.
3. Scientific and practical revision of our catalogues, especially in relation to the metric and decimal system.
4. Problems relating to labour.

Reports on the first and last subjects were duly prepared and circulated for consideration, and in others the work of collecting information and preparing reports was taken in hand.

It happened that the members of the Committee engaged in preparing various reports became more and more occupied with war work, and it was found impossible through this and other causes to secure meetings of the Committee. Meanwhile, by degrees the great importance of the problems in view, which would have been dealt with by the Committee, became more clearly recognised by the British public generally, and these problems were not only taken up by various bodies, such as engineering societies and kindred institutions, but new bodies were formed for the purpose of dealing with particular subjects. The Government also has appointed committees and departments to deal with certain of these questions, notably on research and problems relating to labour.

The object of the Committee being largely in the nature of moving public opinion and getting action taken by the Government, it is not considered desirable, in view of the above facts, to ask for its reappointment at the present time. At a future date it is probable that there will be important work for an independent public body in reviewing the operation of various agencies and making recommendations, and a committee may be then appointed for this purpose.

The question arises as to whether the Council shall be recommended to print in the Annual Report of the Association the reports already prepared. The Council has recently circularised Organising Committees requesting them to limit printing 'as rigidly as possible.' For this reason, and in view of the fact that other arrangements are being made to publish some of the matter, the Committee have reluctantly decided that they are unable to recommend the printing in the Annual Report of the draft reports already prepared, but suggest that these draft reports and various documents containing information and suggestions shall be deposited in the offices of the British Association, where they can be inspected or copied.

Exploration of the Palæolithic Site known as La Cotte de St. Brelade, Jersey.—Report of the Committee, consisting of Dr. R. R. MARETT (*Chairman*), Mr. G. F. B. DE GRUCHY (*Secretary*), Dr. A. KEITH, Dr. C. ANDREWS, Colonel R. GARDNER WARTON, *and* Mr. H. BALFOUR.

Report on Work done in April 1917.

DURING the last fortnight of April 1917 operations were resumed, being exclusively confined to the north side. Their object was to deepen the trench affording access to the cave from this its rearward end. Here a natural gully of unknown depth exists, filled with a very compact clay intermixed with heavy rock-rubbish. An area of some 300 square feet was excavated to an average depth of 10 feet, so as to bring the floor down to about 20 feet above the lowest floor-level of the cave. Flint and bone occurred sparsely over a space of 10 feet, viz., 50-60 feet from the cave entrance, and at a height of 20-25 feet above lowest floor-level, but otherwise the filling of the gully was completely sterile. A well-developed rodent-bed was discovered at the point nearest the old workings, viz., 50 feet from the entrance. The flint included only a few good implements. The bone consists mostly of microtine remains, and is being determined at the British Museum. One bone appears to be that of the red-legged partridge, still known to sportsmen as the 'Jerseyman,' though now locally extinct.

In view of war conditions, professional labour was not employed, but, thanks to Mr. A. J. Robinson, M.Sc., B.A., a Master at Victoria College, digging-squads were organised in which the following College boys served:—J. W. Buck, F. R. Dorey, T. D. C. Faed, B. C. Le Cras, C. Le Marquand, W. P. Le Scelleur, D. Poingdestre, J. Pollock-Gore, R. R. Proud, and C. F. Watkin. Mr. G. Le Bas, B.Sc., also

helped. The Chairman and the Secretary were in charge of operations throughout.

Supplementary Report, on Work done July-October 1917.

From July 16 to October 6 excavation proceeded continuously, professional labour being available only during the last five weeks. The gully on the north side was deepened a further 10 feet, while on the interior side the cave-floor was cleared back to about 60 feet from the entrance. The rubbish-dump near the entrance was also partially removed, so as to render possible the exploration of the lower depths next year. It turns out that the cave narrows considerably at about 50 feet in, and that the base of the human deposit, never more than 10 feet thick, is at this point as much as 10-15 feet above the conventional floor-level. It looks as if the cave at the time of occupation had a sharply sloping back. The rodent-bed here, as elsewhere, immediately overlays the human deposit. The microtine remains include about 200 fairly perfect jaws, which ought greatly to assist the work of determination. Otherwise the yield of the summer's labours is rather poor, amounting to no more than 189 pieces of flint (5 implements of the first class, 51 of the second, the rest unshaped flakes, mostly used) and 108 hammer-stones of granite or greenstone, of which 84 show obvious marks of use. In fact, it would appear that in previous years the cream had already been skimmed off by partial clearance from all rearmost portion of the cave. As it is, very little more remains to be done in order to complete the excavation of the main cave down to the lowest level of Mousterian occupation.

The Chairman and Secretary personally directed the work throughout. Mrs. Jenkinson, Miss Moss, Miss de Brisay, and Mr. Fleming-Struthers came over from Oxford to render most valuable assistance. Mr. Robinson and his College boys lent a frequent hand, as also did other local helpers. The labour was supplied by Mr. W. J. Boniface, whose quarrymen, even if they were long past military age, performed their heavy task with zeal and success.

The Structure and Function of the Mammalian Heart.—Report of the Committee, consisting of Professor C. S. SHERRINGTON (*Chairman*), Professor STANLEY KENT (*Secretary*), *and* Dr. FLORENCE BUCHANAN, *appointed to make further Researches thereon.* (*Drawn up by the Secretary.*)

OWING to existing circumstances it has been impossible to devote as much time as usual to the work. This has been mainly in the direction of preparation of material for use at a future date.

Some progress has been made in connection with the working out in various animals of details of structure of the new connections between auricle and ventricle already described. The points established are of interest, since they illustrate the manner in which necessary physiological function is secured by the development of special histological structure.

The Committee does not seek reappointment.

Science in Secondary Schools.—Report of the Committee, consisting of Professor R. A. GREGORY (*Chairman*), Dr. E. H. TRIPP (*Secretary*), Mr. W. ALDRIDGE, Professor H. E. ARMSTRONG, Mr. D. BERRIDGE, Mr. C. A. BUCKMASTER, Dr. LILIAN J. CLARKE, Mr. G. F. DANIELL, Miss I. M. DRUMMOND, Mr. G. D. DUNKERLEY, Miss A. E. ESCOTT, Mr. R. CARY GILSON, Miss C. L. LAURIE, Professor T. P. NUNN, Mr. F. W. SANDERSON, Mr. A. VASSALL, *and* Professor A. M. WORTHINGTON, *appointed to consider and report upon the Method and Substance of Science Teaching in Secondary Schools, with particular reference to the essential place of Science in General Education.*

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I. Introduction.

The British Association has on several occasions exerted a formative influence upon the teaching of science in secondary schools. At the Nottingham meeting in 1866 a Committee, consisting of Dean Farrar, Professor Huxley, Professor Tyndall, and Canon Wilson, with Mr. G. Griffith, the Assistant General Secretary of the Association, as Secretary, was appointed 'To consider the best means of promoting Scientific Education in Schools.' The report presented in the following year related the experience gained at Rugby and Harrow, and described the position of science teaching at Oxford, Cambridge, and London, and in French and German Schools. Four years previously, in 1860, the report of the Royal Commission on the nine Public Schools—Eton, Harrow, Winchester, Shrewsbury, St. Paul's, Westminster, Merchant Taylors', Charterhouse, and Rugby—had been published. In this report the Commissioners recommended that all boys should receive instruction in some branch of natural science during at least a part of their school life; and that there should be two principal branches, one consisting of chemistry and physics, and the other of physiology and natural history.

The science teaching contemplated in both these reports was that which should form part of the educational course of every boy in a secondary school; its intention was not to train physicists or chemists or to prepare for any other professional occupation, but to make science an essential subject in the curriculum and an effective instrument of mental development. Fifty years ago the advocates of scientific instruction in schools saw clearly that merely to provide information about natural objects and phenomena is of little use, and that a knowledge of the true spirit of science can be obtained only by personal observation and experiment in the field or the laboratory. The following words from the report presented to the Council in 1867 might have been written to-day:—

'There is an important distinction between scientific *information* and scientific *training*; in other words, between general literary acquaintance with scientific facts and the knowledge of methods that may be gained by studying the facts at first hand under the guidance of a competent teacher. Both of these are valuable; it is very desirable, for example, that boys should have some general information about the ordinary phenomena of Nature, such as the simple facts of Astronomy, of Geology, of Physical Geography, and of Elementary Physiology. On the other hand, the scientific habit of mind, which is the principal benefit resulting from scientific training, and which is of incalculable value whatever be the pursuits of after-life, can better be attained by a thorough knowledge of the facts and principles of one science than by a general acquaintance with what has been said or written about many. Both of these should co-exist, we think, at any school which professes to offer the highest liberal education; and at *every* school it will be easy to provide at least for giving some scientific information.

'1. The subjects that we recommend for scientific *information*, as distinguished from training, should comprehend a general description of the solar system; of the form and physical geography of the earth, and of such natural phenomena as tides, currents, winds, and the causes that influence climate; of the broad facts of geology; of elementary natural history, with especial reference to the useful plants and animals; and of the rudiments of physiology. This is a kind of information which requires less preparation

on the part of the teacher; and its effectiveness will depend on his knowledge, clearness, method, and sympathy with his pupils. Nothing will be gained by circumscribing these subjects by any general syllabus; they may safely be left to the discretion of the masters who teach them.

'2. And for scientific *training* we are decidedly of opinion that the subjects which have paramount claims are Experimental Physics, Elementary Chemistry, and Botany.'

Canon Wilson, the only surviving member of the British Association Committee, in his paper on 'Teaching Natural Science in Schools,' published in 1867 in a volume entitled 'Essays on a Liberal Education,' gave a full account of the methods adopted in introducing science teaching in Rugby School. Botany was then selected as the best subject for beginning to train boys in scientific methods, and it was followed by experimental physics, the two being claimed as standard subjects for the scientific teaching in schools. As to other subjects, Chemistry was not considered suitable for lecture instruction, and few laboratories then existed in which the necessary practical knowledge for its intelligent study could be obtained; Geology 'lies outside the subjects which best illustrate scientific method,' and 'Physiology cannot be taught to classes at school. Nor ought it to be learnt before Physics and Chemistry.'

Though most of the instruction was given by means of experimental lectures, the main aim of the best science teachers was the same in those days as now—namely, to train in independent observation and reasoning. Canon Wilson, in the essay to which reference has been made already, states this principle in words which possess the persistence of truth, and are, therefore, worthy of repetition in our own time—fifty years after they were written:—

'Theory and experience alike convince me that the master who is teaching a class quite unfamiliar with scientific method ought to make his class teach themselves, by thinking out the subject of the lecture with them, taking up their suggestions and illustrations, criticising them, hunting them down, and proving a suggestion barren or an illustration inapt; starting them on a fresh scent when they are at fault, reminding them of some familiar fact they had overlooked, and so eliciting out of the chaos of vague notions that are afloat on the matter in hand, be it the laws of motion, the evaporation of water, or the origin of the Drift, something of order, and concatenation, and interest, before the key to the mystery is given, even if after all it has to be given. Training to think, not to be a mechanic or surveyor, must be first and foremost as his object. So valuable are the subjects intrinsically, and such excellent models do they provide, that the most stupid and didactic teaching will not be useless; but it will not be the same source of power that "the method of investigation" will be in the hands of a good master. Some few will work out a logic of proof and a logic of discovery, when the facts and laws that are discovered and proved have had time to lie and crystallise in their minds. But imbued with scientific method they scarcely will be, unless it springs up spontaneously in them.

'For all classes, except those which are beginning, the union of the two methods is best. If they have once thoroughly learnt that the truths of science are to be got from what they see, and not from the assertions of a master or a text-book, they can never quite forget it, and allow their science to exist in a cloud-world apart from the earth. And undoubtedly the rigid and exact teaching from a book, insuring a complete and formularised and producible knowledge, is very valuable, especially with older classes.'

When these words were written it seems to have been supposed

that a training in scientific method could be obtained by attention to experimental lectures, and independent practical work in school laboratories was scarcely contemplated. The apparatus used for lectures in physics was designed for demonstration purposes, and was not suitable for use by individual pupils even if its price did not render the purchase of sufficient sets for laboratory use prohibitive. It was Professor Worthington, whose death while a member of the present Committee is deeply deplored, who was chiefly responsible for the introduction of courses of practical work with simple apparatus in school physical laboratories. His 'Physical Laboratory Practice,' published in 1886, embodies the experimental course followed successfully at Clifton College, and afterwards introduced into many other secondary schools. Experience showed that quantitative results sufficiently accurate to suggest or confirm fundamental principles could be secured by the use of very simple apparatus, and that the work thus done by pupils individually created a far deeper impression than lectures alone could give. Referring to the work at Clifton, Professor Worthington said:

'It is undertaken there, like all the scientific teaching, not with a view of training physicists, but with the object of evoking in the boys a genuine and generous interest in natural phenomena, and of training them to habits of patient and conscientious study; and those of us who have devoted themselves more particularly to the physical sciences are confident that the serious interest thus early aroused in a large number is the best guarantee of future excellence in the few who may afterwards become specialists.'

The teaching of practical chemistry at that time consisted chiefly of more or less mechanical drill in the operations of qualitative analysis. The result was unsatisfactory, and the general adoption of science work in schools could not be justified by it. In 1884, at an International Conference on Education held in London, Professor H. E. Armstrong gave the outline of a more intelligent method of teaching chemistry in which the pupil is faced with problems to be solved experimentally by him. Three years later a Committee was appointed by the British Association for the purpose of inquiring into and reporting upon the methods of teaching chemistry in schools. This Committee presented a report at the Bath meeting in 1888, and suggested that 'teachers stand very much in need of advice and assistance in preparing a modified scheme of teaching suitable for general adoption in schools.' In response to this suggestion Professor Armstrong gave, in reports presented at the meetings of 1889 and 1890, details of practical courses of instruction deliberately intended to develop the faculties of independent inquiry, accurate observation, and intelligent reasoning. The 'heuristic' methods which he advocated were 'methods which involve our placing students so far as possible in the attitude of the discoverer—methods which involve their *finding out* instead of being merely told about things.'

The British Association schemes revolutionised the teaching of chemistry, and physics also to a large extent, in schools. The prescribed preparation of gases and the drill in qualitative analysis, which had constituted the practical work in school chemical laboratories, were superseded by inquiries into the composition of such common substances as air and water, and no experiment was undertaken without

a scientific motive. The Headmasters' Association afterwards approved a course of work based upon the principles laid down by Professor Armstrong; and the Joint Scholarships Board instituted by the Association adopted this scheme, which is published under the title 'Syllabus of an Elementary Course in Physics and Chemistry' (Educational Supply Association, price 3*d.*; postage ½*d.*).

The history of the change in methods of teaching science initiated by Professor Armstrong will be found in his work 'The Teaching of Scientific Method' (Macmillan, price 5*s.* net). There are differences of opinion as to whether strictly heuristic methods are practicable with large classes, but objections raised to them are often based upon misapprehension, and there can be no question that the introduction of the methods have been the means of effecting substantial improvements in the teaching of science in schools. Unfortunately, in concentrating attention upon training in experimental method, the complementary teaching of science as a body of inspiring principles and a truly humanising influence has been neglected; and it is to this aspect of the subject that particular importance is attached in the present report.

What Professor Armstrong did for the study of physics and chemistry has been done by Professor L. C. Miall for experimental natural history. Beginning with such a simple natural object as a bean, pupils are led to examine the seed; to record its form, size, and general structure; to notice the early stages of the bean-plant by sprouting seeds in wet sawdust; to find what difference it makes to the seedlings whether they are kept in the dark, exposed to faint light, or to full sunlight; to determine the nutritive salts required for the continued growth of the plants; to demonstrate that green plants draw carbon dioxide from the air, forming starch from it, and using up the starch in the manufacture of their permanent tissues, as well as in other ways; and so on. The study of plant or animal life based upon such methods of observation and inquiry has been a valuable means of scientific education in many schools.

The Committee has not considered it necessary to make an exhaustive inquiry into the position of science teaching in secondary schools. This will no doubt be done by the Government Committee appointed under the Chairmanship of Sir J. J. Thomson to inquire into the position occupied by natural science in the educational systems of Great Britain. That Committee, however, has industrial and professional interests to consider, as well as the claims of science in education, and it includes only three or four members familiar with the science work carried on in secondary schools. It is believed, therefore, that a Committee consisting almost entirely of teachers with experience in such schools should be able to perform a useful function by presenting a report concerned chiefly with existing methods and scope of science teaching, and giving schemes of work in which humanistic aspects of science occupy a prominent place.

II. Position of Science Teaching in Schools of Different Types.

In considering the amount of time devoted to science teaching it is necessary to distinguish different types of secondary schools both for boys and girls. Schools in receipt of State aid are inspected by the Board of Education, and they include old-established Grammar Schools as well as Municipal and County Schools under Local Education Authorities. State-aided schools for boys number about 620, and the great majority of these are represented by the Incorporated Association of Headmasters. In addition to these State-aided schools there are a number of public schools which are independent of the Board of Education or other public body. All these public schools are represented upon the Headmasters' Conference, together with about forty-five schools which are in receipt of State aid, and therefore come under the regulations of the Board of Education. One hundred and twenty schools are represented on the Conference, and the general condition of admission of a school to representation is that the school has at least 100 boys and about 10 per cent. of its pupils are resident undergraduates at the Universities of Oxford and Cambridge direct from the school. The Association of Headmistresses represents in much the same way about 415 public secondary schools for girls, of which 330 are State-aided.

On account of these distinctions the particulars as to science subjects studied in secondary schools are arranged under three heads—namely, (1) State-aided secondary schools for boys, (2) secondary schools without Government grant or control for boys, (3) public secondary schools for girls. In the case of the first two types particulars presented by a Committee in 1908 have been brought up to date, but for the girls' public schools a special inquiry has been instituted, the results of which are here described, and the details are given in Appendices II. and III.:—

(a) *State-aided Secondary Schools.*

The Board of Education's Regulations for Secondary Schools require that the curriculum of every such school in receipt of annual grants must make provision for instruction in science, and that this instruction 'must include practical work by the pupils.'

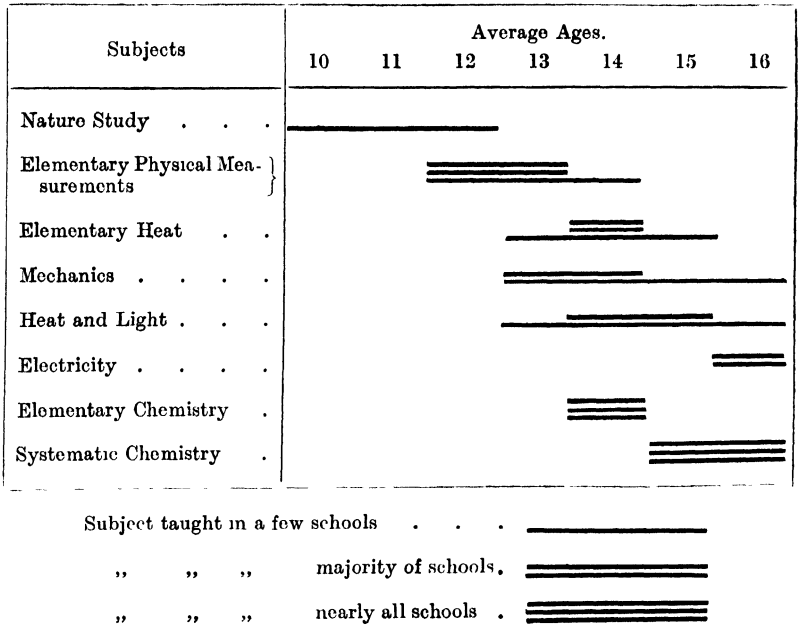
In secondary schools for girls housecraft subjects may be substituted partially or wholly for science and for mathematics other than arithmetic.

About 1,000 secondary schools in England and Wales come under these Regulations, and the number of pupils in them is about 180,000. The leaving age is nominally sixteen or eighteen, but most of the pupils leave before they reach the lower age. In the majority of the schools earning the full grant of the Board of Education science occupies a prominent place in the curriculum, and the provision and equipment of laboratories are usually sufficient.

Owing to the close agreement of the curriculum, the accompanying Table, from a report presented at the Dublin meeting of the Association in 1908, represents the range and sequence of subjects in the majority of boys' schools.

TABLE I.

Usual science subjects in schools where the leaving age is sixteen.



There is a tendency to begin electricity earlier than the last year, but otherwise the subjects remain in much the same position as they were in 1908. Biology does not appear in the Table except as nature study, and it is studied only by a few boys specialising after matriculation. Physics and chemistry practically monopolise the field; geology, natural history, archæology, and astronomy depending upon the boys' voluntary efforts, encouraged by school scientific or natural history societies.

As regards subjects of instruction, there is a wide difference between boys' and girls' schools. In many girls' schools botany is the main science subject; physics, or more often chemistry, is taken in others as an alternative or in addition to botany. In some girls' schools physics and chemistry are taught on the same lines as in boys'; in others, these subjects are used as introductions to a course of domestic science and hygiene or of botany. A course of experimental science which embodies rudiments of both physics and chemistry sometimes precedes formal teaching of these separate branches of science both in boys' and girls' schools, and may be carried through the curricula.

(b) *Boys' Secondary Schools of the Public School Type.*

Rather more than eighty of the schools represented on the Headmasters' Conference receive no grants from the Board of Education,

and, although a few of these are inspected by the Board, the majority are inspected by the Universities, and have therefore no connection with the Board. In most of these there is a strong classical tradition. The actual number of boys (about 36,000) taught in these schools is small compared with those who receive their education in State-aided schools, but the fact that the public schools educate the majority of the future statesmen gives them special importance. The Headmasters are with few exceptions classical specialists. The leaving age before the war was nominally nineteen, but a considerable number of boys leave when they are eighteen.

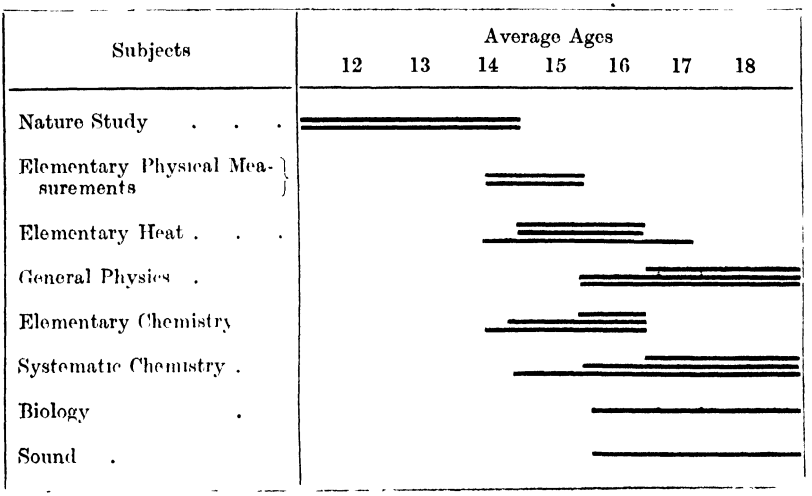
The schools are generally, but not always, divided into classical, modern, and Army sides, science being taught universally on the two latter sides, but to only a certain number of the boys on the classical side. On the Army side the science subjects are determined by the requirements of the Civil Service Commissioners, and are consequently entirely confined to chemistry and physics; on the modern side the tendency is also to limit the science teaching to these two subjects, although in some schools the younger pupils are given courses of geology and elementary biology. Of course, the senior boys who specialise in science have a considerably wider range, but these do not form a part of the Modern side proper. On the classical side progress has been made during the past twenty years. Formerly few schools made any provision for science teaching; now it is the exception to find a school in which science does not appear in the time-table of the great majority of boys at some period of their school career. Since these boys have, as a rule, no science examination in view, educational experiments are more frequently made upon them than on others; hence there is far less uniformity in the teaching in this part of the school than on the modern side; in some the work is of the same nature as upon the modern side; but, since the time devoted to science is as a rule less, the standard attained is naturally lower, whilst in others the 'object' rather than the 'subject' method is pursued—*e g.*, water is investigated in its biological, geological, sociological, chemical, and physical aspects in one course.

In addition to the fact that some attention is now given to the teaching of science on the classical side, the more important changes which have taken place since a Sub-Committee presented a report to Section L at the Dublin meeting in 1908 seem to be that (1) less attention is now paid to elementary practical measurements; this is partly due to the difficulty which has been experienced in many schools in persuading the mathematical staff, without whose co-operation progress is impossible, to undertake laboratory work. There can be but little doubt that many science-masters have found that such work does not interest their pupils, and is apt to give them a disinclination to science. (2) Mechanics is less frequently made a part of the science curriculum, and there is a growing tendency to leave it to the mathematical staff, with the unfortunate result that the experimental side is neglected. (3) Biology is certainly receiving more attention than it did; this may be due to the action of certain Universities in making it a compulsory subject for their first M.B. examination; but it is

probable that the importance of the subject is better realised now than it was a few years ago.

The following table, which is based upon the one presented to the Dublin meeting, shows what is believed to be the present position:—

Usual science subjects in schools where the leaving age is eighteen and over.



(c) *Public Secondary Schools for Girls.*

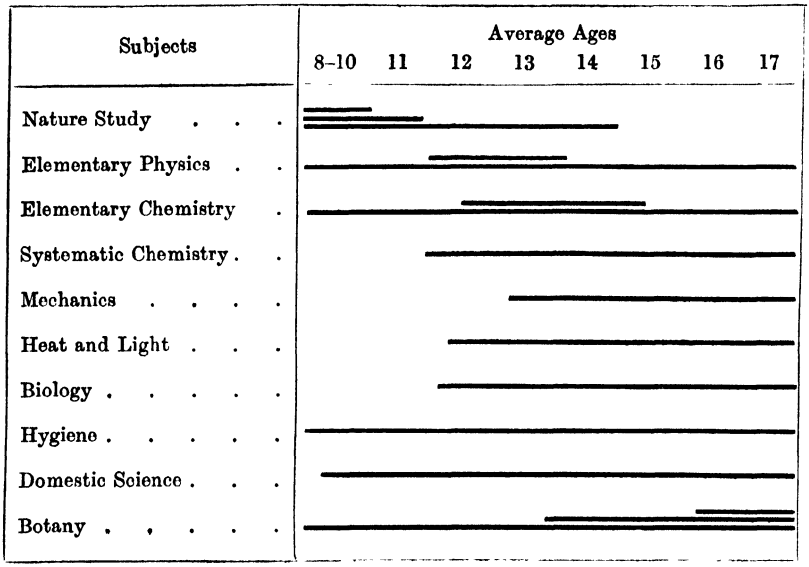
(A Memorandum based on replies sent in by 171 typical schools to a questionnaire issued by the Association of Science Mistresses. November 1916.)

Some science forms part of the curriculum throughout the whole of the pre-specialisation period in almost every public secondary school for girls. In one or two exceptional cases the continuous course is broken at a certain stage for one year.

In nearly every school nature study forms the basis of the work with children below eleven or twelve years of age. For the following two or three years there is, most often, a continuous course of elementary physics and chemistry treated experimentally. Though the total time given to science at this stage does not, as a rule, exceed two hours per week this experimental course frequently runs concurrently with a course of lessons in some other subject, as hygiene. Botany is most commonly taught above this stage, but in a considerable number of the larger schools there are alternative courses of botany and chemistry, and a few schools make chemistry their main subject. Physics is rarely taught above a very elementary standard.

In very few cases does the science course appear to be determined by correlation with courses of lessons in the domestic arts.

The following table indicates the subjects most commonly taught at different stages:—



Note. — ——— means taught in some schools.

═══ means taught in the majority of schools.

≡≡≡ means taught in nearly all schools.

The time spent on science in the majority of schools is from 1 to 1½ hours per week below twelve years of age, and from 2 to 2½ between the ages of twelve and sixteen or seventeen, above which specialisation begins. In a considerable number of cases (see Appendix III.) the laboratory accommodation is insufficient to allow of the whole even of this time being spent in experimental work, and a part is therefore frequently given to some subject as, for example, hygiene or descriptive botany, which can be taught in the classroom.

III. Time Required for the Teaching of Science.

There is a tendency at the present time, especially in some of the more conservative schools, to introduce science teaching for two hours per week, and to regard this as sufficient to meet the claims of science to an adequate place in the curriculum. In the opinion of the Committee it is impossible for any real training in scientific method, or for knowledge of any practical value, to be secured with so short an allowance of time. Also pupils are apt to consider that the importance of a subject may be judged by the time allotted to it in school, or to

imagine they have acquired a grasp of a subject of which they know only the introduction.

Whilst the actual number of school hours is fairly uniform in boys' schools, there is considerable difference in the number of periods into which these are divided; and in girls' schools the number of hours per week is, as a rule, much less than in boys' schools. The Committee hesitates, therefore, to specify how many hours per week should be devoted to science teaching; it is, however, of the opinion that for pupils who are not specialising—*i.e.*, for those who are between the ages of twelve and about sixteen and a half—an average of at least one-sixth for boys and one-seventh for girls of the total number of teaching periods in each week should be used for science work independent of work in geography and mathematics.

IV. Method in Science Teaching.

In recent years more attention has been given to method in science teaching than to substance. One result of this has been to promote the view that all subjects, in different ways and to different degrees, can be made to give a training in scientific method; and that, therefore, instruction in science has no specific educational advantage over that of any other subject in the curriculum taught by methods of deduction and induction. It will be shown later in this respect how science—by which is here meant all departments of natural knowledge which depend for their development upon observation and experiment—differs from other subjects of instruction, but a general statement as to the meaning and application of scientific method in science teaching seems to be necessary.

Ambiguity of 'scientific method.'—It has often been remarked that the adjective 'scientific' has a double significance. Sometimes it is used to distinguish one kind of knowledge, such as physics, from another kind, such as history. At other times the distinction it connotes is not between objects of knowledge but between modes of investigation—between the 'conduct of the understanding' which alone leads to certain truth and ways of thought that inevitably end in error. The second sense of the word is evidently much wider than the first; for, while the realm of 'scientific knowledge,' though vast, is limited, the dominion of 'scientific method' is universal, extending wherever there are facts to be determined or general truths to be ascertained.

If, however, it is admitted (1) that the chief business of the science teacher is to train in scientific method, and (2) that scientific method is the characteristic not of science only but of every properly conducted intellectual inquiry, the science teacher is perilously near to the surrender of his special claim to existence. For does scientific method imply the habits of observing facts with care, of classifying them clearly and exhaustively, of forming hypotheses without bias, of testing them with rigour? Then a good classical teacher may make the study of Latin grammar as 'scientific' as the study of chemistry, while, under a bad teacher, work in the laboratory may be as little 'scientific' as anything ever done in a Latin lesson. Again, does scientific method

imply 'respect for fact' and the pursuit of truth in defiance of prejudice? Then it may be maintained that the study of recent history offers a field for its exercise at least as favourable as (say) an inquiry into the composition of water.

Matter and Method not separable.—This paradoxical conclusion depends upon the assumption that the method of scientific investigation can be regarded as separable from the matter, which is not correct. In other words, it is not strictly true that scientific method is one and the same wherever it is employed The physical method and the historical method, for example, have common fundamental features, but cannot be simply identified the one with the other. In short, scientific method is an abstraction which does not exist apart from its concrete embodiments; and the person who desires adequate knowledge of it must study it in all its typical manifestations. No one ought to expect a training in scientific method acquired in one field of inquiry to be transferable to—that is, to guarantee competence in—a field substantially different from the former. This conclusion is illustrated and supported by many recent experimental investigations. For instance, Dr. W. G. Sleight[1] has shown conclusively that practice in one form of memorising (*e g* , the reproduction of the substance of a passage of prose) produces no general improvement of the memory, but may even cause deterioration in the power to memorise material of a different kind. Ability acquired in memory-exercises of one type is, in fact, transferable to exercises of another type only if the second contains special elements that are also characteristic of the former, and then only if the learner perceives and deliberately takes advantage of the partial identity. Thus a boy trained in memorising series of numbers shows an improved power to memorise 'nonsense-syllables' if, and only if, he has recognised that the use of rhythm is an aid to the mastery of the material in both cases.

It appears, then, that the training received in a specific course of study is an ability acquired in dealing with situations of a certain kind, and is of service without the boundaries of the study only in situations that can be regarded as substantially identical with those within it. Scientific knowledge and scientific method must not, therefore, be thought of as distinct and separable things, but as things whose relation is comparable with the relation between a living body and its life. Just as the life of a body consists in its growth and activities, and in nothing else, so the methods of a science are nothing other than the ways in which it grows, reaching ever wider and deeper views of some aspect or department of nature. The science teacher has not, therefore, to adjust or to choose between the claims of knowledge and of training, for the two are inseparable. Let him give his pupils the knowledge that (in Spencer's classic phrase) is 'of most worth'—that is, the knowledge which best expresses the special genius of his science—and he may be confident that he is at the same time giving them the best training the subject can supply. It need only be added

[1] Dr. Sleight's book, *Educational Values* (Clarendon Press), gives a critical account of all the more important researches on the transference of acquired abilities.

(for fear of misunderstanding) that this giving of knowledge is not to be confounded with the mere imparting of 'facts.' It implies in the pupil a genuine *pursuit* of knowledge—an activity, guided by the teacher but motived from within, which represents, so far as the necessarily artificial conditions of teaching permit, the historic activities of scientific minds working at their best.

Principles and Motives in Teaching.—In selecting what is to be taught the teacher must take account not only of the intrinsic worth of the knowledge but also of the varying powers and interests of immature minds at different ages. Are there any general principles to guide him in ordering his curriculum to meet their needs? The obvious maxim that the easy things should come first and the more difficult things later is not in itself sufficient, for it gives no principle for determining what is easy and what is difficult from the point of view of the pupil. Some of the simplest ideas in science may prove to be quite out of the natural range of activity of young minds because they appeal effectively only to a riper experience or to a developed scientific interest. It is, indeed, for these reasons that such ideas have often emerged late rather than early in the history of a science. Can we, then, find criteria which will discriminate between things suitable and things unsuitable for pupils at different stages of progress? In other words, is there a normal course of development of the scientific interest in the young?

In considering this question we must, in view of the infinite variety of human minds, be on our guard against sweeping and dogmatic generalisations. At best we can hope to discover laws that hold good, as Aristotle said, ἐπὶ τὸ πολύ : rules that give general guidance but do not free the teacher from the obligation to treat individual pupils in accordance with their special natures and needs. Attacking the problem in this modest spirit, we may usefully note that, among the motives which have prompted men to make those persistent attempts to understand nature which we call science, three have always been especially conspicuous. First, and in a sense foremost, is delight in the intrinsic beauty and charm of natural phenomena—delight in the forms and ways of plants and animals, in the splendour of the heavens, in the surprising behaviour and transformations of matter under certain assignable conditions. To use a familiar phrase, the foundation of science is the love of nature. Next, we may distinguish the motive that springs from the perception that man can exploit the forces of nature for his own purposes only if he is prepared to take the trouble to understand them—that man must become the interpreter of nature if nature is to become the handmaid of man. This is the motive that has created the vast fabric of 'applied science.' Lastly, there is the craving for theoretical completeness and unity—the motive that prompts men on one hand to seek 'fundamental principles' in nature, and on the other to organise their ideas about the different aspects or departments of nature into closely knitted logical systems. These three—which may be called the 'wonder motive' (in the absence of a better term), the 'utility motive,' and the 'systematising motive'—are not, of course, to be thought of as working in isolation. In differing

degrees all are, no doubt, present in all scientific activity. Nevertheless, they are evidently distinct sources of such activity, whose relative predominance at different stages in the history of a science, and in minds of differing cast, may vary to a very great extent.

Our question resolves itself, therefore, into the following: Can we count upon the presence and activity of these motives in the minds of boys and girls, and is there any normal order of predominance among them? To the first part of the question, thus expressed, we can give a confident reply. There are few children, if any, who do not feel the charm of natural phenomena and cannot be led by it to pursue inquiries which, however rudimentary they may be, are yet in the direct line of the development of science. The 'utility motive,' represented by the desire to find out 'how it works' or 'how it is made,' is notoriously conspicuous. The systematising motive, while apparently much more variable in strength, cannot be said to be inoperative in any normal child. With regard to the second and more important part of the question, it may be said (subject to the reservation mentioned above) that, although young minds feel the pressure of all the motives, yet each of the three enjoys its special period of empire Children before an age which is not far above or below eleven years seem to respond most surely and actively to the direct appeal of striking and beautiful phenomena. From eleven or twelve to (say) fifteen or sixteen the 'utility motive' assumes the mastery, and may, at least in boys, reach the force and volume of a passion With the full advent of adolescence the 'systematising motive' has for the first time its opportunity of predominance, but there seem to be many minds in which its full power is never developed.

Practical Conclusions.—The practical bearing of these observations is clear. It is important, in the first place, that the teacher should not fail to give due scope to the 'wonder motive.' A science lesson should not degenerate into a display of fireworks or into sentimental vapourings about the 'marvels of nature,' but it is easy to fall into the opposite error. Science-teachers have by no means always avoided it. It must be remembered that teaching which is not founded upon the pupil's direct interest in natural phenomena for their own sake cannot stimulate genuine scientific activity, and that no 'scientific training' can be effective which kills instead of fostering the root from which all scientific activity has grown. In addition to this general consideration, applicable to all ages of the pupil, we draw the particular conclusion that the first stage in science teaching should be a stage of 'nature study,' of which the distinctive aim should be not to establish the logical foundations of any science, but to awaken the pupil's interest in the more attractive and obvious happenings in garden and wood, in pond and field, in sea and sky, and to begin the work of disciplining this interest into scientific inquiry.

Next, it is suggested that to fail to make full use of the 'utility motive' is to allow one of the richest sources of intellectual activity to run to waste. Many teachers of science are discovering that for pupils between the ages of twelve and sixteen (or later) the most effective method of instruction takes the form of an analysis directed to the

discovery of the principles involved in the typical triumphs of applied science. In this method Archimedes' Principle is regarded not as a 'property of fluids' nor as means of determining specific gravities, but as the principle that explains the flotation of ships; the study of the processes by which metals are won from their ores displaces chemical inquiries of academic interest; to study electricity is to analyse the working of the electric bell, the dynamo, the installation for wireless telegraphy. In other words, such topics as these, instead of being regarded as 'applications' of scientific principles, to be taught if time and the demands of a public examination allow, are treated as the foci of interest from whose study the pupil's knowledge of the scientific principles is to emerge.

Lastly, we must recognise that the 'systematising motive' is one that has long been worked in our schools beyond its natural strength. Not infrequently teachers of some experience express the doubt whether boys and girls are capable of studying science before the age of fifteen or sixteen. Still more often university professors of science express the wish that their students might come to them with minds unperverted by the teaching of the schools. Whatever truth these pessimistic suggestions contain is probably accounted for by the failure of teachers to mould their instruction in conformity with the natural development of children's minds. The young man (or woman) who teaches science in schools from the point of view of the university often achieves with the best intentions a disastrous amount of harm. The mischief will not be prevented until it is universally recognised that the logical theory of a science should be not the *terminus a quo* of instruction, but the *terminus ad quem*.

V. Experimental and Descriptive Teaching.

Methods of Instruction.—School instruction in science has, in England, taken the form of individual practical work, laboratory demonstrations, and lectures. In some cases laboratory work is carried on independently of the lectures as regards subjects, while in others it is arranged to run parallel with the theoretical course. Frequently all lessons are given in the laboratory by means of demonstrations and discussions in conjunction with practical work, and there is little lecturing in the usual sense of the term. The basis of the instruction in science in schools where this plan is adopted is the laboratory work, and points are explained or elaborated as they are reached in the practical course.

Another plan is to make the laboratory work ancillary to the lectures, and to regard it as a necessary means of making the pupil understand clearly some points dealt with in them or met with in his reading.

The Unique Value of Laboratory Work.—The primary value of laboratory work in schools is that it brings the pupil into direct contact with reality through his own senses and his own manipulation. In this way only can he learn to see things in their right proportions, to distinguish the essentials of an experiment from the non-essentials, and obtain a firm grasp of a scientific subject. Reading about an

experiment, or even seeing an experiment performed, cannot give that security of knowledge which practical contact affords.

Experience shows that when scientific knowledge has been secured by practical work it becomes part of the permanent mental equipment of the pupil. The laboratory is, further, the one place where the pupil learns to acquire first-hand evidence, and to distinguish between that and information obtained verbally or by reading; for this reason also it alone fulfils an essential function in an educational course.

It is possible to use scientific method in the study of history, languages, and other literary subjects, but applied in this way the method can never be accepted as providing the same means of training as laboratory experiment.

Distinction between Manual Training and Experiment.—Although the principle of 'learning by doing' is followed also in courses of manual instruction in which each pupil is impressed with the necessity of relying upon himself, of arranging and carrying out his work in an orderly manner, and of interpreting instructions accurately, and though other advantages may be justly claimed for such work, yet there is always a decided difference between the best scheme of workshop exercises and the experimental work of a rightly arranged experimental course. In the laboratory the development of dexterity and skill is only a secondary consideration, and the attention is fastened on the answer given by Nature to the question put to it: on the method to be adopted for eliciting the answer, on its significance when obtained, and on the degree of accuracy with which it can be credited.

Preliminary Work to Systematic Instruction in Science.—It is because of the demand thus made on the reasoning powers that in 1910 a Joint Committee of the Mathematical Association and the Association of Public School Science Masters expressed the decided opinion that systematic work in science should not be taken at too early a stage; laying down that 'It is undesirable that either formal physics or chemistry be taught in Preparatory Schools,' and that 'Questions should not be set in formal physics or chemistry at the entrance or entrance scholarship examinations to the Public Schools.' The same Committee, however, recommended that instruction which could be taken at an early stage, in elementary practical measurements of length, area, volume, mass, and density, should be given by the mathematical staff and not by the science staff. Such work can be done in an ordinary class-room with the simplest apparatus, and is thus more easily co-ordinated with the mathematical lessons than when carried on in a room specially devoted to it. The course of measurements, including the use of simple balances, need very seldom exceed twenty hours of practical work; and there can be no doubt that it is of the highest value in giving actuality to the mathematical teaching. Unfortunately, mathematical teachers have often been found to have little sympathy with these practical methods of illustration.

Introductory work in science, whether in preparatory schools or in the lower forms of State-aided secondary schools, should consist of such elementary practical measurements as are referred to above, and of a course intended to interest pupils in natural knowledge and

to encourage observations of animal and plant life, earth and sky, and of everyday phenomena manifested in them. Such observations provide material for cultivating the art of expression, and with suitable reading or descriptive lessons will create and foster attention to many aspects of Nature.

Laboratory Methods and Scope.—In laboratory courses two methods of instruction may be distinguished—the subject-method and the problem-method—one or both of which may be followed, or, more often, a combination of the two. The subject-method may be described as a system of impressing fundamental properties and principles upon the minds of pupils by means of a graduated course of experimental exercises. The pupils usually work independently or in pairs, but in some schools the same exercises are performed by a whole class simultaneously as a form of drill, in which case they tend to become of the type of cookery-book recipes rather than that of scientific experiment.

The problem-method aims at suggesting a motive and purpose for every experiment, and thus of creating the spirit of experimental scientific inquiry. It consists in facing a problem, and by means of experiment endeavouring to solve it and related questions which arise during the work. The intention is not, as is sometimes supposed, to make pupils discover for themselves laws and principles previously unknown to them, though to some extent this can be done, but rather to provide a continuous thread of reasoning for the practical work and a definite purpose for whatever is undertaken. It is obvious that this method demands much more intensive work on the part of the teacher than is required when a prescribed course of exercises is followed; and on this account varying opinions are held as to its practicability and value. What is wanted for the teacher is a laboratory which he has freedom to use exactly when and for whom the teaching requires it, and independently of syllabuses prescribed by external authorities, whether the subject-method with a definite laboratory course is being followed, or the ancillary method in which the experiment to be undertaken by any pupil may arise from his own demand, or be assigned to him to clear up some observed misapprehension, or as a challenge to test his knowledge of what he has been taught, and his resourcefulness, or simply to give the final security of personal practical experience, as already mentioned.

The field which can be surveyed practically in any school course of laboratory work which forms part of a general education is necessarily limited in scope even when the subject-method is followed, and is more so when the object of the work is to encourage the natural spirit of inquiry, and thus to create a perception of the means by which new scientific knowledge is gained. Increased attention to laboratory exercises has, indeed, in recent years often been associated with a very restricted acquaintance with the world of science. The tendency has been to make all the teaching a matter of measurement, to the neglect of the human aspects of the pursuit of natural knowledge. The teaching is, in fact, inclined to be narrow and special rather than broad and catholic. Experimental work should bring appreciation of the precision and methods of scientific inquiry, but, in addition to this instruction,

an attempt should be made to cultivate interest in achievements of research outside the school walls.

While, therefore, prime importance must be attached to adequate provision for laboratory work undertaken with the view of imparting a knowledge of experimental methods of inquiry, it is essential that there should also be instruction in the broad principles and results of scientific work which cannot be brought within the limits of a laboratory course. Every pupil should not only receive training in observational and experimental work but should also be given a view of natural knowledge as a whole. The object should be to evoke interest rather than to impart facts or data of science prescribed by an examination syllabus, or even to systematise their rediscovery. There should be no specialisation before the stage of Matriculation has been reached, and whatever instruction is given should be from the point of view of general education.

Human Aspects of Science.—Assuming that laboratory work is commenced at a suitable stage, the question arises as to the best means of presenting the broad view of scientific facts and principles desirable in a modern liberal education. It should not be possible for any pupil to complete a course at any secondary school without a knowledge not only of experimental methods but also of the meaning of common natural phenomena. Much of this knowledge can be given, and is being given, to an increasing extent, in connection with the teaching of geography; but in any case descriptive lessons are required in which the aim should be to impart broad ideas, and promote interest in Nature, rather than to train in practical methods applied to a limited field.

It is desirable also, by means of general lectures, discussions, or reading, to introduce into the teaching some account of the main achievements of science and of the methods by which they have been attained. Science must not be considered merely as a burden of material fact and precise principle which needs a special type of mind to bear it. There should be more of the spirit, and less of the valley of dry bones, if science is to be of living interest, either during school life or afterwards. Everyone should be given the opportunity of knowing something of the lives and work of such men as Galileo and Newton, Faraday and Kelvin, Pasteur and Lister, Darwin and Mendel, and many other pioneers of science. One way of doing this is by lessons on the history of science, biographies of discoverers, with studies of their successes and failures, and outlines of the main road along which natural knowledge has advanced. It would be far better, from the point of view of general education, to introduce courses of this kind, intended to direct attention and stimulate interest in scientific greatness and its relation to modern life, than to limit the teaching to dehumanised material of physics and chemistry which leaves but little impression upon the minds of boys if seen only 'in disconnection, dull and spiritless.'

Under existing conditions, which are largely controlled by prescribed syllabuses and external examinations, there is little opportunity for teachers to direct attention to the useful applications of science on one hand, or on the other to awaken interest in the solution of the mysteries which surround us, though this could be done incidentally in connection with lectures or practical work if the present pressure were removed.

History and biography enable a comprehensive view of science to be constructed which cannot be obtained by laboratory work. They supply a solvent of that artificial barrier between literary studies and science which a school time-table usually sets up. In the study of hydrostatics, heat, current electricity, optics, and inorganic chemistry, the attention which has been given to laboratory work has succeeded in developing the powers of doing and describing. The weak points have been insufficient attention to the broader aspects and to scientific discovery and invention as human achievements, and failure to connect school work with the big applications of science by which mankind is benefiting. The study of optics is seldom pursued to a useful point, and in the teaching of mechanics there are more failures than in other science subjects. The time-table is particularly overcrowded during the last two years in the State-aided secondary schools; the work is over-compressed, and the philosophical aspects cannot, therefore, be presented effectively. The extension of the normal leaving age to seventeen years would have a valuable effect in raising the potential standard of scientific knowledge, and in spreading intelligent appreciation of science throughout the country.

At present, as instruction in science proceeds in the school, there is a tendency for it to become detached from the facts and affairs of life, by which alone stimulus and interest can be secured. It is important that every opportunity should be taken to counteract this tendency by descriptive lessons in which everyday phenomena are explained and the utility of discovery and invention is illustrated.

Domestic science and hygiene are frequently introduced into girls' schools with the object of effecting a link between science and the experience of everyday life. It must be pointed out, however, that such courses are incoherent and of little value unless science or domesticity is the definite objective. If the scientific aim predominates, the course can be made to give a good training in elementary experimental science and should afford a useful background to later practical study of domestic arts. If domesticity is dominant, the work cannot be accepted as an effective substitute for a proper science course.

Summary.

The observational work by which the study of science should begin opens the eyes of the pupils and may be used to train them in the correct expression of thought and of accurate description. The practical measurements in the class-room have for their object the fixing of ideas met with in the mathematical teaching. Every pupil should undergo a course of training in experimental scientific inquiry as a part of his general education up to a certain stage, after which the laboratory work may become specialised and be used to supply facts which may be a basis for more advanced work or to prepare pupils for scientific or industrial careers.

At suitable stages, when pupils are capable of taking intelligent interest in the knowledge presented, there should be courses of descriptive lessons and reading broad enough to appeal to all minds and to give a general view of natural facts and principles not limited to the

range of any laboratory course or detailed lecture instruction, and differing from them by being extensive instead of intensive.

Finally, the aims of the teaching of science may be stated to be: (1) To train the powers of accurate observation of natural facts and phenomena and of clear description of what is observed; (2) To impart a knowledge of the method of experimental inquiry which distinguishes modern science from the philosophy of earlier times, and by which advance is secured; (3) To provide a broad basis of fact as to man's environment and his relation to it; (4) To give an acquaintance with scientific words and ideas now common in progressive life and thought.

VI. Supply of Science Teachers in State-aided Schools

Salaries.—It is upon the efforts of those actually engaged in the work of education that the degree of success of any scheme for educational reform depends; the standard of education rises or falls with the teachers, and is largely influenced by the conditions under which their services are rendered. A careful review of the present conditions of service compels the conclusion that nothing approaching adequate compensation is afforded for the outlay of time, money, ability, and energy entailed on the properly equipped science master or mistress in a State-aided secondary school. The average salary paid to the assistant masters in these schools in England and Wales is only 175*l.* 10*s.*, and to mistresses 150*l.*, after eleven or twelve years' service. If an adequate supply of properly qualified science teachers is to be secured the question of salaries should receive immediate attention; the best type of man will not be obtained unless the nation is prepared to pay more than 3*l.* 7*s.* 6*d.* per week for his services after long experience.

Many men accept posts as teachers in secondary schools when leaving the University because the teaching profession offers them an immediate means of maintenance. A man leaves the University at an average age of twenty-two years, or later if he has thought it necessary to take a course at a Training College. He then can command a salary of from 120*l.* to 150*l.* per annum—rarely more—according to his qualifications; and this compares favourably on the average with what can be offered him to begin with in other professional spheres. But he soon finds that tenure is insecure, that superannuation is still 'under consideration,' and that he may in the course of some twenty years secure on the average a competence of not more than 190*l.* per annum. Under these conditions teaching cannot be a profession which will attract into it the best intellects from all classes and spheres of life, but will be regarded by many merely as a temporary occupation until the opportunity arises of entering a more remunerative and encouraging calling.

It is becoming increasingly difficult to meet the demand for efficient science teachers, and a considerable improvement in the salaries and conditions of service will be required before this problem can be settled satisfactorily. In secondary schools for boys teaching is not an attractive profession; parents have a poor opinion of it, schoolmasters rarely recommend it, and the best students in recent years have avoided it

because its obvious disadvantages overshadow the few advantages it offers.

The supply of masters is being maintained at its present level only by the large influx of clever pupils who pass from the elementary schools to the secondary schools and are maintained out of public funds almost entirely throughout their scholastic career. The time seems fast approaching when the scholarship will be recognised as the normal means of entry into the profession.

The scarcity of well-qualified science masters and mistresses will become accentuated in the near future by the fast-growing demand for scientific experts from the various branches of manufacture and industry, and by the attractions offered by medicine as a profession for women. Unless far better salaries and conditions of service are offered, it is hopeless to expect that sufficient numbers of well-trained scientific men and women will take up teaching in preference to much more remunerative and less exacting appointments in other spheres of life

Promotion.—Headmasterships and administrative posts connected with education should be filled from the ranks of the teaching profession.

Classes.—The large size of classes is one of the greatest obstacles to successful science teaching Modern methods demand classes not exceeding sixteen to eighteen if efficient supervision is to be given in the laboratory.

Hours of Teaching.—A science teacher should be afforded opportunities for study and research in order that his instruction may represent increasing scientific knowledge. On this account it may reasonably be urged that his teaching hours should be less than those of masters concerned with literary or mathematical subjects. In the case of the senior science master, who is responsible for the organisation of the science department as a whole, including the supervision and upkeep of the laboratories, much more non-teaching time is necessary.

Tabulated statements on salaries and other details will be found in Appendix I.

VII. Academic Qualifications of Headmasters.

Closely related to the questions of the prospects of science teachers and the position of science teaching are the academic qualifications of headmasters. Inquiry has shown that schools of the Public School type are to a very large extent in the charge of classical specialists. Only a numerically insignificant minority have been recruited from the ranks of graduates in science, and not one of the largest or best-known Public Schools has a science graduate as headmaster. Without in any way wishing to maintain or imply that academic qualifications are, or should be, regarded as the sole, or even the chief, criterion of eligibility for such posts, it is difficult not to recognise that many of the defects and deficiencies in the organisation of the schools (from the science point of view) are related to the apathy or antipathy of their headmasters towards science. Among such defects are: The bias given to classics and literary subjects in the Entrance Examina-

tion to the Public Schools; the preponderance of scholarships, prizes, and other tokens of success given to boys who are specially proficient in classics; the existence of an exclusively classical 'atmosphere'; the absence of efficient organisation to ensure the timely and regular promotion of boys who do well in science; under-staffing of the science instruction and insufficient time-allowance for science subjects.

The position in the State-aided schools is more satisfactory, but even here it may be reasonably contended that a more even distribution of headmasterships among teachers of different academic qualifications would not only help to improve the position and facilitate the progress of school science, but would also tend to remedy the ignorance and neglect of science which have prevailed so long in the nation at large.

VIII. Inspection and Examination.

Certain broad distinctions may be distinguished between the functions of inspection and examination. Inspection tests school and class. It should guarantee that the curricula and syllabuses are suitable and that the teaching is efficient. Examinations test individuals. Inspection does not aim at testing individual pupils. During a visit an inspector may question pupils, inspect note-books, essays, &c. So far as the information thus obtained is used for sampling the class, the process is part of inspection; when judging the individual pupil, the inspector acts as examiner. Conversely, the summarised results of examinations may be used to supplement inspection. Judgment of the teacher's efficiency solely—or even mainly—from the results of a central examination is to be deprecated, since the influence of parentage, environment, and the conditions of work in and out of school are necessarily ignored. (In this report a central examination means one in which the same questions are set to a group of schools without regard to the varying syllabuses of instruction.)

We have to apply the above general principles to the consideration of science teaching as part of the education of non-specialists. Inspection should guarantee that the school provides, and that *every* pupil at the appropriate age pursues, a suitable course of instruction in science. While the examiner's criticism should aim at improving the method and content of the teaching, the more personal aspects of efficiency are the concern of the headmaster and the inspector. It is obvious that genuine guarantees of efficiency can be given only by *qualified* inspectors and examiners, who should have had experience in teaching.

With certain important exceptions, to which reference will be made later, the principal examining bodies have adopted in the past the method of central examinations. Whatever arguments may be urged in favour of this method for students aged eighteen or older who are entering upon a specialist training, the testimony as to its injurious influence on earlier teaching has been remarkable for a practical unanimity sustained for several years. Evidence has been quoted to this effect in reports by investigating committees, notably by the Committee which reported at Dublin on the sequence of Science Studies in Secon-

dary Schools. Accordingly the present Committee passed the following resolution and issued it for publication in November 1916:—

> 'That in order to secure freedom of action for teachers of science in schools, and to prevent the instruction from becoming stereotyped, it is undesirable for any examining authority to prescribe a detailed syllabus in science for use in schools, whether intended as the basis of examinations or otherwise'

It is of special importance to general science teaching that schools examination by an external authority should be based upon the work of the individual school. We recommend also that all schools should be inspected, that examiners should consult teachers before setting question-papers, and that teachers should exercise great care in preparing syllabuses of instruction accompanied by illustrative detail sufficient to show clearly the aim, method, and limits of the courses. Co-operation between inspectors and examiners should be encouraged. Inspectors and examiners, as well as teachers, should be trained for their work, seeing that testing by the inexpert is an expensive farce.

An effective science course being guaranteed for every inspected school, it will be natural and desirable that science should form an important subject in such school examinations as those proposed for the 'First Examination' by the Board of Education in Circular 849. It should not be grouped with mathematics in the sense that a pass in science may excuse mathematics, or *vice versa*. In order to obtain a certificate a candidate should reach a satisfactory standard in a substantial portion of the school curriculum, considerable option being allowed as to subjects in which the pass is demanded. The pupils should be required to pursue a wider curriculum than would suffice for the passing of the test, and the headmaster should guarantee this, and that the course has been followed for a sufficient period to ensure a training of real value. It would be unwise to make passing in science compulsory; the aim should rather be to remove compulsion in other subjects. The teaching of science, as of other subjects, has suffered from academic tradition; rigidity of examination requirements is adverse to progress by educational experiments. At the same time it is important that science should not be placed in a position inferior to classics, modern 'humanistic' studies, or mathematics, in the examinations which form the gate to university or professional courses, to the Army, and to junior appointments of the Civil Service.

The examinations for the 1st Division of the Civil Service do not directly come within the reference of this Committee; but we have to report evidence that boys have been discouraged from the study of science in the great Public Schools through the mistaken view that scientific knowledge and training in experimental method were of little use to administrators, and that the allotment of marks in this and other competitions has tended to the neglect of science. The Consultative Committee, in its reports to the Board of Education on Scholarships for Higher Education, states: 'It is desirable in the national interest that after the war the Public Schools should devote more energy to scientific and practical training.' We endorse this statement and regret

to observe that the recommendations which follow must inevitably, unless modified, tend in the opposite direction. By limiting the Government scholarships to pupils from grant-earning schools, the Consultative Committee's proposals would seriously reduce the field of competition, lower in quantity and quality the supply of well-trained students, and increase the difficulty of following a scientific career which now faces the sons and daughters of the poorer professional men. It would be wiser to leave these scholarships open to pupils from all inspected schools, and to utilise the Second School examination of Circular 849 as one avenue to a Government scholarship. The Board's proposals for the Second Examination accord well with the principle of giving considerable latitude to school and candidate; if the school is inspected, there should be no hesitation on the part of Universities in approving the free play to the individuality of the teacher which is implied.

The Application of the Principle of Decentralisation to the First School Examination.

Objections have been urged against the adoption of decentralisation—*i.e.* of examining each school on its own curriculum and syllabuses. The main are (1) inequality of syllabuses, (2) inequality of question-papers, (3) increased expense.

With reference to (1) and (2), it should be observed that the certificate will not be merely a record of a certain performance in the examination-room; it will guarantee a course of training in an inspected school. Moreover, it should be possible to obtain standards which can be equated by utilising the judgment of experienced, trained examiners. If the ground covered according to the syllabus is restricted, the examiners should reduce or omit the opportunity of selecting questions. They should also be empowered to determine (within reasonable limits) the minima for a 'Pass' and a 'Pass with Credit.'

As regards expense, it is to be observed that the University of London has successfully conducted school examinations on the decentralised plan for several years. Science has formed an important part of these examinations in all three grades, Higher, Senior, and Junior. Even when the policy has been pushed to the extreme limit of a separate question-paper for each school, the cost has not proved prohibitive. The present Committee is, however, of opinion that it will be found in practice that school syllabuses fall into certain groups, and that question-papers can be readily framed for all schools in a group. Thus a paper of twelve questions might ask for eight to be attempted, and include eight questions directly on the syllabus of each school in the group. While considering the difference in cost between such a plan and that of a central question-paper for all schools, it is necessary also to reflect upon the great influence which the questions have upon all the teaching in the schools, as well as upon the success of the candidates Central examinations should not be adopted for administrative convenience, nor to coerce instruction into grooves favoured by members of examining bodies.

Oral and Laboratory Tests.

It will usually be desirable to associate oral with laboratory tests. Such oral tests might include (1) discussion arising from inspection of the note-books of the candidates; (2) discussion of the effect of varying conditions of experiment or of the actual placing and displacing of apparatus, such as lamp, lenses and screen, prisms, &c. (in such cases the candidate may be asked to predict effects and to verify); (3) examination of electrical connections, of a lock, &c., affording useful supplementary exercises serving to initiate oral discussion of principles.

Laboratory tests are unsatisfactory unless the examiner is present. Examiners should rehearse each exercise under examination conditions as to limits of time, method, and apparatus (including drying facilities). The available supplies of water, heat, electrical power need to be known. The best tests are, as a rule, those which require scientific examination of common things other than laboratory specimens. One of the tests (which we will call type A) may usefully involve the carrying out of printed instructions; marks depending much on accuracy of result. The other (type B) may be a trial of resourcefulness in experiment; originality of idea and its general correctness being rewarded, while it is recognised that accuracy of result would be somewhat providential in the circumstances.

The Committee is of opinion that teachers should take part in the setting of laboratory tests. It is not desirable to prescribe any plan for universal adoption, but the following is a possible method. Let four questions be set, numbers 1 (type A) and 3 (type B) by the external examiners, numbers 2 (A) and 4 (B) by the teacher, candidates being at liberty to select either 1 and 4 or 2 and 3. If time and laboratory arrangements permit, it will be useful to add a drawing test—*e g.*, of a biological specimen seen in the field of a microscope—or of apparatus arranged for a physical or chemical experiment.

The use of squared paper should be restricted to purposes for which ordinary writing-paper is insufficient. The use of logarithms should be encouraged. In the more advanced examinations the use of books of reference (not notes) may be permitted; this is scarcely to be recommended for examinations below the level of the Second (Higher) School certificate. When the examination will determine the award of a scholarship, or of a certificate affecting the career of a candidate, the examiner should inspect the candidate's note-books and take into consideration the order of merit in which the teacher of the subject has placed the candidates.

It is hoped that, with precautions such as are suggested above, laboratory tests may afford trustworthy evidence which may be used in conjunction with the written examination to determine the abilities and training of the candidates. At the same time such tests will afford valuable opportunities for associating examiner and teacher, and prevent neglect of laboratory work, or its relegation to an inferior position, as has often occurred in the past in cases where written examinations only have been employed.

IX. Typical Science Courses.

Experience has shown that the most useful function a committee on science teaching can perform is to present schemes of work which can be carried out practically. Examples of the influence of such schemes are afforded by the Reports on Teaching Chemistry presented by Committees at Newcastle-upon-Tyne in 1889 and Leeds 1890, and the Report on the Teaching of Elementary Mathematics presented at the Belfast meeting in 1902. The effects of these Reports have been so beneficial and far-reaching that the present Committee is hopeful that the specimen courses here submitted will have a like influence upon science teaching. It is not suggested that the schemes should be prescribed for any particular schools, but rather that they should be considered as examples of courses which have been proved successful.

I. SCIENCE FOR ALL IN A PUBLIC SCHOOL.

By ARCHER VASSALL, Harrow School.

I. A scheme of work in science at a Public School must allow for the special features which obtain normally there as compared with the conditions at many other secondary schools. The peculiar features which affect the science scheme are that (1) practically all the boys come from a particular class of preparatory school; (2) their age at entrance is just under fourteen; (3) they may join the school over a wide range of Forms; (4) they may remain till they are eighteen and a-half years old.

The terminology of Forms varies so much at different schools that it is convenient to regard the school as divided into four blocks, A B C D—A containing the Upper School, B and C the Middle School, and D the lowest Forms. The abler boys are expected to join the school in B and Upper C, the less able in Lower C, and the worst (intellectually) in D.

Roughly, the majority of Block A corresponds to a post-matriculation stage and the rest to a pre-matriculation stage The latter are entirely concerned with their general education, but the former in the lower Forms of Block A are beginning a semi specialisation in groups of subjects which will culminate at the top in completely specialised or even vocationalised work.

'Science for All' constitutes an essential part of general education; therefore it must be compulsory where it will embrace the greatest number of boys for a sufficient portion of their general time-table This is best achieved by making it compulsory in Block B and Upper C, equally for Classical and Modern sides if such exist in this part of the school. There is no difficulty about this or the other suggestions which are put forward when the ultimate school authority is sympathetic; they are *possible* at any Public School, but they may not be desired by those in power.

Compulsory science in B and Upper C, however, may not secure the ablest boys for a sufficient length of time, as they may pass into A very quickly. This can be corrected by making science compulsory for a minimum number of *terms*—*i.e.*, a boy passing quickly into A must continue science in A until he has completed the science comprised in the general education.

A. Science should be alternative with other subjects in A for such boys as have completed the compulsory 'Science for All' The boys taking science then will have completed the general courses and will begin the systematic study of science with a view to their after-life profession, reading further science on leaving school, &c. They should give not less than eight hours per week to the subject. Classical and Modern side boys should come together and be re-graded in divisions according to their progress and ability in the subject

The alternative subjects for those boys in A who do not take science must be decided by each school for itself There is obviously one main consideration for a boy of scientific aptitude in deciding whether he will take science or the alternative subjects in A. The other subjects *can* be studied by securing a competent teacher, whether in the holidays or in 'out-of-school' hours in term time. But for science a laboratory is essential, and term time at school will be for many boys their one and only opportunity of doing experimental work in a laboratory At one school where this scheme is in force the alternative subjects for the Classical side in A are French and Classical Verse Composition, whilst for the Modern side they are Latin and Extra History.

The boys in A who do not join the science divisions proper can profitably devote some two hours per week to certain scientific principles as an extension of the 'Science for All' which they have done—*e.g.*, history of science progress, agriculture, geology, &c.

Thus the science in A comprises four sets of boys: (1) Science specialists, (2) those giving eight hours per week to science, (3) those giving two hours per week, (4) those completing 'Science for All.'

B and Upper C.—Science is compulsory for a minimum of five hours in school and one hour's preparation per week for six terms—or its equivalent. The boys should be re-graded for science as in A.

Lower C.—The work consists of object courses of a heuristic nature. These boys need not be re-graded.

D. Natural knowledge and practical work in connexion with mathematics co-ordinated with similar work begun at the preparatory school.

II. *Aims of the Compulsory Science.*

1. Training in scientific method by experimental investigation.
2. Conveying useful information and fixing it by practical exercises.
3. Arousing interest and discovering special aptitude for science.
4. Emphasising the human aspect of the work as much as possible by using daily-life phenomena, practical applications, machines, agricultural processes, &c., as the material wherever possible.

III. *Freedom of the Teacher.*

Within the above principles complete freedom should be left to the teacher in accordance with his interests and opportunities. He should arrange his own courses, syllabuses, &c., decide what material he employs for any of the above objects, and whether he achieves them by 'object,' 'subject,' 'problem,' or any other method.

IV. The 'Science for All' should be carefully co-ordinated with the other work of the school—more especially the mathematics and geography. Where essential work is not adequately dealt with under these subjects, it must be included in the science course—*e. g.*, elementary mechanics with sufficient practical work, and elementary physiography.

V. Every school should be free to create its own syllabuses and treatment of them, provided the two vital essentials of conducting experimental investigations and emphasising the human aspects of the subject are attained.

Some examples are here given—they are not prescribed or even recommended but simply selected as illustrating the above points.

A. A course taken by boys in Lower C as an introduction to the experimental method.

Experimental Investigation of Chalk.

Experiments to be done by the boys themselves in the laboratory, with occasional lecture demonstrations and discussions to connect up the results arrived at and for those experiments which are unsuitable for the boys to perform at this stage, such as the electrolysis of fused calcium chloride.

Examine chalk, notice its physical properties, and find out if it is soluble in water. Is it an element or a compound? Effect of heat on it. Does it change in weight when heated?

Collect the gas given off on heating chalk in a silica tube. Study the properties of this gas. The same gas is given off when chalk is treated with acids, and this is a more convenient way of making it.

The gas will not support the combustion of most substances. Try if burning phosphorus and magnesium will continue to burn the gas. The latter continues to burn with a spluttering noise. The residue left is composed of a white substance, similar to the ash left when magnesium burns in air or oxygen and black specks.

This white ash is a compound of magnesium and oxygen, therefore the gas contains oxygen. Separate the black specks from the white ash by treating the whole ash with hydrochloric acid; wash with water—collect and dry. The black stuff looks like charcoal. It burns in air or oxygen and forms a gas which turns lime-water milky. But carbon burns in air and forms the same gas. Therefore the black specks are carbon, and the gas from the chalk is composed of carbon and oxygen. We call it carbon dioxide or carbonic acid gas.

Return to the residue left when all the gas has been driven off by heating chalk. It is a white substance. Try the action of water on it. Is it soluble in water? Shake it up with water filter, and blow air from the lungs into the clear filtrate. It turns milky. It is lime-water. Excursions here into the slaking of quicklime, and the uses of slaked lime. Demonstration of the preparation of calcium by the electrolysis of fused calcium chloride.

Burn some of the calcium obtained in oxygen and prove that the white substance obtained is identical with quicklime. Therefore quicklime is a compound of calcium and oxygen.

Chalk . . { Gas . . . . . { Carbon / Oxygen
Quicklime . . . . { Calcium / Oxygen

Many objects are suitable for such courses—e.g., *the candle, common salt, hæmatite, &c.*

B. Some teachers prefer to take the work as a problem rather than as subjects. Much of the conventional 'subject' matter naturally arises when this treatment is adopted, and each suitable occasion for experimental inquiries germane to the general inquiry is taken. Moreover, the manipulation and laboratory practice arise as a necessity in the course of the investigation and the various subjects are correlated. Of course, both these ends should be attained whatever the method employed. But in 'subjects' there is a strong temptation to take elementary practice as an end in itself; something to be 'got through.' There are few things more unattractive and dehumanised than such courses, which seem absolutely pointless to the boy. For example, he does not feel the need of accurate weighing, determination of density, specific gravity, &c., and he has no mental picture of any problem on which such matters bear. When they are not done as 'ends in themselves,' but taken as they occur as necessary machinery in the course of an investigation, their apparent pointlessness disappears, and the boy is at least reconciled to them as necessary evils.

In 'subject' courses also so much time is often taken over the laws and their establishment that the applications and machines are never reached; of twelve elementary text-books on 'Heat' taken at random from a shelf, not one mentions the existence of such a machine as the steam-engine.

This result is avoided if the course starts from a machine and is then left to create itself under the direction of the teacher. Suggestion and discussion at the end of a period as to the next thing to 'go for' result in some questions being simply answered, some discarded by consent for various reasons, whilst others are dealt with experimentally by the boys themselves or by demonstration lectures.

Thus the properties of water can be investigated as so many geological, biological, chemical, and physical 'subjects.' Or they can be correlated into one problem course beginning, for instance, with the hydraulic press and then developed as above. Starting from the press, there immediately arise transmission of pressure, fluids and solids, principles of machines, work and force. Various pumps follow, leading directly to air pressure and experimental investigation into it by the boys themselves. Barometers, pressure on divers, dams, lock-gates, together with deep-sea sounding, chalk, sand, clay, and Artesian wells provide the humanising element. Flotation follows with Archimedes' Principle, buoyancy, &c; where there is a school bathing-place it is best worked out there practically with a raft, a raft of casks, and a weighing machine.

Sea-water's buoyancy leads on to its properties, solution of solids, crystallisation and solution—all arising out of the problem, instead of as pointless and seemingly useless preliminaries necessary for some future unknown work of which the boy is ignorant. Solution of air and its influence on fish, &c., lead to Harrogate water, soda-water, sparkling wines, bread or sugar in a lemon squash.

Carbon dioxide suggests its preparation and properties, respiration, breathing, burning, and decay, and so nitrates and manures on the one hand, and limestone, with limestone caverns, stalactites, hard and soft water, water supply, good and bad water on the other. Organic matter in water and its purification can extend as far into typhoid, diphtheria, bacteria, infection, inoculation, vaccination, milk, &c., as the teacher desires.

The compounds and mixtures reached as above lead to inquiries as to the nature of water and suitable chemical investigations, which are followed naturally by more physical considerations—its change of volume on becoming

steam, pressure in boilers, and the steam-engine with B.H.P., ending in the boys determining their own B.H.P. The source of the energy being heat, the rate at which the gas-burners supply heat can be determined, and so the unit of heat is reached, together with the mechanical equivalent (Callender's Apparatus) and the thermal efficiency of the engine. The effect of pressure on the boiling-point introduces evaporation and boiling, together with rain, dew, and hydrometers.

They are now ready for another change of state, so formation of ice, bursting water-pipes, disintegration of soil, icebergs, deep sea and life in the abyss, provide one line, whilst latent-heat cooling by evaporation, freezing machines, and liquefaction of gases afford another.

C. The majority of schools, however, find the 'subject' method more convenient. Except perhaps in the matter of correlation, the disadvantages mentioned above can be avoided if it is realised that the introduction of the human element and experimental investigations should be the main features. Since this is the only science work many of these boys will get, the object is not to clear the way for a future study of science, but to provide self-contained work complete in itself. This means a broad landscape as the general picture, with detailed work in particular fields to provide the experimental inquiries. The geographical work of the school may provide it; but, if not, an introductory course should present a broad view of the Universe, the position of the earth in it, the changes which the earth undergoes by volcanic and other action, as well as some of the usual physical and chemical properties of the atmosphere.

Forms of life on the earth can be begun here, but not taken very far, as much of this biological work is helped by some physical and chemical understanding. It is a disadvantage where the 'subject' method is employed to get the biological work ahead of this ancillary knowledge. The most satisfactory results are attained by retaining a portion of the time each week for biological work throughout the six terms Different stages in it are then reached *pari passu* with the progress in physics and chemistry. The final stages are attacked with the more adult and trained grip, following four or five terms' work at science. At the least the biological work should comprise the life of a plant, simple agriculture, crops, fixation of nitrogen, manures; an excellent experimental investigation into the overthrow of the humus theory by Ingenhauss can be carried out, together with other practical work. In the botanical section there should come an introduction to the work of Darwin, Mendel, Pasteur, and others. In fact, this acquaintance with the foremost men in the history of scientific knowledge should be included in each subject. Material full of human interest is provided by coal, fungi, yeast and its uses, bacteria, ferments and fermentation, with many examples, pasteurisation, tinned and bottled goods, ptomaines, infection, refrigeration, and so on. University framers of a syllabus for the average boy and external examiners revel in the action of sulphuric acid on copper and similar phenomena as an educational medium; the vast majority of candidates pass through life without ever meeting such an action outside the academic atmosphere of the class-room, any more than they meet the Greek particles. Bread, cheese, and beer are apparently beneath the consideration of academic science specialists. None the less, fermentation, moulds, bacteria in hay infusions, &c , are unequalled as a material for experimental investigation and instilling a true scientific habit.

In the same way in zoology, the work of Jenner, Lister, Metchnikoff, and other great discoverers should be brought out in connexion with simple hygiene. This course should also include reference to microscopic animal life and its effect on the earth's surface (*e g.*, chalk and flint), respiration, blood circulation, malaria, sleeping sickness, or to useful natural products within the Empire, and some simple agriculture.

The other subject courses are more familiar. It is only necessary to direct attention to the special human features of the work and to give one or two examples of experimental investigations. Thus, the hydrostatics can be based on a machine and involve consideration of other familiar applications in addition to those already mentioned in *A*, such as pulleys, jacks, balloons, siphons, and turbines. If the mathematical work of the school does not comprise them, then falling bodies, Newton, &c , Galileo's disproof of Aristotle should be

taken here. It is important that typical instances of the overthrow of a generally accepted theory, as well as the work of some of the great pioneers, should be familiar. The elementary chemistry affords excellent material for this, as well as for experimental investigation. For example, in the consideration of combustion and the phlogistic theory, let the boys perform the six following experiments :

1. Does magnesium really lose weight when burnt? Gain in weight may be due to crucible, therefore
2. Does crucible gain in weight? Perhaps the air is concerned in the increase, therefore
3. Burn phosphorus in bell-jar over water. One-fifth of air active; rest, inactive. What has become of the phosphorus and the active constituent?
4. Test water with litmus. Dissolve some phosphorus pentoxide in water and add litmus.
5. Burn phosphorus in a weighed round-bottomed flask with stopper and valve. (*a*) Heat has no weight, (*b*) conservation of mass, (*c*) gain in weight on opening valve shows that air has been used.
6. Burn candle and catch products; determine gain in weight.
7. Demonstration with oxygen and nitrogen to show properties of active and inactive constituents.
8. Lecture on history and overthrow of phlogistic theory.

The study of the atmosphere and the chemistry of daily life should form the basis of the whole chemical course in this general science. In connexion with flame, the simpler hydrocarbons and their combustion should be dealt with, and the artificial distinction of 'organic' chemistry should not preclude the average boy from dealing with the petroleum industry, coal-tar products, benzene, phenol, toluene, aniline dyes and mordants, sugar, alcohol and its uses, oils, fats, soaps and glycerine, nitroglycerine, and other explosives.

The subject of heat probably provides the ideal experimental investigation in heat quantity—*e.g* :

1 Heat 500 grammes and 1,000 grammes of water over a steady flame; plot graph of time and temperature for each
2. Mix 500 grammes of hot water with 500 grammes of cold water.
3. Mix 500 grammes of hot water with 1,000 grammes of cold water.
4. Mix 1,000 grammes of various cold metals with 500 grammes of hot water.
5 Mix 100 grammes of hot water with 200 grammes of cold mercury.
6 Make a cooling curve for, say, phenol.
7. Heat ice steadily until the water formed boils—make a temperature-time curve.
8. More accurate determination of specific heat and latent heat.

The rest of the work should be associated with practical applications as much as possible. Out of the small total time available for science, it is an unjustifiable waste to devote part to filling and sealing thermometers, coefficients of expansion, &c., beloved of the text-book and the examiner. All of this type of work is very necessary for those who are going to continue the study of science, but perfectly useless for that majority which will not do so. Men of science are prepared to use a watch without having made one. Why should not the 'general science' pupil use a thermometer without first making it? With the saving of time thus effected, there is plenty available for work which really interests them, such as heat values of fuels, heat and work, work and power, horse-power, B H.P. of an engine, steam-engine, energy losses, I.H.P. efficiency, and so on.

In the Light course the simplest treatment of rectilinear propagations, candle-power, intensity, photometers, plane mirrors, laws of reflection and refraction, images, internal reflection, and dispersions will allow the pupil to deal with what he 'wants to know about'—viz., searchlights, prisms, lenses, the eye, spectacles, magnifying glasses, telescopes, microscopes, rainbows, the spectrum, and fluorescence.

In the subject of sound, waves and frequency are practically all the average boy requires in addition to the ear, Doppler effect, siren, gramophones, and Claxon horn. In all these he is interested.

After magnetism, electro-magnets, and telegraphs, the boy reaches his electrical paradise. The effects of a current and its measurements by any of these effects, B.O.T. unit of current, ammeters, voltmeters, microphone, telephone, dynamo, magnets, motor, *X*-rays, wireless telegraphy, electrical energy and power, Watt lamps, wiring of houses—these abolish all need of punishment for lack of industry in trying to understand physical laws; indeed, they help that understanding.

In this scheme emphasis has been laid especially on those aspects of the work which make the subject alive and personal; this treatment does not exclude a grasp of those elementary laws with which an educated man should be familiar. It only insists on associating such laws with their practical applications. This generalised science scheme for those boys who are not pursuing the subject any further has been evolved during ten years at a school In arriving at its present stage, which is far from perfect, some golden rules have been applied :

1. Make sure of the landscape; do not start the boy on a niggling bit of formal science.

2. Exclude rigorously any work, practical or otherwise, which is not worth doing for itself.

3. Some work is worth doing because it is valuable educationally—*e.g.*, experimental investigations. Other work is worth doing not only because it has educational value; it also concerns itself with matters which occur in the average life of an educated citizen who is not actively concerned with a scientific career.

4. Some work is only contributory to the further study of science beyond what is necessary for a general education This work is an unjustifiable waste of time for those boys who will never study science further.

5. Be suspicious of anything which occurs in any existing examination syllabus It is usually there for the convenience of the examiner, or because it is contributory to the formal study of science

6. Consider the conditions of the school and the personal equation of the teachers rather than examinations in drawing up a syllabus for the average boy.

His need is to understand (1) the multifarious ways in which the results of scientific investigation affect his daily life, (2) the experimental methods by which the natural phenomena of daily life are being investigated, (3) whilst knowing the value of an expert, none the less to be confident and resourceful within his own limitations

II. SCIENCE IN A PUBLIC SCHOOL.

By F. W. Sanderson, Headmaster, Oundle School.

The course here outlined indicates the kind of work which may be done in schools by boys below the age at which specialising begins. This age depends upon the type of school and the leaving age, and varies with the tastes and capacities of individual boys. In a Public School where the leaving age is nineteen the specialising age is about seventeen years The course presented applies to boys below the age of seventeen—*i.e.*, to boys of the Preparatory School age, and to the lower and middle forms of the Public School. The methods proposed are based on the belief that the early stages of science teaching may be taken through applied science. Science, like history, may with advantage be read backwards. Pure science and pure mathematics may be taught in parallel with applied science, as the grammar of the science, but it will be found for the most part that the amount of pure science that the average boy can understand will be included in the applied work.

A claim is therefore made for the inclusion of applied science within the general science curriculum of a school. There is some reason for this now, when so many of the applications of science come within the daily life of the people. It is a well-known saying that a motor-bicycle has taught a boy more of true dynamics than he has ever learnt from the Laws of Motion. However this may be, it is obviously a wise educational principle to base teaching on all that is now common knowledge.

It must be confessed that much of the pure science which comes within an elementary course is better left to a later age. Experiments on Boyle's law, and the other law of gases; the discussion of the laws of motion; complex questions on specific heats, should be reserved for the specialising age. This is following in the wake of the reforms in the teaching of geometry. Applied science actually simplifies the problems. The steam-engine is a good example, as is shown in many parts of Perry's 'Steam Engine' Here is material for an elementary course on heat, and a source for easy direct calculations of practical importance. Moreover, the method is informative, and gives a working knowledge of the engine which will stand in good stead.

A further claim is made This form of science teaching is stimulating and arresting, and gives the boy plenty to do and much to think about It arouses interest, develops intelligence, and promotes catholicity of taste. Teachers will find that the application of science, and all that may be called the romance of science, are alive with possibilities for the education of the young in everything connoted under the words Culture, the Humanities, and Art. Much depends upon the faith of the teacher, but no one can study the life and works of a great discoverer without finding himself within a realm of art. There is abundance of evidence for this in the works of those masters of science who to their creative faculties have added the literary art. But the science art remains even without its literary expression, and men and women may learn to appreciate the art as they appreciate music and painting, though they have no skill as musicians or painters.

Science in a General School Course.

There are many considerations why the science in a general course, especially for those boys who will not specialise in science, should not be restricted to the elementary syllabuses. Many of the syllabuses and elementary text-books dwell upon principles which now form the grammar of science, whilst the larger developments of modern days are not touched upon. 'Science for all' does not mean this kind of science—grammar without the books. Except in the hands of a good teacher such work may have little of inspiration, and in a general course inspiration is everything. A claim is therefore made for a kind of science teaching which at first sight may be thought specialising and technical. In sympathetic hands specialising need not be feared.

The branches of science which may be included in a general course for schools are indicated below. These can be organised according to the ages of the boys. The methods of teaching which they imply will be especially valuable for young boys of the Preparatory School age. In his early years the small boy can wander through these fields of knowledge. He can learn to handle tools in an engineering shop; he can work with motors and other machines; he can open his eyes in the romance of physics, chemistry, and biology; and he can practise weighing and measuring in his class-room. The older boys, from fourteen to seventeen, will go over the same ground, but on a higher plane, and will in the later stages acquire a working knowledge of applied science.

The following are the subjects :—(1) Workshops; (2) 'Romance of Science,' including Astronomy; (3) Experiments on the Use of Machines; (4) Biology; (5) Chemistry; (6) Physical Measurements, and, at a later stage, (7) Applied and Pure Science.

1. *Workshop Practice.*—Belief in the value of a continuous workshop training must be the excuse for the space here given to the organisation of shops. In the first place, the shops must be on a scale which will employ a class of twenty-five boys effectively. They must form a small manufactory, and have an engineering machine shop, a carpenter's or patternmaker's shop, a smithy and foundry of some size. These conditions are essential for true work. Smaller shops tend to be of an amateur character, and only a few boys can get the best out of them. Workshops to be effective must be on a large scale. It is seriously necessary that such shops should be established, not for Public Schools only, but for Secondary and Elementary Schools, nor should expense stand in the way. Such shops could be made self-supporting. Schools should be able to turn out good craftsmen as leaders or workers in the industrial life of the country, and the training can be given in schools better than in works. In works, unfortunately, much of what is good is spoilt by the spirit which competition and the conflict of capital and labour engender. Boys sent out from the schools can not only be made good craftsmen, but they can also be inspired with ambition to rise to high standards of skill, and to have a deep insight into the significance of their work Enthusiasts believe that vocational teaching is capable of giving the highest training for life.

There are two methods of working shops Under one system boys make things for themselves, and may follow some hobby. This is the individualistic principle, and is the only one possible in small shops. The other system is to organise the shops on manufacturing or co-operative lines The war has given the opportunity of doing this more effectively than before, and the possibility for true education of this kind of working has been discovered. Co-operative work involves repetition work, and there are many excellences in this repetition In shops of fair size a variety of work can be contracted for, and this work will fill several types of machines, such as the lathe, drilling, planing, milling, slotting, grinding machines A contract of the kind now being given for munition work provides work both rough and fine, so that all boys can be occupied; and no boy need be kept too long at the same class of work This work gives opportunities for boys who do not distinguish themselves in other parts of the school; and they can therefore take a higher place among their fellows, as well as gain self-respect and reliance.

The following are some influences of workshop training :—

(*a*) One chief characteristic is the attitude of mind which is fostered by the shops. This is all towards attention and creativeness. Workshops are places where things are made, and the objective is to make something. A boy goes there to do, and not to learn. His attention is fixed on his work Determination to do the work in front of him and to acquire skill and practice is the chief aim. This spirit towards work is transferred to the class-room and changes the boy's view-point there. The influence is infectious, and keeps alive the spirit of creativeness.

(*b*) Another effect of the workshops is to develop craftsmanship. A boy acquires the virtues of a first-class workman He becomes deft with his tools,

learns to be patient, careful, accurate, inventive. He acquires the power of construction and of initiative.

(c) In a workshop a boy lives in the atmosphere of mechanics and physics, and is continually either making or reading engineering drawings. He has the chance to acquire a mechanical sense, and to learn by intuition the significance of force, speed, acceleration, rotation He has many opportunities of using measuring instruments, and of making physical measurements. He learns machine drawing, and mechanical drawing is becoming daily of more interest and importance—even to the non-specialist. A drawing-office can be made the very heart of mathematical teaching, as it is the centre of engineering works. Very young boys can be effectively employed in a drawing-office, and they learn in a practical way many of the principles of geometry.

(d) Incidentally, boys are given a vocational teaching. There are many professions where a knowledge of technical work is essential A craftsman's knowledge is of value to barristers, solicitors, clergymen, social workers, landowners, and all whose aim in life is 'to do'

2 *Romance of Science*.—It is about fifty years ago since science was introduced into the Public Schools. This was done largely by the influence of Huxley and Tyndall, and the form it first took was that of demonstration lectures. The object in view was to interest the sons of the governing classes in the astonishing discoveries that were being made, and to inspire them with the love of science. Many a boy must have found inspiration in these lectures, but for the great mass of boys the results on the whole were not successful, and the chief reason for this is that boys like to do things for themselves rather than watch other people doing them They want a share in the doing, and to investigate for themselves Some years later a change came, and the lecture theatre gave place to the laboratory. Boys were set to work for themselves. The houristic method was emphasised, and courses were arranged in physical measurements, chemical experiments, and nature study This method is now well established in schools, and forms the basis of most schemes of study and syllabuses for examinations It would seem, however, that this necessary laboratory work has driven the more inspiring experiments into the background. At the moment it is important to return to the lecture theatre, to come into contact again with striking experiments, the history and development of discoveries, the lives of the great; in fact, to the romance of science. It is the romance of science which contains within itself the great inspiration, and the first duty of the teacher is to inspire boys with an awakening love of the natural world and bring them to the verge of knowledge where lies the mystery.

There are difficulties in the way of holding the balance between the two methods Romance of science opens out ideals, whilst physical measurement trains for exact work in investigation Both aims are necessary. The regular laboratory work should therefore go on *pari passu* with any system of demonstration experiments.

A suggestion may be made for the 'Romance of Science' experiments. Groups of Forms, Senior, Junior, or Preparatory, may be organised to prepare an exhibition of experiments and demonstrations. The masters apportion the work to groups of boys, and these groups prepare the exhibits and experiments. They make the diagrams and sketches required, write up explanatory and historical matter, work the experiments, and explain the exhibits. Such exhibitions can be left in working order for the instruction of the science classes Mechanics, physics, chemistry, biology, provide a host of such exhibits. Junior Forms may set up a series of well-known historical experiments; Senior boys may be encouraged to illustrate modern advances. There are many books amongst the classics in science which will form the basis of such an exhibition. The 'Heat and Sound' of Tyndall; Ball's 'Experimental Mechanics,' or Perry's 'Steam Engine'; Thompson's 'Light: Visible and Invisible'; Wright on 'Projection,' Boys's 'Soap Bubbles' or Perry's 'Tops'; Worthington's 'Splash of a Drop'; Lodge's 'Pioneers of Science.' There are fascinating experiments on the discharge through rarefied gases, with radium and *X*-rays, vibrating springs, liquid air, rotating bodies; many chemical experiments and biological exhibits. Lectures or exhibits can be prepared to illustrate the life and works of a great investigator—men like Faraday, Dalton, Darwin, Pasteur.

Original papers can in this way be brought before the school. If the school possesses plenty of space, many exhibits can be on view permanently.

A valuable addition to a school, or combination of schools, is a museum of history, where developments in art and science may be illustrated. In the museum there should be a gallery of the world's workers and pioneers, that something may be learnt of their lives and what they looked like. Here may be shown such things as the genealogical tree of the aeroplane, the uprising of biology, the influence of science in the social life, and so on.

3. *Experiments Based on the Use of Machinery.*—The teacher of science has now at his command a large number of machines, tools, and measuring instruments. The use of these for their normal purpose, or the testing of them, affords a striking method of introducing young boys to the principles of science, and gives good exercise in mathematics. Experiments can be arranged for young boys of the Preparatory or Elementary School age with engines, dynamos, measuring instruments, testing machines, &c., to infuse the spirit of science and lay a foundation of information upon which to build at a later stage. A few of the experiments can be given as examples: (1) To find the horse-power and efficiency of a motor; (2) to run a test of a gas-engine—B H P, consumption of gas, I H.P., working out of cards, efficiency; (3) steam-engine with varying loads and cut-offs; (4) experiments with voltmeters and ammeters; (5) testing strength of material. Very young boys can with advantage be brought to this kind of work, but the teacher must be content to sow in faith. He must sow the seed and wait for the fruit

The calculations required in experiments of this kind will suggest their extension into the mathematical class-room. The mathematical class-room may be used as an office, for it is a useful thing in all parts of the school, especially the lower half, to give practice in working out a series of continuous calculations. Data may be given drawn from an engine test, from the working of a crank shaft, from agricultural operations, trench fire, artillery maps, food rations, measuring velocity of wind; and the class may be set to work out the calculations required. It is useful for the master to talk round the problem for a few minutes before starting work. If many calculations are required, the work can be divided up amongst the boys. The results can be stated not as an answer, but in the form of a written report. This form of teaching considerably extends the range of mathematics which may be covered in the early years, and boys of fourteen or fifteen may be introduced through it to the study of the calculus and co-ordinate geometry.

4. *Biology.*—The importance of biology in a scheme of general education cannot be overstated. It is the science which very closely touches the life of the nation, and its economic value is found in all directions. Every branch of knowledge in the years to come will be influenced by the study of biology, and the humane studies in history, economics, sociology will be re-written under the same.

Biology should be an integral part of school studies, and take its place by the side of languages and mathematics. In the early years it should be taught to all, and later to a group of specialists.

The following brief notes on equipment may be useful:—

The neighbourhood can provide material for observation and study, but in addition to this there are needed for experiment and observation some or all of the following: (*a*) Biological or botanical garden; if possible, a small experimental farm. The gardens may contain natural-order beds, herbaceous border, Alpine garden, pond, marsh, seashore, climbing plants, &c. (*b*) Experimental plots. (*c*) Laboratory and museum; in these, aquaria, breeding cages for life-history of insects, terraria, vivaria, insect incubators, &c.; microscopes and lenses, &c.

5. *Chemistry.*—Here again the work should be almost entirely experimental, enlarged by demonstration. Much help can be given by the boys who are specialising in chemistry. Much of the work should be of a quantitative character, and this aspect should develop side by side with the qualitative nature of the same. Many points of contact with the order of Nature in everyday life will occur, and the utmost should be made of these in correlation with biology and physics. None but exact scientific types of apparatus should

be used where there exists no valid reason to the contrary. As an example, a boy should, after his discovery of the composition of the atmosphere, make an exact determination of the properties of oxygen by Hempel's or some similar apparatus. A muffle furnace should be in the laboratory for use in metallurgical work.

6 *Applied Science* —It is strongly recommended as an alternative course in the later years of the general school teaching—*i. e.*, from the ages of 15½ to 17 years—that the ordinary mechanics and physics should be replaced by a careful experimental study of applied mechanics, heat, and electricity. In the reorganisation of examinations it is to be hoped that an examination on these subjects will be included in the leaving certificate, and wherever possible a practical examination be held on the experiments which belong to a well-equipped engineering laboratory A syllabus based on these lines is now adopted by the Admiralty for two of the papers of the Direct Entry examination.

III. SCHEME OF SCIENCE WORK FOR AN URBAN SECONDARY SCHOOL FOR BOYS.

By T. Percy Nunn.[1]

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The following scheme is drawn up for a four years' course (ages twelve to sixteen) in an urban Secondary School for boys. The work of each year is divided into two sections—'biological' and 'physical'. The proportion of time assigned to biology decreases from more than a half in the first year to a fifth or less in the last year, with a corresponding increase in the relative importance of the physical section. It is assumed that about five hours a week are assigned to science teaching in each year, and the great bulk of the matter here set down is to be dealt with in this time. It may, however, be taken for granted that in a well-organised school there will be close co-ordination between the teaching of science and the teaching of mathematics and geography. It has seemed advisable, therefore, to include in the science syllabus the corresponding programme of work in mechanics and geology, though much of the former, and possibly the whole of the latter, may and should be taught in lessons assigned to the teachers of mathematics and geography as integral parts of their work.

In a condensed outline it is not possible to give a full programme of the practical work to be done by the boys, or to distinguish those topics that are more suitable for demonstration. It is to be understood that the course is intended to throw into clear relief the fundamental ideas and results of science, and to give the pupil a real, if rudimentary, acquaintance with the true character of scientific inquiry. To attain these ends the work will often be 'heuristic' in character and as often take the form of lecture-discussions between teacher and class, preceded, accompanied, and followed by experimental work. Occasional practical exercises of the 'drill' type will be necessary to give the pupil a sound grasp of a principle or a method, but one of the presuppositions underlying the scheme is that technical exercises of this kind divorced from the development of a definite scientific argument have comparatively little value and have received too much emphasis in the past.

First Year

[In Section I. the work is arranged in accordance with the seasonal sequence. In Section II. the work in astronomy should also run throughout the year side by side with the other subjects.]

I. *Biological Section.*

A *Autumn Term.*

1. Life-history and habits of wasp and humble-bee.
2. Study of a few typical flowers; plan of a flower.
3. Change of flower to fruit. Collection and examination of fruits; classification; methods of seed dispersal.
4. Winter sleep of seeds and other plant forms. The planting of sleeping bulbs. Winter sleep of animals.

B. *Spring Term.*

1. Trees in winter: recognition by (i) branching; (ii) bark, (iii) buds. Examination of buds.
2. Seed-sowing. The forms of familiar seeds. How the farmer and the gardener sow.
3. Seeds grown for study in lamp chimneys, gas jars or test tubes; diagrams of growth. Discovery (i) that water is needed for germination, (ii) that light is needed for healthy growth, and (iii) that seedlings grown apart from soil die when the cotyledons are exhausted.

[1] With the assistance (for the Biological Sections) of Miss C. von Wyss.

4. Subjects to be taken while seed-growing is in progress :—

(*a*) Study of structure of seed and bulb. Were the shoots originally packed within?

(*b*) Comparison of seed with egg; study of hen's egg. Parental care of birds

(*c*) Frog's eggs; weekly record of changes Habits of frogs and newts.

C. *Summer Term.*

Studies of plants and animals to be pursued concurrently

1 Plant Life. Typical spring and summer flowers; need for classification; natural orders; how to use a 'Flora'

Insect visitors to flowers. Transference of pollen; significance of pollination; fertilisation and cross-fertilisation.

2 Animal life **in the pond.**

(*a*) Record of growth and metamorphosis of tadpoles.

(*b*) Life-history and habits of : Water-beetle, water-boatman, water-scorpion, caddis-fly, dragon-fly, gnat, water-spider, water-snail.

(*c*) Common pond weeds

(*d*) Study of green water-plants in aquaria Evolution of gas noted for future investigation.

NOTE.—It is desirable that the formal work should be supplemented by (*a*) rambles and excursions to study plants and animals in their natural setting; (*b*) holiday work, including collection of specimens, records of life-phases of some animal or plant, drawings and paintings; (*c*) gardening. Common plots may be worked in school hours for demonstrations and experiments; individual plots in leisure hours

II. *Physical Section.*

A. *Astronomy*

Simple observations and graphic records (i) to establish the (apparent) diurnal rotation of sun and stars about an axis directed (nearly) to the Pole Star, and (ii) to explain the principle of civil time-measurement. The observations are to be made, as opportunity offers, partly in and partly out of school hours. The graphic records will be drawn and discussed from time to time in class. The data for the several records may be accumulated concurrently.

1 Direct observation that the sun appears to move Closer study by means of the shadow of an upright rod gives data for graphic records showing (*a*) the direction of the shadow at a series of fixed times of the day in different months, (*b*) the lengths of the shadow at these times. The latter brings out the facts (i) that the shortest shadow has a fixed direction (south to north), and (ii) that the shadow is shortest (*i.e.*, the sun highest) at varying times shortly before or after 12 o'clock (or 1 P.M. 'summer time')

Discussion of results (supplemented by the table of 'equation of time' in 'Whitaker's Almanack') leads to the notions of 'mean noon' and the 'mean solar time' kept by an ordinary clock. The difference between 'local mean time' and 'Greenwich mean time.' Longitude lines as lines of identical local mean time. The international system of standard time-zones, and time-signals by wireless telegraphy. Determination of longitude at sea, &c.

2 Graphic records of the sun's track across the sky on typical days at or near midwinter, the equinoxes, and midsummer. Discussion of these elucidates the varying length of day and night and the correlative phenomena at the antipodes.[1]

[1] The following method works well A number of thin rods (*e.g.*, long knitting-needles) are mounted perpendicularly at equal intervals along the circumference of a circle marked out on a drawing-board Each rod carries a small paper or cardboard slider. The board is fixed horizontally in sunshine. As, from time to time during the day, the shadow of one of the rods falls across the centre of the circle the slider is so adjusted that its shadow covers the centre. The heights thus registered are entered upon a sheet

3. Some conspicuous stars and constellations. A circular chart to be drawn showing the Plough, Cassiopeia, Vega, and Capella, with the Pole Star occupying (nearly) the centre. This, pinned to rotate on a cardboard base, serves to record roughly the positions of the stars at different hours of the night and early morning.

Discussion of the records indicates a uniform diurnal rotation of the starry sky about an axis drawn (nearly) to the Pole Star Specially enterprising pupils determine the approximate inclination of the axis to the horizon.

4 Does the sun appear to move around the same point in the sky as the stars? An affirmative answer obtained by observing the uniform rotation of the shadow of a thin rod, directed towards the stellar pole, upon a cardboard disc fixed at right angles to its length. Use of this (or equivalent) apparatus as a sun-dial.

At the earth's poles the rod (or 'style' of the sun-dial) would be vertical; on the equator it would be horizontal Parallels of latitude are lines of identical inclination of the style. Elucidation by means of a globe

5. The following may be commenced in preparation for discussion in Second Year:

(*a*) Record of the noonday (or 'meridian') altitude of the sun measured in degrees by a simple instrument;

(*b*) Record (by means of the rotating star-chart in § 3) of the position of the circumpolar stars at the same hour (*e.g.*, 9 P M) on different dates.

B. *General Physics*

Under this title are grouped simple exercises preparatory to the formal study of hydrostatics, mechanics, and the 'properties of matter' Much of the work should be taken in close association with the course in mathematics.

1. Density and specific gravity Determination of weights by the balance and of volume by calculation or displacement

2. The mechanism of the balance and the conditions for true weighing. The laws of the lever. The grocer's scales Weighing-machines.

The pressure on the fulcrum of a loaded lever The centre of gravity of a body as a fulcrum, and as the 'centre' of the weights of its parts Experiments, toys, &c., illustrating stable and unstable equilibrium

Simple calculations and laboratory experiments on centre of gravity, &c.

3. Time-measurement. (To be taken in connection with A. 4) Essentials of the mechanism of a simple clock driven by a weight or a spring and controlled by a pendulum (A single-handed clock, like that of Westminster Abbey, is most suitable.)

Isochronism of the pendulum Effects of loading or changing length of pendulum. The 'simple' pendulum; connection between swing-period and length. Experimental determination of simple pendulum equivalent to a given pendulum. The balance-wheel in watches and clocks

Ancient time-measures: the water-clock, the hourglass, &c.

4. Examination of common pieces of mechanism, such as a door-lock, the 'three-speed' gear of a bicycle (There is scope here for individual work, involving written descriptions aided by diagrams, &c.)

5. The mariner's compass; simple investigation of properties of magnets to elucidate its use. Measurement of deviation of magnet from the south-north line established in A 1.

C. *Heat.*

1. The varying warmth and coldness of weather as dependent on the season, direction of wind, &c. The thermometer. how it works; expansion of mercury. Necessity of a standard scale of graduation (compare weights and

of graph-paper whose length is equal to the circumference of the circle, and a smooth curve is drawn through the recording points A well-drawn specimen is pasted on a wooden or cardboard cylinder to be used in the discussion and to serve as a permanent record. The method of 'cylindrical projection' thus taught may usefully be applied in subsequent geography lessons.

measures). Experimental graduation of a thermometer by placing it in hot and cold water together with a thermometer already graduated.

2. Expansion as a phenomenon generally accompanying heating. Rough estimates of expansion of water and of metal rods. Expansion and pressure-increase of heated air. Geographical applications.

3. Examination of the steady heating and cooling of water; discovery of constancy of temperature during boiling and freezing.

Definite melting and boiling points of substances. Freezing of sea-water. Melting-points of alloys, &c. Change of volume on solidification: ice, type-metal, dentist's filling, &c.

4. Maximum and minimum thermometers; construction of temperature-charts. (Records of wind-directions and rainfall should also be kept throughout the year.)

SECOND YEAR.

[Section I. must be taken, as before, in seasonal order. Section II., E., is closely related to it and should be begun in the autumn term.]

I. *Biological Section.*

A. *Autumn Term.*

1. Animal life in the garden. Individual observations, guided by question papers, directions for practical work, reference books, &c., supplemented by class-work. The following are suitable subjects: snail and slug, earthworm, centipede and millipede, earwig, green-fly, lady-bird, hover-fly, lace-wing fly, crane-fly.

2. Soil: general characters of clay, sand, chalk, peat, &c; closer study of local soil; subsoil. Simple experiments to ascertain proportions of water, clay, sand, silt, grit, and organic matter in a sample of soil.

3. The ingredients of soil. Clay: why called 'heavy'; impervious to water and air; comparison of growth of seeds in pure clay and garden soil; experiments on effects of 'liming.' Experiments to test properties of sand and chalk. Leaf-mould and humus: origin and distribution.

4. Biology of soil. Adaptations of animals that inhabit soil. Why the farmer thinks soil itself 'alive'; demonstration of activity by respiration within the soil. Soil bacteria and protozoa needing air, water, and food.

B. *Spring Term.*

Relation of plant life to soil.

1. Soil-water; comparison of retentive power of different soils. Rise of water in soils; capillarity (see II, C, 3). Importance of hoeing and mulching.

2. Local differences in water-supply of soil; effects on plant forms studied *in situ*.

3. Differences in form of leaves of plants from dry and wet localities. Experimental investigation of differences directed to (i) absorption of water by roots, (ii) loss of water by leaves. Hale's experiments. Construction of potometer. Microscopic examination of leaf-epidermis; stomata, water-pores.

Ascent of water in stem; osmosis (see II., C., 4).

4. Mineral substances in soil as food for plants.

(*a*) Soil-water shown by evaporation (II., E., 1) to contain dissolved mineral matter; comparison with transpired water suggests that the matter is retained by the plant. Suggestion confirmed by examination of ash of burnt plant. The more important constituents. Practical preparation of water and sand cultures. Selective absorption by roots.

(*b*) Rotation of crops. The nodules on roots of leguminous plants; fixation of nitrogen by bacteria. Bottomley's researches. 'Symbiotic' relations between green plants and fungi.

C. *Summer Term.*

Studies in plant physiology.

1. Respiration. Germinating seeds found, like human beings, to emit carbon dioxide. Probability (in spite of negative experimental tests) that the

developed plant continues to respire. Reference to behaviour of water-plants (First Year, I., C., 2 (*d*)) leads to discovery that they emit oxygen. Distinction between respiration and assimilation of carbon dioxide. Experimental discovery (i) that both processes occur in plants growing in air, (ii) that oxygen is necessary to plant life, (iii) that breathing proceeds in light and darkness, in cold and warmth.

2. Assimilation of carbon dioxide by plants; importance in general life-economy Plant substances built up mainly of carbon, hydrogen, oxygen, and nitrogen. The leaf the organ of assimilation of carbon; microscopic differences between leaves according as carbon dioxide is supplied or withheld; starch grains, the iodine test. Starch shown to contain carbon. Manufacture of starch Relation of starch to other substances in plants. Experiments on relation of light and darkness, cold and warmth, to assimilation; also of seedling leaves, green leaves, and variegated leaves.

3 Assimilation of carbon dioxide as feeding. Comparison of food-processes in plants and animals. Dependence of animal life on activity of the green plant.

II. *Physical Section.*

A. *Astronomy.*

Observations and discussions to lead up to the explanation of the (apparent) annual motion of the sun The work to be conducted as in the First Year.

1 Revision of, and exercises upon, First Year's work—including the problem of graduating a horizontal sun-dial. (Dials for permanent use may be made in the handwork class, also simple altitude-meters for home observations.)

2. The moon. The class to make a collection of drawings of the phases preparatory to explanation by means of a simple model. The moon observed to move among the stars. Rough measurement of interval between southings. Conception of 'mean lunar day.' (Compare with First Year, II., A., 1. A clock may be regulated to keep 'mean lunar time.') Lunar and calendar months Note that at the same 'lunar time' on different dates the constellations occupy a series of different positions, repeated each month.

3. Completion of the record begun in First Year, II., A., 5 (*b*). At the same 'solar time' the constellations occupy a series of positions repeated each year Comparison with results in § 2 brings out that the sun moves among the stars.

4 Continuation of First Year record, II., A., 5 (*a*) Graph of a year's observations to be drawn and compared with similar graphs of former years.

A horizontal line across graph represents the sun's mean altitude at noon and divides the curve into two balancing segments. The sun spends half the year above and half below this line (the 'celestial equator'). The equator corresponds to the plane of the sun-dial used in First Year, II , A , 4 Compilation of a table of the sun's 'declination' from the graph. Use of this table in determining latitude at sea.

Representation of the curve on a cylindrical projection (see footnote to First Year, II , A , 2), the equator being taken as datum-line The paper above the curve is cut away and the residue bent into a cylinder. The (apparent) annual path of the sun among the stars is then seen to be a plane (the 'ecliptic') inclined at $23\frac{1}{2}°$ to the plane of the equator Explanation of the seasons.

5. Revision and summary of the two years' work. Distinction between the 'solar,' 'lunar,' and 'sidereal' days. Explanation in terms of (i) a diurnal rotation of the earth about its axis, (ii) an annual revolution of the earth about the sun, (iii) a monthly revolution of the moon about the earth. The Gregorian calendar.

B. *Geology.*

Field-work arranged as part of the course in biology or geography should include observations of the stratigraphical disposition of different types of earth and rock (*e.g.* of the sand and clay on Hampstead Heath in London), and of the relations thereto of the surface features (including the outflow of streams). The nature and effects of river action should also be studied unless taken in a previous year.

C. *General Physics.*

1. How ships float. Measurement of extra displacement produced by adding 'cargo' to a box floating in water suggests Archimedes' Principle. Confirmation in case of other liquids. Extension of principle to bodies that sink. Use of camels and pontoons. Submarine boats. Balloons and airships; contrast with aeroplane.

Exercises on use of Archimedes' Principle in determining volumes and specific gravities.

2 The barometer as a meteorological instrument. Construction of siphon barometer. Pascal's theory of action illustrated by demonstrating increasing pressure at lower depths in a jar of water. The experiment of the Puy de Dôme. Reduction of barometer readings to sea-level for construction of barometric charts. Relation between isobars and winds.

Boyle's experiments in confirmation of Pascal; leading to notion of the 'spring' of the air and to Boyle's Law.

Experiments and apparatus illustrating air-pressure: pumps, vacuum-brake, parcel-transmitter, siphon, &c. The aneroid barometer: its use in determining heights in mountaineering, aeroplaning, &c.

Archimedes' Principle explained by theory of liquid-pressure. The theory applied to explain water-supply systems, hydraulic lifts and engines.

3. Capillarity. Experiments to supplement those of I., C., 1. Measurement of surface tension (in grams-weight per cm.) by rise of water in tube. Simple study of bubbles, drops, and jets; also of common phenomena such as writing with ink.

4. Osmosis. Simple experiments to supplement I., C, 1. Passage of dissolved salts through a porous partition until equality of concentration is set up. Use in purifying beet-molasses. Semi-permeable membranes; law of osmotic pressure; comparison with Boyle's Law for gases. Application to plant-cell.

5 Revision of work of First Year, II., B, 2 Use of spring balance to measure a 'force' (*i.e.* a push or a pull) in terms of weight. Hooke's Law in the stretching of strings, the bending of beams, &c. Use of a single (rough) fixed pulley; measurement of its 'efficiency.' Use of movable pulleys. The Principle of Work introduced for the determination of their efficiency.

Loss of work by friction; simple laws of friction.

Application of Principle of Work to lever, to haulage on an incline (without and with friction), &c.

6 Conditions of equivalence of a single force (*e.g.* a pull in a cord) to two others. The vector law. Applications: the suspension bridge, cantilever frames, &c.

D. *Heat.*

1. Revision of First Year work. Mean temperatures in meteorology; regularity of mean seasonal changes over long periods. Geographical isotherms.

Temperatures at high altitudes and at great depths in sea.

Dependence of boiling and freezing points on pressure; regelation, skating, snowballs.

2. Hot-water circulation; convection. Function of radiators. Loss of temperature through conduction. Experiments on and illustrations of convection, radiation, and conduction: clothing, bark of trees, radiation from gravel and vegetation, &c.; thermostats, the thermos flask, temperature of 'Tube' railways, &c.

Curves of cooling of equal amounts of different substances (*e.g.* water and sand); geographical importance of slow rate of cooling and heating of water.

Lagging of temperature at different depths below surface of soil. (To be taken in connection with I., B.)

3. Extension of First Year, II., C., 3; separation of liquids by distillation. Applications: petroleum industry, turpentine and resin.

Simple treatment of vapour pressure.

Evaporation and condensation. Precipitation of rain and dew. Simple hygrometry; determination of dew-point; relative humidity. Wet and dry bulb thermometer.

Cold produced by evaporation. Ice-making, cold storage.

E. *Chemistry.*

NOTE.—§§ 1-4 should be taken during Autumn Term.

1. Washing soda a *crystalline* substance which degenerates (especially in warm weather) into a shapeless powder Distillation shows changes to be due to loss of 'water of crystallisation.' Water derivable from other crystals (but not all) and from vegetable and animal substances (*e.g.* a potato) where its presence is not apparent First notions of chemical combination between substances.

Crystallisation from solution in water. Manufacture of common salt, cane and beet sugar; plaster of Paris; 'sympathetic inks.' Variations in solubility. Crystalloids and colloids. Other solvents (*e.g.* petrol, solvent naphtha in water-proofing, turpentine, &c.) and their uses.

Soluble and insoluble substances in soil. Residue from evaporation of tap-water; formation of sea-water.

2. Use of soda in cookery leads to discovery that it turns the juice of pickling cabbage green. (The juice is extracted by pounding in a mortar.) Vinegar (preferably 'white' vinegar) turns the juice red. Soda and vinegar can 'overcome' one another's effects. Caustic soda, mild and caustic potash, ammonia and lime, being found to turn the juice green, are classed with washing soda as *alkalis*; *acids* are found to turn it red Other vegetable extracts found to show colour changes with acids and alkalis, *e.g.* litmus. Other 'indicators': phenolphthalein, methyl orange.

Neutralisation; careful study by means of burette, different boys working with different acids and alkalis. Evaporation of neutral solutions reveals presence of common salt when mild or caustic soda is neutralised by hydrochloric acid, and other 'salts' in the other cases Salts named from acid and alkali (*e.g.* sulphate of ammonia). Manufacture of sulphate of ammonia for manure, and of sal-ammoniac.

3. How does caustic differ from washing soda? On addition of acid the latter yields a heavy gas which extinguishes flames, turns lime-water cloudy and ultimately clears it again The cloudy matter, when collected, returns the gas if acid is added. Chalk is known to yield the same gas when 'burnt' to make lime. Finally, caustic soda is made by boiling washing soda with lime, the latter becoming converted into chalk (Similar statements apply to mild and caustic potash) Thus, washing soda, mild potash, and chalk are to be classed together, and also caustic soda, caustic potash and lime. But there are two 'limes'—quicklime and slaked lime. Dry 'heavy gas' liberates water from caustic soda, caustic potash and slaked lime, but not from quicklime; hence the analogy is with slaked lime.

4. The 'heavy gas' is produced in breathing, and also in the burning of coal-gas, candles, &c. Burning of these substances in a jar demonstrates its production together with water, and shows, further, that one-fifth of the air is consumed. The burning of metals (*e.g.* magnesium), and of phosphorus, sulphur, &c, the rusting of iron, the 'drying' of boiled oil, &c, also remove the 'active' one-fifth of the air and leave four-fifths 'inactive.' Consideration of the mode of manufacture of red lead suggests that if heated it may restore the absorbed active constituent. Oxygen and nitrogen; argon. Manufacture of oxygen from liquid air. Properties and uses of oxygen. Oxides.

The 'heavy gas' is produced without water when pure carbon is burnt in oxygen. It is, therefore, an oxide of carbon. Confirmation by burning magnesium in gas. Oxygen passed over red-hot carbon (as in a domestic fire and in the smelting furnace) produces a gas which burns to form the heavy gas. The latter must, therefore, contain more oxygen (compare litharge and red lead); hence the names carbon monoxide and carbon dioxide.

5. Oxides and oxidation in nature and industry. Oxides of iron, copper, magnesium, aluminium, &c.; ochres and other painter's colours; 'drying' of oils; linoleum.

6. Is water also an oxide? Affirmative answer obtained by passing steam over hot magnesium. Discovery of hydrogen. Production in bulk by passing steam over hot iron; properties. Known to be produced also when the plumber 'kills spirits of salt' with zinc. Composition of water confirmed by burning a

jet of hydrogen obtained by this method, and by using the gas to 'reduce' oxides; also by electrolysis. Reducing action of coal-gas.

Carbon and hydrogen constituents of living matter; also nitrogen, sulphur, and phosphorus.

Solutions of the oxides of carbon, sulphur, and phosphorus are acids. Carbonates, sulphites, sulphates, phosphates.

7. Action of sodium, potassium, calcium (all obtained by electrolysis) on water. Deductions: quicklime is an oxide; slaked lime, caustic potash and caustic soda are hydroxides; chalk, mild potash, and soda are carbonates. Action of heat on carbonates: iron carbonate (spathic ore), zinc carbonate (calamine), magnesium carbonate (magnesian limestone); manufacture of white lead.

8 Examination of action of dilute hydrochloric and sulphuric acids on zinc, iron, magnesium. Salts of these metals Salts also produced (without hydrogen) by action of acids on oxides. Theory of action confirmed by passing dry hydrochloric acid over heated oxides. Salts named from acid and metal (*e.g.* sodium chloride) The special case of 'ammonium' salts

9 Manufacture of sulphuric acid by 'contact process' Manufacture of hydrochloric, nitric, and phosphoric acids from salt, saltpetre, and calcium phosphate. Sources of these salts Salts in the soil (see I., B., 4).

10. Summary of results in (verbal) chemical equations. The quantitative constancy of chemical reactions and combinations (discovered in numerous simple gravimetric and volumetric exercises during the course) is also to be brought out and emphasised.

Third Year

[Section I is assigned to the second and third terms. The divisions of Section II may be taken in any convenient order.]

I. *Biological Section*

A *Spring Term.* A study of micro-organisms

1 Action of yeast in bread-making as an example of *fermentation.* Cultivation of yeast in Pasteur's solution. Fermentation in manufacture of beer and wine; acetic-acid fermentation. Pasteur's proof that different effects are due to activity of definite plant-growths. Association of fungi with other changes in food materials: moulds on bread, jam, &c.; fungi in milk; colonies of bacteria in putrefying broth, meat-jelly, &c. Germ-cultures; practice and theory of staining.

2. The source of fermentation-fungi. The 'spontaneous generation' controversy; Appert's invention (*c* 1800) for fruit preservation; experiments of Schultze and Swan, sterilised air; germs and dust, the Pasteur flask

Presence of germs in tapwater, dust, and surface soil demonstrated by cultivation in Lister's tubes.

Sterilisation by heat; resisting germs (*e.g.* in dirty milk).

Sterilisation of food by preservatives—harmless and harmful.

3. Micro-organisms in disease. Pasteur and silk-worm disease; Lister and the antiseptic treatment of wounds; Manson and Ross and malaria. Phagocytes and bacteria; recent developments of antiseptic practice. Vaccines and anti-toxins: Jenner and vaccination; Koch and Pasteur and anthrax, rabies; Wright and typhoid fever. Anti-toxins in diphtheria, tetanus, &c.

The extermination of infectious diseases: rabies in England, malaria in Panama, &c. Preventable diseases still to be exterminated; need of scientific investigation, educational enlightenment, and administrative action.

4. Micro-organisms as useful agents: cheese-making, tanning, &c.; micro-organisms as scavengers; the fixation of nitrogen.

B. *Summer Term.*

1. The structure and life-history of select animal types: Euglena, Paramœcium, Vorticella, Hydra, sea-anemone, earthworm, crayfish, frog, rat, or rabbit.

2. Structure and life-history of Spirogyra, a moss, a fern.

II. *Physical Section.*

A. *Astronomy.*

The following subjects should be taken in class. Further voluntary work may be directed and encouraged by the School Science Club.

1. Revision of previous work. The fundamental importance of sidereal time. The astronomical clock. Fixing positions of stars by right ascension and declination. Construction of star-charts. (In connection with these the use of the polar and meridional gnomonic projections may be either taught or applied from the geography course.)

2. Plotting of monthly course of the moon upon a cylindrical projection (compare Second Year, II., A., 4), right ascensions and declinations being taken from 'Whitaker's Almanack.' The path of the moon thus shown to be approximately a plane inclined to the ecliptic.

Plotting on enlarged scale of paths of moon and sun about the times of new and full moon. (It is best to use the gnomonic projection, since the paths are then straight lines.) Conditions for eclipses.

3. The variation in distances of sun and moon deduced from varying observed diameter. (Data from 'Whitaker's Almanack.') Perihelion and aphelion; perigee and apogee. The orbits of earth and moon elliptical Calculation of eccentricities

Regression of moon's node; influence on dates of eclipses The precession of the equinoxes.

Simple theory of tides.

4 The planets. The Ptolemaic and Copernican theories.

The relative distances of the planets from the sun and of the moon from the earth. Measurements of absolute distances by parallax, transit of Venus, &c Kepler's laws.

B. *Geology.*

The following subjects may be expected to be taken during this year in geography lessons :—

1. The stratigraphy of the home region One or two lessons based on evidence acquired on field-excursions or reported by individual pupils, museum collections, &c. Thus, in London a clear idea should be given of the geology of the Thames basin from the northern to the southern chalk heights, the evidence of borings for artesian wells, &c , being examined. The probable geological history of the region.

2. Extension to neighbouring regions : for example, in London to the Weald, Surrey, Hants, and the Isle of Wight.

3. Outline of the geological structure of typical regions, such as Wales and the northern coal-fields of England.

C. *Mechanics.*

The following subjects are to be regarded as territory common to the courses in science and mathematics. Much (or all) of the work may be taken in mathematics lessons.

1. Uniform and variable velocity (linear and angular), average velocity. velocity at a given moment; distance-time and speed-time graphs.

Two cases of special importance: (i) Falling bodies and projectiles. The vertical distance fallen found to vary with the square of the time; hence the average, and therefore the final, vertical velocity must be proportional to the time. Value of 'g.' (ii) Pendulum motion. Here, since the time of swing is constant for small arcs, the average velocity is proportional to the amplitude It follows that the velocities at all corresponding moments, including the moment of mean position, are proportional to the amplitude.

2. Velocity as a vector. Relative velocity. Vectorial representation of changes of velocity Utilisation of the property given in 1 (ii) to measure changes of velocity produced by collision of swinging balls (Goodwill's 'Vector Balance').

Discussion of results leads to distinction between weight and mass, to the idea of change of momentum as the measure of the dynamical action of bodies upon one another, and to the principle of conservation of momentum. Alternative measure of force (hitherto measured in terms of weight) as rate of change of momentum. The poundal and dyne.

Weight as rate of change of momentum. Newton's Law of Gravitation. His verification by calculation of rate of fall of moon.

3 A suspended ball is made to swing through a constant vertical distance along various curves, and to collide directly with a stationary suspended ball. Measurements show that the velocity immediately before impact depends entirely on vertical distance fallen. Connection of result with Principle of Work (Second Year, II , C , 5). Kinetic energy. Apparent loss of energy in collisions (considered in connection with D., 4).

D *Physics.*

1 Revision and extension of Second Year work on radiation and conduction Graphic study of temperatures at points on a bar heated (i) steadily (Forbes), (ii) rhythmically (Ångstrom), to illustrate measurement of conductivity and seasonal temperature-changes of soil.

2. Solar radiation its fundamental importance. Separation by prism into light and dark radiation. Intensity of radiation · law of inverse squares; photometry; the cosine-law; Newton's law of cooling. Influence of character of radiating and absorbing material; the incandescent gas-mantle, &c. Absorption and reflection of light and dark radiation. Laws of reflection : plane and curved mirrors Applications : periscope, searchlights, lighthouses, &c The sine-law of refraction; indices of refraction

3. Heat as a measurable quantity. Study of the temperature-changes of variable weights of water heated for the same period by a constant flame leads to the formula $H = Wt$, where W is the weight of water, t the rise of temperature, and H the number of 'calories' represented by the heating. Repetition with other liquids (*e g* linseed oil, glycerine) leads to the more general formula $H = sWt$, where s is a constant for each substance (the 'specific heat') Confirmation by 'the method of mixtures' Measurements of specific heat.

Latent heat. Rough determination of latent heat of steam by Black's method, of water by method of mixtures.

4. Temperature-changes of gases under the conditions (i) of constant pressure and (ii) of constant volume. Absolute temperature.

Cooling and heating of gases by adiabatic expansion and compression. Applications of results in meteorology. Equivalence of the heat-change to work done. Joule's experiments, &c. Internal-combustion engines. Liquefaction of gases; cold storage, &c

5 Vapour pressure Variations of boiling-point with pressure. Steam-engines (cylinder and turbine). Uses of superheated steam (in engines, in chemical industries, &c.), and of subheated steam (concentration of beet sugar).

6 Electric.ty : a preliminary course of work, almost entirely qualitative in character; the quantitative aspect of the subject being reserved for study in the Fourth Year. Examination of an electric-bell circuit as a type of electro-magnetic mechanism Analysis of magnetic effects of the current : Oersted's experiment, Maxwell's screw rule. Industrial and other uses of electro-magnets. The electric telegraph. Magnetic effect as an index of current strength; the galvanometer. Preliminary notions of voltage and resistance.

The electric bell as a motor; elaboration of the same principles in the motors used for locomotion and power.

Faraday's experiments on electro-magnetic induction. The induction coil The dynamo; the 'magneto'; reciprocal relation between the principles of the motor and dynamo; conversion of mechanical into electrical energy, and of electrical into mechanical. The telephone.

Conversion of electrical energy into heat; the incandescent and arc lamps; the electric furnace.

Electrolysis : industrial applications Secondary batteries : relation with

primary batteries with reference to conversion of chemical into electrical energy and electrical into chemical.

E. *Chemistry.*

1. Revision and extension of Second Year work

(*a*) The aim of chemistry to regard all substances as elements or compounds of elements Quantitative definiteness the mark of chemical union. Distinction between compounds, mixtures, and solutions.

Alloys and glass as 'solid solutions': conversion of iron into steel, manganese steel; manufacture of glass. Amalgams of mercury; the extraction of gold

(*b*) Law of multiple proportions, based on analysis of sodium bicarbonate, lead peroxide, &c Provisional use of the terms 'molecule' and 'atom' to describe results Molecular composition of water The basicity of acids Use of chemical formulæ and equations Valency of the common metals

(*c*) Combustion Nature of flames The incandescent gas-mantle Use of high-temperature flames in welding, cutting steel, &c Flameless combustion

(*d*) Sulphides, sulphuretted hydrogen: their analogy with oxides and water. Action when sulphides are roasted; applications in metallurgy.

(*e*) Acidic and basic oxides, peroxides. Action of sulphuric acid on peroxides; hydrogen peroxide Dry hydrochloric acid passed over a heated peroxide (*e.g.* red lead) yields chlorine Its properties Molecular constitution of hydrochloric acid Bromine and iodine Oxidation and reduction as general chemical processes

(*f*) Ammonia: its composition Ammonium salts

2. The law of chemical equivalence Determination of weights of metals that (i) displace equal volumes of hydrogen, (ii) unite with equal weights of oxygen, (iii) replace one another in salts. Confirmation of results by determining the volume of hydrogen and the weight of oxygen involved in the decomposition of steam by hot iron Equivalent weights Smallest combining (or 'atomic') weights, that of hydrogen being taken as unity

3. Revision and further applications of previous work in simple explanation of some important chemical industries and processes (*a*) The winning of the more important metals (*b*) Coal-distillation, the main products and their uses. (*c*) Soda; bleaching powder. Bleaching (*d*) Tanning (*e*) Dyeing (*f*) Phosphorus matches (*g*) Photography (*h*) Glass and pottery

FOURTH YEAR

[In schools where the arrangement is possible the subjects marked with an asterisk should be reserved for a course of lectures and discussions to be given (to non-specialists in science together with specialists) in the fifth year. This course should include some treatment of the philosophy of science illustrated from the history of scientific discovery Classical works in biology or physical science may be recommended for private reading and discussion]

I *Biological Section*

1 Civilisation based on the domestication of plants and animals. The history of food-plants, &c. Modern methods of improving breeds of plants and animals. Vegetable and animal products in industries and manufactures: cotton, timber, paper manufacture, wool, silk, &c Importance of forestry.

* 2. The theory of organic evolution. The evidences and main phases of the evolutionary process: the beginnings of life; divergence of animals and plants from one another; main morphological developments along each line; origin of sex; general character of progress—'progressive differentiation and integration'; adaptation to environment, degeneration.

Problems of heredity and variation: Darwin, Mendel, de Vries. Selection. Function and environment.

II *Physical Section.*

A. *Geology.*

Lessons should be given (in, or in close connection with, the geography course) on (i) the forms of life characteristic of the chief geological horizons,

including the earliest appearances of man (*cf.* I, 2); (ii) special subjects of geographical importance, *e.g.* the coal age and the ice age, 'block' and 'fold' mountains, rifts and faults; (iii) questions of economic geology selected on the ground of either local or national importance. In connection with (i) visits should be made to a geological museum, and holiday collections of fossils encouraged by the School Science Club.

B. *Mechanics.*

1. Revision of work of Second and Third Years, straightforward problems on motion and equilibrium to give a firm grasp of principles.

Rate of doing work; horse-power; dynamometers. Work of engines in road, rail, and water traffic Economy of power

Simple theory of the aeroplane.

2. Circular motion. Harmonic motion of pendulum, vibrating spring, &c Connection with Hooke's Law (Second Year, II, C., 5).

The formulæ $y=a \sin \frac{2\pi}{\lambda}(x \pm vt)$ as descriptive of progressive harmonic waves. Stationary waves Wave-motion as a mode of transmission of energy.

3. The principle of energy in the case of a thin cylinder rotating about its axis while the latter is moving parallel to itself. Determination of 'g' by measuring time taken by such a cylinder to roll down a sloping plane.

Derivation of the principle of Conservation of Moment of Momentum, and of the formula *torque=rate of change of moment of momentum.* Applications to phenomena of bicycling, spinning tops, gyroscopes, &c. Moment of inertia and radius of gyration in simple cases. Motion of a rod struck at a given point Harmonic vibration of a compound pendulum and of a horizontally suspended magnet. Inversion of compound pendulum; 'centre of percussion.'

C. *Physics.*

1. Electro-magnetic measurements.

(*a*) Distribution of magnetism along a bar magnet. Magnetic fields; lines of force; use of small compass-needle to map field near magnet or current circuit.

Deflection of small compass-needle by magnet; the tangent law; application in the tangent galvanometer. The moment of a magnet.

(*b*) Chemical equivalence of substances liberated by a current passing through electrolytic cells in series. Definition of the ampère in terms of silver deposited per second. Congruence with measurement in terms of deflection in tangent galvanometer.

(*c*) A long platinoid wire is 'tapped' by the terminals of a high-resistance galvanometer. The results lead to the notions of a regular 'fall of potential' and of the connection of potential difference with current-strength and resistance. Definition of the ohm and the volt. Ohm's law.

(*d*) Quantitative statement of Faraday's law of induction. The earth-inductor; the transformer. Magnetic force and magnetic induction in iron; permeability; hysteresis.

2. Optical measurements and calculations.

(*a*) Spherical mirrors; theoretical derivation of the formula $1/v+1/u=1/f$; experimental verification.

(*b*) Lenses: experimental discovery of the formula $UV=f^2$; deduction from this of the formula $1/v-1/u=1/f$. Magnification; telescopes, microscopes; the prismatic field-glass. Achromatic lenses. The lens of the eye and its optical defects; spectacles.

(*c*) Methods of determining the velocity of light.

3. Wave-motion in sound, light, and electricity.

(*a*) General properties of harmonic wave-motion, longitudinal and transverse (to be taken in connection with B., 2). Application to elucidate the behaviour of sounding forks, strings, and pipes. Free and forced vibrations; resonance.

(*b*) The undulatory theory of light. Colours of thin films, interference; diffraction; polarisation. Deduction of behaviour of mirrors, prisms, and lenses

from wave-theory. Spectrum analysis: applications in chemistry, astronomy, &c.

(*c*) Electro-magnetic waves. Wireless telegraphy. Electro-magnetic theory of light.

* 4. The main results of modern investigations on the discharge of electricity through gases; Rontgen rays; radioactivity. The ultimate constitution of matter: the kinetic theory of gases, the radiometer; experiments of Perrin and Bragg; theories of solution, osmosis, and electrolysis.

* 5. A general review of physical (including chemical) phenomena from the standpoint of the principle of the Conservation of Energy. Availability and degradation of energy. The world's present and possible future sources of energy. Economy of energy.

D. *Chemistry.*

1. The atomic theory; Avogadro's hypothesis. The density of a gas and its volumetric reactions as an index of its molecular constitution. Relations between oxygen and ozone, acetylene and benzene.

2 Composition of ordinary alcohol. It behaves like a weak hydroxide, yielding 'ethereal salts' and a substance, ether, which is analogous to an oxide. Ethane and its relations to alcohol. Comparison of ethane with methane ('natural gas'), alcohol with wood-spirit. The paraffins, their alcohols, ethers, &c., as homologous series. Theory of the carbon atom Formic and acetic acid. their relations to and reactions with alcohols Chloroform and iodoform.

3 The manufacture of soap, candles, and glycerine. Fats and vegetable oils are ethereal salts, glycerine an alcohol; hydrolysis. Nitro-glycerine and dynamite.

Cellulose, collodion, gun-cotton, blasting, gelatine, cordite.

4 Benzene and toluene as 'closed chain' compounds. Isomerism Carbolic acid; salicylic acid, 'aspirin'; tannin, nitro-benzene, aniline and the aniline dyes 'T.N.T.' explosive. Picric acid.

5. The proximate constituents of food · proteins, carbo-hydrates, fats Separation of the protein (gluten) and the carbo-hydrate (starch) in flour, of the protein (curd), carbo-hydrate (whey), and the fat (cream) in milk Tests The conversion of starch into soluble sugar, solution of meat-stuffs; enzymes, their rôle in plant life and animal digestion Food values. Ultimate constituents of foods and of living matter. Anabolism and katabolism.

* 6. General review.

(*a*) Chemical industries from the standpoint of the nation and the world. By-products, economy. Interrelations of theory and practice; synthetic chemistry, the microscope in metallurgy, &c.

(*b*) Inorganic and organic chemistry. Families of elements and compounds The periodic table of the elements. The new elements

IV. SCIENCE SCHEME OF A RURAL SECONDARY SCHOOL.

By WILLIAM ALDRIDGE, Headmaster, Shepton Mallet Grammar School.

The school in which the work here described is carried on is an old endowed Grammar School, founded in 1627, which was reconstituted and transferred to new buildings nearly twenty years ago. The commencement of the experiment in rural education in this school was coeval with this change, and the work has been continued ever since. For the first few years aid was given by the County Council alone, but grants were afterwards obtained from the Science and Art Department, and ultimately the school came under the Board of Education, which, however, refused to give a special grant under Article 39 of the Regulations for Secondary Schools, on the ground that the work was no longer an educational experiment but was a proved success.

The scheme has undergone modifications since its inception, but the position reached is roughly outlined below, and there is no doubt as to its efficiency as a means of general education

The underlying motive of the scheme is to vivify the class-room teaching by bringing it into intimate contact with the out-of-school life of the district in which the pupils move, thereby making the pupil an interested learner, developing into an accurate, observant, reasoning, and adaptable man, with bodily, mental, and spiritual faculties developed to the fullest possible extent

The school is situated in a small market-town of 5,000 inhabitants, served by two lines of railway The number of pupils has varied from fourteen at the start to eight-five, and now averages about seventy to seventy-five boys, aged eight to eighteen, of whom all, except at most half-a-dozen, are day boys. About two-thirds of the total come from surrounding towns and villages. The chief industries of the locality comprise farming (milk, cheese, butter, and cider making, with little arable land), brewing, quarrying, coal-mining, a little lime-burning, brick-making, and the manufacture of lace-making machinery. The school staff consists of the headmaster and four assistants, who receive occasional help in the more technical portions of the science course from the county experts in agriculture and horticulture.

The buildings comprise a main block, including headmaster's house and three class-rooms, cloak-room, &c , and a detached block containing workshop, physical and chemical laboratories, lecture-room, balance-room, and store-rooms The physical laboratory is also used for practical botany, but experiments in this connection are also set up in the lecture-rooms and chemical laboratory.

Out-of-doors about two-fifths of an acre are devoted to experimental and demonstration plots, and there is a meteorological station. Formerly the plots included gardens cultivated by individual boys, but they proved to be unsatisfactory and of little real educational value, and were ultimately abandoned. A model fruit plantation has been substituted. The boys are not called upon to do much manual labour in connection with these plots, but they use them largely for experimental and observational work

For science work the school may be divided into three main divisions—Preparatory, Middle, and Upper—and a boy spends an average of three years in the Middle Division after reaching the age of twelve years. The following is the division of time in class which has been found to give satisfactory results :—

Preparatory Division, 8-12 years old —Religious knowledge, 1½ hour per week; English subjects, including reading, writing, spelling, grammar, composition, history, geography, 15 hours; arithmetic, 7½ hours; physical exercises (excluding organised games), ¾ hour; art and music (singing), 2¼ hours; science, 1½ hour.

Middle Division, 12-15 years.—Literary subjects, including religious knowledge, English, geography, history, 7½ hours; mathematics, 6 hours; language (French), 3¾ hours; manual and physical training (apart from organised games), 3 hours; science, 6 hours; art and music 2¼ hours.

Upper Division, 15-18 years.—Literary subjects, 9 hours; mathematics, 6 hours; language, 5¼ hours; science, 6 hours; physical training, ¾ hour; art, 1½ hour.

In the Preparatory Division the science taken is of an informal character, such as that usually included under the term 'Nature Study.' The object of the course is to stir up interest in Nature at large, and to develop the observational and descriptive powers. Plants, animals, insects, natural phenomena, simple experiments in mechanics, chemistry, physics, &c., are all drawn upon to furnish subject-matter. Scientific terms are, as a rule, avoided, but accuracy of observation and of description are demanded The lessons usually take the form of a conversation between the teacher and the class on the specimens to be described, or the experiment to be observed. It is a general rule all through the school that every observation made or answer given shall be a complete sentence grammatically constructed, and 'No' or 'Yes' without amplification is never accepted as a satisfactory reply. Sketches are frequently made in the course of the lesson, and the information gained is often utilised in the next lesson on English composition or a question upon it is set to be answered as home-work The boys frequently suggest subjects for future lessons, and the indoor lessons sometimes develop into country rambles and scientific excursions with a definite object in view on half-holidays Outdoor lessons in class hours are not usual. They have been found unsatisfactory, as there are too many distractions and much valuable time is lost.

In the Middle Division science becomes more systematic; the system is not, however, that of the text-book, but is determined by the underlying principle that the elements of botany, physics, chemistry, &c , shall be made to throw as much light on country life as possible. The various subjects are therefore blended more or less into a whole and not kept in watertight compartments For convenience, chemistry, physics, and botany are treated separately in different lessons, but one period per week is devoted to what is called 'Rural Economy'—an application of scientific knowledge to the elucidation of the mysteries of rural life.

The outlines of the chemistry course at this stage are published and need not be repeated here. (See 'A First Course in Practical Chemistry for Rural Secondary Schools,' published by G Bell & Sons, 1*s* 6*d*)

The physics course begins with a general lesson or two on matter and its properties, and proceeds with heat—expansion, liquefaction, vaporisation, conduction, radiation, absorption—temperature and its measurement; heat as a form of energy—its production by chemical and physical means—its measurement—specific heat—latent heat; anomalous behaviour of water with respect to heat and its importance in the economy of nature—vapour pressure—boiling; atmospheric moisture—its measurement—effect on barometric height—the connection of the barometer with weather phenomena, &c

General Physics and Mechanics —Methods of measurement—mass—density—flotation—osmosis—surface tension—capillarity—fluid pressures—siphon—pumps—hydraulic press—barometer—Boyle's and Charles' Laws—levers—pulleys—work—time and its measurements—friction (how minimised in machinery)—inclined plane—parallelogram and triangle of forces—motion—velocity—acceleration—momentum, &c.

Botany.—The structure of a plant so far as observable with a pocket lens. Seeds and seedlings—roots, their structure and work—stems, branching, buds, effects of pruning—the green leaf and its work—flowers, essential and non-essential parts, their use and importance—fruits, how formed, uses, dispersal, life-histories of common plants and weeds. How plants feed—comparison of plants, leading to a system of natural classification—contents of plant cells—enzymes and their work—the nutrition of plants and animals compared—reproduction processes, &c.

Rural Economy —Soil, its origin, composition—agents of denudation—work of lowly animal and plant life in formation of soil—characteristics of sand, clay, silt, lime, humus—heavy and light soils—soil and subsoil—why differences—food materials of plants, how and whence obtained—fertility, how

maintained—tillage—reasons for operations—effects on soil moisture, soil air, soil temperature, plant food, &c.—chemical knowledge applied to manuring and its principles—farmyard dung—chemical fertilisers, their composition, production, and mode of action—application of scientific principles to farm operations, *e.g.* haymaking, grazing, ensilage—bacteria, yeasts, moulds and their work—nitrification and denitrification—souring of milk—putrefaction—decay—ripening of cheese—souring of cider—sterilisation—pasteurisation—preservatives—plant diseases and pests—remedies and preventives, &c.

The above is not an exhaustive syllabus, but it gives an idea of subjects treated, though not of the order in which they are taken up. The lessons consist of conversations and discussions carried on in connection with specimens, experiments, demonstrations, diagrams, and so forth. The whole is treated in an experimental and descriptive manner, and the connection with local industries and phenomena is constantly kept in view. Laboratory work goes on in connection with the course, but, except in chemistry and botany, no attempt is made to keep lecture discussions and practical work together. In the physical laboratory the course commences with practical mathematical measurements and verification of mensuration formulæ, and then proceeds to determinations of volumes, densities, &c., flotation, hydrometers and their uses—mechanics and simple machines—capillarity, surface tension, friction, gravitational and other forces, and so on, always keeping the fundamental object of the course in view and choosing objects and illustrations in accordance therewith The object of each experiment is stated, results obtained, and finally a full description of the method followed is written out in pencil at the bench, deductions and inferences are drawn, sources of error are sought for, and their effects estimated. As a rule each boy, or pair of boys, has a separate problem from his fellows.

As a sample outline of a lesson in 'Rural Economy'—suppose the subject is *Rolling*, which the boys have seen proceeding in the meadows early in March as they came to school. The investigation probably brings out the following points—Smooth surface—hoof-marks of animals—presses in stones (how came they to surface? lifted by frost—laid bare by washing of rain, &c), hence minimises risk to mowing machine later on—makes surface firm—loosened by winter frost; effect on capillarity—capillary tubes made finer, therefore water rises to top; effect on evaporation—air usually moist at this season, therefore slight; effect on soil temperature—evaporation causes cooling tendency—tight soil a better conductor than loose soil—sun beginning to have more power—tends to make soil warmer—total of effects, warming; effect on plants—warmth causes more rapid growth—roots in loosened soil would tend to be short of food and to be dried up and withered—seedling grasses pressed into soil and enabled to grow—shoots broken—causes dormant buds to grow out—result, a thicker and more abundant crop of grass Effect on conservation of soluble plant food formed during winter—capillarity keeps it near roots. Why do we now start rolling the cricket pitch?

The whole of the information can be elicited from the class by serial questions.

Up to this point few text-books have been used, but note-books contain summaries of all lessons and home-work exercises on them. In the course of the lessons interesting facts about the history of science and its pioneers are given as occasion arises.

In the higher division text-books are used more freely and the different branches of science are followed out still more systematically; but the underlying principle of the course is never forgotten, and applications of the facts are constantly demanded. Heat, light, and sound, studied as forms of energy, and magnetism and electricity are taken in alternate years. Chemistry is further developed, and botany is revised and extended to include plant ecology and the study of some of the commoner orders. Soil physics and soil biology are further developed, and the chemistry is applied to crops, animals and animal products, feeding stuffs, manures, &c Enough animal physiology is given to enable boys to understand the digestive and feeding processes in animals, and to compare these processes with those in plants, bringing out the fundamental difference that plants in total store up energy, and animals in the

total liberate and use that energy in various ways. An outline of the chemistry of foods and the principles upon which animals are fed is dealt with (the boy's own body being *the* specimen usually under immediate consideration). The reproductive process is traced through plants, and the principles of breeding can thus be dealt with in systematic order, while many valuable lessons can be impressed without difficulty.

The laboratory work takes on a character more closely resembling research work, and sometimes deals with problems connected with soils, plants, feeding materials, manures, milk and milk-products, &c., requiring the application of knowledge and methods previously studied in some other connection. The lines along which such studies are to be conducted are usually suggested by the master, but may be modified by the pupil at his discretion.

In the physical laboratory the exercises are connected with the branch of science under study, and the compound microscope is now used in the study of botany.

Meteorological instruments, soil temperatures, &c., are read and recorded daily, with occasional discussion of the meaning and explanation of the records.

The school has a Natural History Club. Excursions are frequent. Regular meetings are held at which boys read papers which usually embody their own observations and are illustrated in their own ways. These meetings and excursions take place out of school hours.

V. SCIENCE COURSE FOR A PUBLIC SECONDARY SCHOOL FOR GIRLS.

By I M DRUMMOND, Headmistress, Camden School, formerly Science Mistress, North London Collegiate School; and R. STERN, Science Mistress, North London Collegiate School.

(Average time given about three hours per week from twelve years of age.)

I. *Ages up to* 11 *or* 12.—The power of clear, logical reasoning makes rapid strides about the age of twelve, and this, therefore, would seem the most suitable age at which to begin a definite course of experimental science. This by no means precludes the study of natural phenomena before this stage. Indeed, such study must begin as soon as a child wakens to interest in the world around her. Science for these younger children will take the form of observations on, and very simple experiments with, growing plants, caring for animals, and watching them; recording observations on sun, sky, and weather; investigating the structure of simple machines in daily use, and finding out how they work. The material should be as varied as possible, and should follow, as far as this can be done, the interest of the children at the moment, the continuity of work throughout a course of lessons being, as a rule, a minor consideration.

II. *Ages* 12 *and* 13.—When regular work in the laboratory first begins at about the age of twelve the lessons must necessarily become more systematic. The main objects of the teacher at this stage will be —

(*a*) To encourage the natural inventiveness of the child and to help her to direct it towards definite ends.

(*b*) To encourage her to give practical expression to her ideas by her own manipulative skill.

(*c*) To help her to distinguish between observed facts and the inferences to be drawn from them, and to express herself accurately in written records.

The problems must be closely connected with the everyday life of the child, and at first should be so simple that an experiment, complete in itself as far as it goes, can be carried out in a single lesson. The power to follow a line of argument, and to draw inferences by collating the results of several experiments, comes at a later stage. Easy problems relating to simple mechanical appliances, flotation, pressure of liquids and gases, effect of heat on substances, its method of transmission and its measurement, all form excellent material. The method of attack and the actual choice of problems may vary widely. Some teachers may begin with the investigation of an actual instrument; others prefer to begin with a discussion of the phenomenon of weight, leading the children to realise at the outset how little they know as to what weight really is, but that they have some knowledge to start with in their experience that one body is harder to lift than another, and that one presses more heavily on the hand than another. The idea of a downward force is thus obtained, and methods of measuring it may be discussed. The impossibility of making accurate comparisons by means of feeling the weights leads to the devising of a simple instrument. The pull on a bit of elastic may be measured, and a realisation of the imperfections of this instrument, owing to incomplete elasticity, will lead up to the spring balance. Other methods of comparing weights lead up to the see-saw, and so on to the structure of the kitchen scales and the laboratory balance. The value of a piece of fine and delicate machinery is thus appreciated and it is treated with respect. A comparison of the weights of different objects leads rapidly to the need for a standard or unit of weight.

Experiments with the see-saw show the result of altering the position of the fulcrum, and this leads on to levers and experiments on mechanical advantage. Pulleys and inclined planes will now naturally be experimented with. Observations will be made on the working of pickaxes, cranes, wheel and axle, and so forth. Models may be made by the children, and many problems may be answered by their own experiments, as, for example, if a loaded wheelbarrow

has to be raised to a certain height, is it better to have a short steep slope or a longer and more gradual one?

A study of flotation may very naturally develop from such a course as this. Why do some bodies float on water and others sink? Why do some bodies float higher in the water than others? Why do bodies float higher in salt than in fresh water? Is any of the weight of a body that sinks supported by the water? These will be among the questions asked and answered by experiments. They will lead up to an understanding of relative density, and of the Principle of Archimedes. When the principle has been grasped, practical applications should be worked out, calculations being made and the results tested by experience. The weight of cargo which it is safe for a boat to carry, or the size of a cork life-belt necessary to support a person, are problems which, even if toy boats and tin soldiers are used, help the children both to grasp the practical value of the knowledge gained and also to appreciate the need for accuracy.

The fact that ice floats on water may well lead on here to investigations into (1) changes of density and volume produced in substances by change of temperature, (2) change of state, together with the influence of pressure upon it, (3) some methods of transmission of heat, and (4) means of measuring temperature and heat. Plotting curves of temperature for the heating of water over a flame till it boils, and for the cooling of melted paraffin wax, will give the idea of latent heat The heating of a definite weight of water by the immersion in it of given weights of different substances at the same temperature will give the idea of specific heat, and these conceptions may now be developed in their geographical and practical bearings. Discussions as to the methods of heating buildings and obtaining hot-water supply, the working of a cooking-box, &c., will naturally arise during this course.

Flotation in the air will lead on to an estimate of the weight of air by the method of driving it from a flask by boiling water, and this to the idea of pressure of the air. The experiments of Torricelli and the work of Boyle on the 'Spring of the Air' may here be considered in historical order, and different forms of barometer, pumps, siphons, and so forth may be studied. A consideration of winds and of weather charts will here, again, form a link with geography.

At this stage a continuous piece of investigation necessitating the framing of tentative inferences or hypotheses, and the testing of these by further experiment, becomes increasingly possible, and helps greatly to deepen the understanding of the method of development of scientific knowledge. Many chemical problems form excellent material. Amongst others, the problem as to what we understand by burning arises very naturally out of work already done.

Preliminary questioning as to what burning is will usually lead to the suggestion that it consists in a partial or complete disappearance or 'consuming' of the object burned Experiments with match, candle, &c , *seem* to confirm this; the weighing of magnesium before and after burning discredits it, and demands, therefore, further investigation. The fact that some member of the class has probably observed the magnesium glow more brightly on the lid of the crucible being removed, suggests that air influences burning and may cause the increase of weight. The question then arises, does the air then diminish? Burning magnesium in a crucible floating on water under a bell-glass shows that it does. Therefore the magnesium calx must represent magnesium and air Why has the whole air not disappeared? Suggestions that this may be due to insufficient magnesium being burned must be put to the test, and the properties of the gas left compared with the properties of the air to begin with. Details of Priestley's and Lavoisier's experiments with the red calx of mercury may now be given for comparison, and the red calx heated by the pupils. Other substances may then be dealt with, *e g.*, carbon. Carbon disappears. Is a new gas formed? Collection of the air above the heated carbon and testing of this, together with ordinary air, by a match, by litmus, and by lime-water, reveal the fact that a new gas has appeared. Probably someone, in the effort to collect the gas, has failed to get the carbon to disappear, owing to heating it in too limited a supply of air; this will lead to the suggestion that the

carbon also unites with oxygen. Heating small quantities in oxygen and nitrogen will reveal the fact that no new gas is formed in the latter case, while it is formed abundantly in the former. A further confirmatory experiment may be made by the burning of magnesium in carbon dioxide.

The candle can now be more thoroughly investigated, the decrease in volume of air demonstrated by burning it over water under a bell-jar, and the products of combustion found This will naturally lead to the question—Is water an oxide? and its composition may be proved by the burning of magnesium powder in steam, with the formation of magnesium oxide and a new gas, hydrogen.

A closely knit piece of work of this kind, in which fresh materials and facts are arbitrarily introduced by the teacher as little as possible, is of the utmost value. The girls may be left very free to suggest and carry out their own experiments, the class being pulled together from time to time by discussion, summarising of results, and formulation of fresh problems. Variety of method will enable different members of the class to make their own individual contributions to the discussion, and excellent practice in clear exposition may be given by allowing one member who has performed a particularly useful experiment to demonstrate to the whole class and be questioned by the others.

III. *Ages* 14 *and* 15.—As adolescence progresses the mind rapidly expands, and more or less consciously craves wide horizons and broad and generous views. Very simple astronomy, giving some idea of our present knowledge of the Universe and how it has been attained, may be made a most fruitful and stimulating study at this stage. While it must be in large part didactic, it can be taught in such a way that the pupils' own observations, supplemented by diagrams and lantern slides, are used as the groundwork, and the gradual accumulation of observed fact and consequent modification of opinion can be appreciated. An historical treatment is at the same time both helpful to a clear understanding and very rich in human interest

The following practical work can easily be done by girls of this age, in a school situated in a district not too liable to fogs, if the work is begun in the autumn term. The observations must of necessity be made out of school and must constantly be discussed and checked in class.

1. Identification of the chief constellations; observation of the fact that the fixed stars and constellations keep the same relative position but trace out a circle round the Pole Star complete in twenty-four hours; and that the whole scenery of the sky shifts its position as the seasons progress

2. Identification of such planets as may be visible; the keeping of careful charts to show the apparent movement of one which moves in a larger, and one which moves in a smaller, orbit than the earth.

3. Observations on time of rising and setting, position of rising and setting, and path across sky of sun and moon.

4. Phases of the moon.

With a small telescope or even very good field-glasses the work can be greatly extended, the nebula in Orion which can just be detected by the naked eye can be found with certainty; the surface of the moon can be studied; the moons of Jupiter can be found, their movements observed; and the fact discovered that whereas the planets can be magnified to appear as discs, the fixed stars cannot.

It is important that the observational work should get well ahead of the lessons which deal with its interpretation, and there is no difficulty in this as at first a good deal of help will have to be given in suggesting points for observation, in criticism of charts, and so forth. Early ideas with regard to the earth, sun, and stars may be described, and possible interpretations of the girls' own observations of the apparent movements of the fixed stars and of the sun discussed. It is important that, at the outset, they should realise the possibility of the movement being regarded as *either* real *or* only apparent, and what the acceptance of either theory would involve. They are then prepared to follow with zest the interpretations given by Ptolemy, Kepler and Copernicus, to sympathise with those who still doubted the real movement of

the earth, and to be thrilled at the discovery of the parallax of some of the fixed stars. The scope of the course must vary greatly with the ability of the class and with its mathematical knowledge, but it must not only deal with the solar system, but give an idea of the magnitude of the Universe as a whole. Theories of the origin of the solar system, the history of the earth and its movements, may lead naturally to a discussion of the seasons, of early modifications of the earth's crust, and of the great wind belts.

Such a course as this may run concurrently with a course of experimental work on light, the two sets of lessons being constantly linked together. Very simple experiments showing propagation of light in straight lines, formation of shadows, reflection and refraction will lead on to the study of the eye, and of optical instruments and their use in the observatory. Colour, the wave theory of light, and means of measuring the velocity of light can also be simply dealt with.

IV. *Ages* 15 *and* 16.—During the last two years of the general school course the pupils should be introduced to some of the theories which dominate scientific thought at the present day. They should realise how great theories grow—the industrious collection of data, the leap forward of some master-mind to grasp the deeper truth which underlies and unifies the apparently disconnected facts, the laborious process of verification. (*a*) The object of the first term's work is to bring forward the wide conception that all forms of energy are convertible one into another, and that the great mechanical devices which have been invented are methods of converting the forms of energy into the most useful kind for any special piece of work. It may also form an introduction to the study of magnetism and electricity and show how the electric power used in every-day life is generated. For example, it is quite easy to measure the mechanical equivalent of heat, to show how chemical energy can be used to generate electric energy, and to show how electric energy can cause chemical change. In the study of the dynamo, magnetic and electric energy can be shown to help each other and to produce heat, light, and mechanical work. This will lead to a discussion of the working of electric trams, the production of electric light, and of much else. (*b*) The object of this part of the course is to obtain experimental results which lead on to an understanding of the general theories with regard to the constitution of matter.

The experiments can be made to develop in a logical sequence starting from the study of air and the oxides. They can be carried out both qualitatively and quantitatively, leading to the knowledge of the quantitative nature of chemical action and also to the properties of many substances—*e.g.*, acids, alkalies, and salts. Equivalent weights of some of the elements may be found by simple but accurate work.

A possible arrangement of this experimental work is as follows:—

1. Chemical changes caused by heating substances in air
2. Chemical changes due to heating substances out of contact with air.
3. Chemical changes due to the action of substances on each other.

When new substances are discovered their properties can be investigated and the history of the discovery in many cases given.

An important bit of work which should not be omitted in a course of this kind is the application of chemical properties of substances used in every-day life—*e.g.*, the softening of water, the preparation of explosives and fertilising agents, the comparison of baking-soda and washing-soda, the manufacture of matches, &c. But these will be side issues

The collection of experimental results and a discussion of the explanation of these will give rise to an historical treatment of the molecular and atomic theory, Dalton's work being dealt with. The newer theories of the constitution of matter and their bearing on the older theories may then be discussed. The theoretical explanation of many results obtained in the early part of the course now becomes evident, and facts which had hitherto appeared disconnected and comparatively meaningless are suddenly seen to be intimately connected and interdependent; a new mental outlook is reached which both transforms the view of knowledge already obtained and suggests fresh problems to attack.

V. *Ages* 17 *and* 18.—No girl should leave school without some acquaintance

with the laws of health based upon a knowledge of the working of a living body. It is preferable that this should be given at a late stage in the school course, both on account of the greater maturity of mind and body which has been attained, and also because sound elementary knowledge of physics and chemistry is a necessary antecedent. It is best to put such a course between the years of 17 and 18, and it might well be given to all at this age, even if specialisation has begun; where, however, the majority of girls leave when they are about 16, some part of it at least should be allowed to run concurrently with Science lower down the school. It should, if possible, be prefaced by a course of general elementary biology, and in any case as much experimental and observational work should be introduced as will give the girls an understanding of the metabolism of a green plant, a fungoid plant, and an animal, transformation of energy being dealt with as well as transformation of matter, and the interdependence of the three types being clearly brought out. The actual processes in the human body may be dealt with more in detail, the work being given a definitely human trend and used, not only to instruct the girls in personal hygiene, but still more to give some knowledge of the social problems of the present day. Thus the nutrition of the body leads directly to a consideration of dietaries and to the effect of an insufficient or badly balanced diet, and this especially in the case of growing children. The function of respiration will lead to a consideration of methods of ventilation and to the harm inevitably resulting from lack of ventilation and from overcrowding This will be followed by some consideration of present housing conditions in town and country, the powers of local authorities in the matter and steps already taken for improvement. The functions of nerve and brain lead to the influence of narcotics and stimulants and also to the study of fatigue. An account of the growth of legislation with regard to work in factories and to child labour naturally follows.

This last course goes considerably beyond the work usually undertaken by the Science Mistress, but it is very valuable that such questions should be studied in a scientific manner and with a sound scientific background. It is of the utmost importance that the general mass of citizens shall learn to think more biologically on such questions, and this link between live human interests and their scientific studies is invaluable for the girls.

In every school course much is necessarily omitted, but it is understood that voluntary work done in connection with school societies will supplement the laboratory teaching to some extent. Thus through a Field Club may be given familiarity with common plants and their habitats, or, again, a knowledge of the geological structure of the neighbourhood with its effect on scenery and on history.

VI. SCHEME OF SCIENCE WORK IN A PUBLIC SECONDARY SCHOOL FOR GIRLS.

By LILIAN J. CLARKE, Senior Science Mistress, James Allen's Girls' School, Dulwich.

The following scheme of science work has been thought out and adopted in a large secondary school for girls, but it is not put forward as one to be followed by all. Each teacher must herself decide what is best suited to the special conditions of the school in which she works. The school in which this scheme is followed is an endowed day school containing nearly 400 girls, who are allowed to enter at the age of seven, and may stay until they are nineteen. Special permission is needed for girls to remain after they reach the age of nineteen.

Post-matriculation work in botany and chemistry is taken by some girls, but details of the general or pre-matriculation science course only are here given. For many reasons great value is attached to the study of botany; and botany is the science to which most time is given; it was felt, however, to be so essential that all girls should have some knowledge of physics and chemistry that half the time given to science in the three forms of the Middle School (two hours per week) is allotted to elementary physics and chemistry, and half to botany. Every girl who passes through the school studies elementary physics and chemistry for three years.

In the classes above the Middle School, all the time allotted to science is given to botany, but lately a voluntary class has been arranged, so that girls wishing to continue the study of elementary physics and chemistry may do so on one afternoon a week.

The aim throughout is for the work in both botany and chemistry to be thoroughly practical; the girls have, therefore, to make their own experiments. After experiments have been carried out the results obtained by each girl are received and tabulated and conclusions are then drawn from these results by the whole class. If some results are in opposition to the greater number they are carefully examined, and the girls themselves often suggest possible explanations of the discrepancies.

No text-books are used, but each girl in the Upper Forms possesses a small Flora.

In the botany classes the plants are studied mainly as living things by means of observations and experiments. Drawings are made from actual specimens and experiments, and not from drawings on the blackboard.

Microscopes are not used by girls taking the pre-specialisation science course, except in the highest classes, where the structure of a green cell, a stomate, and a leaf are studied.

Great help has been derived in the study of botany from the botany gardens which have been gradually made in response to the needs of the botany teaching in the laboratory. As a rule two girls are responsible for a garden; and every year the girls change their gardens. The work in the botany gardens each year is determined by the nature of the work in the laboratory, and the indoor and out-of-door work are closely connected. So far as possible the girls choose the gardens for which they will be responsible.

No time is allowed in the actual school hours for gardening (except in the case of a few girls responsible for vegetable gardens): the girls look after their gardens in the mid-morning and mid-day recesses. The work is voluntary, but so many applications are received for botany gardens that the difficulty has been to provide gardens for all who wished to have them.

The science work of the pre-specialisation period may be divided roughly into three stages, namely:—

Division I.—The work in the younger forms, before a course of systematic science is begun.

Division II.—The work in the Middle School, where definite courses of botany, and elementary physics and chemistry, are taken.

Division III.—The work in the Upper Forms, where botany is the only science studied as a regular class subject.

Division I.

Age of girls, seven to eleven approximately. Average time per week, ¾ hour.

The work varies in different years. an account of what is done in a particular year is given below :—

Land plants and animals in school gardens. Water plants and animals in school gardens. Trees in winter, spring, summer. Study of common weeds, with special reference to the reasons for their success in competition with other plants. Simple descriptions of flowers. Stages in life-histories of various plants grown by the girls in their own plots. Study of fruits in the lane and wood of botany gardens, and various methods of dispersal of seeds observed in the botany gardens and elsewhere.

Division II.

Science in the Middle School—a three years' course. Age of girls eleven to fourteen approximately.

A. Elementary physics and chemistry. B. Botany. Total amount of time given, two hours per week in each of the three Forms. (One and a-half hour a week has lately been given to elementary physics and chemistry, and no time allowed for homework; one hour a week, as in former years, being given to botany.)

A. *General Elementary Course in Physics and Chemistry.*

So far as possible all girls, working in pairs, carry out separate experiments along the lines indicated, enter during the lesson all measurements taken, make sketches of apparatus, and learn to express themselves accurately and concisely in written records. Some experiments are, of necessity, demonstrations.

The course need not follow the prescribed lines, and is open to modification by the girls themselves; the ground can generally be covered, though the details may vary. The spirit of experimental inquiry is always encouraged, and the girls are led to depend upon the results they themselves obtain.

I. First Year.

Elementary Physics and Mensuration.

(The mensuration is partly taken in arithmetic lessons.)

(*a*) *Measurement of Length.*—The measurement of the straight edges of a variety of objects in English and metric units. The measurement of the curved lines of a variety of objects. The discovery of the ratio π.

(*b*) *Measurement of Area* (English and metric units).—Areas of rectangles, triangles, parallelograms, and circles; first from drawings on squared paper. Simple examples of the division of irregular areas into known figures. The making of plans to scale (maps). Measurement of the surface area of some common solids.

(*c*) *Measurement of Volume.* The units of volume (from actual models).—The volumes of rectangular blocks, prisms and cylinders. The volumes of irregular solids (floating and non-floating) by the method of displacement.

(*d*) The unit of weight being given, the simple lever (see-saw) is examined and the Law of Moments arrived at. The application of this principle and the use and construction of the Beam Balance follows. The densities of some solids (the volumes have been previously measured) is found; also the densities of some common liquids. *Archimedes' Principle* is then discovered, and some of its applications are discussed (the principle of ship-loading and Plimsoll's mark is introduced). The specific gravity of some solids and liquids is found by varying methods, and seen to be useful as a means of identification and of determining purity.

(*e*) *Atmospheric Pressure.*—Simple experiments on the pressure of the air. Measurement of air pressure. Barometers. A barometer chart is kept and observations are made of wind and weather.

Simple experiments follow on the vapour pressure of water and of methylated spirit at different temperatures. Conditions determining evaporation of water are discussed, and the application of this to everyday life (drying of clothes, &c.)

(*f*) *Other Physical Properties of the Air.*—Air is seen to possess weight. Air is seen to expand when heated and contract when cooled. Its density is roughly determined.

II. Second Year.

Elementary Chemistry.

The action of air on a variety of common substances, suggested by the class, is examined, the balance being used. Iron—having shown an increase in weight—is left to rust in an enclosed space. The *air* is thus seen to consist of at least two gases—active and inactive, so far as burning and rusting are concerned—called oxygen and nitrogen.

A candle, phosphorus, and other combustible substances are burned in an enclosed space and observations recorded. Increase in weight of phosphorus is discovered on burning it in a tube plugged with asbestos

Phosphorus burned in a closed vessel shows no change in weight until the vessel is opened. *The Law of the Conservation of Matter* is thus illustrated.

Various metals are heated in the air, and observations recorded. The processes of rusting and burning are compared, and a definite statement of the composition of air is arrived at; also a first insight into the differences between mixtures and compounds

Two oxides easily decomposed by heat (red lead and mercury oxide) are examined; and *oxygen* tested for. Potassium chlorate is also found to yield oxygen on heating, and, with manganese dioxide, is used in the preparation of the gas

Various metals and non-metals are burned in the oxygen prepared, and, when possible, the oxides are dissolved and their solutions tested with litmus.

Thus a chemical distinction between metals and non-metals is arrived at. The terms Element, Compound, Mixture are discussed.

The work of *Priestley* and *Lavoisier* is briefly described, together with an outline of the development of theories relating to combustion

The properties of *Acids* are next examined, especially their corrosive action on metals (suggested by the known effect of vinegar on a steel knife). A new explosive gas (*Hydrogen*) is discovered; and green vitriol and white vitriol are prepared and examined A chemical change is seen to have taken place when the metal dissolved in acid. Heat was evolved. Hydrogen is prepared and its properties examined. The formation of a mist after exploding or burning the gas suggests that its oxide is a liquid, and an apparatus is set up for collecting hydrogen oxide Some of the physical and chemical properties of the liquid so made are examined and compared with those of the only other known liquid which is colourless, tasteless, odourless, and neutral The oxide of hydrogen is thus proved to be *water* (synthetical method).

By using sodium, potassium, magnesium, and other metals with water or steam, the chemical composition of water is further confirmed, and the alkaline hydroxides are met with again.

Water is also analysed by the use of an electric current, and the volume relationship of the gases composing it is established

III. Third Year.

Elementary Physics and Chemistry.

The various physical changes undergone by *water* under the influence of heat are observed, and some of the laws of heat thus taught incidentally.

Other substances (liquids, gases, metals, and glass) are found to *expand* with heat.

Methylated spirit is found to expand more than water for the same amount of heat. The construction of a *Thermometer* is explained, and scales of temperature are compared. *Convection* is found to take place in air as well as in water.

Ventilation and the heating of buildings by hot-water pipes are studied in the light of this knowledge

Conduction of heat is seen in metals, and the conductivity of copper and iron is compared. Wire gauze is seen to cool a flame below the ignition point of the gas. The historical application of this in the Davy lamp is explained Air and water are found to be bad conductors. *Radiation* is discussed very briefly, together with the general heating of the school building by radiators and fires.

The effect of cooling water is observed, and attention is directed to the importance of the anomalous behaviour of water on freezing. Reference is made to the bursting of pipes in winter, weathering of rocks, movement of glaciers, &c.

Tap water is now examined, its solid and gaseous impurities being separately obtained and investigated. *Carbon dioxide* is discovered in the atmosphere, and also in the gas given off when tap water is boiled.

The *percentage volume of air dissolved* in the laboratory water is measured and its composition determined. Reference is made to animals and plants living in water.

Chalk—over which the London water has certainly passed—is examined; also marble, and the 'furring' from a kettle.

Carbon dioxide is prepared, and a connection is discovered between the presence of this gas dissolved in tap water and the presence of chalk in the water.

Lime is obtained from chalk, and the chemical constitution of chalk established.

The action of air on lime is found; hence the hardening of mortar.

The sources of carbon dioxide and the means of renewing it from the air are discussed, and again the weathering of rocks is explained.

The *hardness* of tap water, boiled tap water, and rain water is compared, and methods of softening are suggested and tried; among others, the effect of *Washing soda* is ascertained The cleansing properties of this and other alkalies is examined.

Acids and Alkalies are found to neutralise one another; *salts* are formed (Common salt and potassium nitrate are prepared, and others as time allows)

At the close of this course voluntary classes are held for girls wishing to continue the study of chemistry, and during the next year they become acquainted with the preparation and properties of the three chief mineral acids and of some of the elements and compounds derived from them They also make a series of simple quantitative experiments, which lead to an elementary introduction to the rudiments of chemical theory.

B. *Botany in the Middle School One hour per week*

1 *Study of Plants in Lane in Botany Gardens.*—The girls of the youngest class in this section are responsible for the care and development of the lane in the botany gardens, and the work in the laboratory for the year is in close connection with the out-of-door work

The plants are examined in spring, summer, autumn, and winter As often as possible the whole plant is taken Drawings of the plant are made by the girls, and detailed descriptions are given of various parts. In this way roots, underground stems, above-ground stems, foliage leaves, flowers, fruits, seeds, and seedlings are studied in a simple way, and practice is obtained in making accurate drawings. Records are kept of the plants in the lane in successive months.

Study of Plants in Wood in Botany Gardens.—In some years the girls in a class, parallel to that in which the girls are responsible for the lane, have charge of a small wood and study woodland plants. In other years the girls of the class above this one may undertake the work.

2. *Study of Trees.*—There has been planted in the gardens an example of every tree common in England; also in the oak wood recently made there are numbers of oak trees and ash trees. With the help of these and twigs given by various people the girls are able to study trees. The following are some of the points taken: Branching (monopodial and sympodial); structure of buds; development of buds; structure of wood as seen with the naked eye; sections

of dicotyledon stems and monocotyledon stems, as seen with a hand lens; lenticels; experiments to show passage of gases through lenticels.

3. *Pollination Experiments*.—The girls have charge of many plots in which they grow plants which they use in pollination experiments. When the plants are bearing flower-buds, many botany lesson-times are spent in the garden.

Experiments are first made to see if pollen is necessary for the formation of fruit, and the girls themselves usually suggest that another set of experiments should be made in order to see if the non-formation of fruit is due to shock caused by cutting out the stamens of the flower. Experiments are then made to see if self-pollination can take place in various plants. Many different genera are taken, and as many experiments made in each case as time will allow.

In the year 1916, after the girls had made experiments to see if pollen is necessary for the formation of fruit in a certain plant, and were comparing the results they had obtained with results obtained in previous years, they had the records of 500 experiments to consider before they drew any conclusions.

The experiments in pollination afford good training in manipulation, in noting results of experiments, in comparing these results with other results, and in drawing conclusions from a large number of facts.

After the results of a number of experiments have been noted and tabulated, references are made to Darwin's and Muller's experiments in pollination; and if the girls happen to have chosen any of the plants used in the experiments described in 'Cross- and Self-Fertilisation' or 'The Fertilisation of Flowers,' they often hear the results obtained by Darwin and others and compare them with the results of their own experiments.

4 *Study of Fruits*.—There are many opportunities for the girls to study and draw the fruits in the lane, the wood, the Order beds, and the pollination beds. The observations enable the fruits to be classified. Many opportunities for the study of dispersal of seeds are also found in the botany gardens. The girls find growing in their gardens plants which had not been planted by them; and after the long holidays thousands of groundsel plants have been found in the wood. Dispersal of winged and plumed seeds and fruits by wind, and of hooked fruits by animals, are soon noted. Reference is made to Darwin's observations and experiments on the dispersal of seed, and many of the girls read the chapter on dispersal of seeds in 'Origin of Species.'

Division III.

Age of Girls, 14-17. Average time per week, 2½ hours

1. Detailed study of seeds and seedlings, leading to many experiments, are carried out by the girls themselves in laboratory and garden. Various dicotyledon and monocotyledon seeds are examined and drawn. Experiments are made to see in what gases seeds germinate, and if seeds germinate at all temperatures. After the germination of various seeds has been watched, and successive stages in the seedlings drawn to scale, simple experiments are made to see in what parts of the root and stem growth is most rapid, to find if roots can absorb solids, to trace the path of the water in the plant, to determine the influence of light, gravity, and moisture on the direction of growth of roots, and the influence of light and gravity on the direction of growth of stems.

Experiments are made by the girls to find what gas is given off by germinating seeds, and to determine if there is a rise of temperature when respiration takes place.

Other experiments show what gas is given off by a green plant in the presence of light and carbon dioxide; the formation of starch in a green plant in the presence of light and carbon dioxide; the influence of light, warmth, and the presence of carbon dioxide and chlorophyll on the production of starch.

Experiments are made to find whether a plant gives off water, to prove the presence of pores in leaves, to see from which side of a leaf more water is given off, and to measure the weight and volume of water given off by a plant in a certain time.

The percentage of water and ash is found in plants, and then the composition of the ash is taken. Sometimes a girl in the Upper VI., specialising in science, may be able to analyse the ash; but, failing this, an analysis of the ash by

an expert is given to the girls. A list of elements constantly present in plants is thus obtained, and the girls can then find out by means of growing plants in food solutions which of those elements is necessary to the life of plants. Many perennials are grown in normal food solutions, and generations of plants that have never been in the soil have been reared.

2. *Climbing Plants* —The girls compare the rates of revolution of various twining plants, see if twining is influenced by the nature of the support, and make many other experiments.

3. *Classification* —Before the girls study classification they become familiar with many of the British plants growing in the lane, wood, heath, and pond of the botany gardens. When they are studying the Natural Orders they have charge of the Order beds in the garden.

4. *Soil Experiments.*—Experiments are made on soils from different parts of the botany gardens Some of the experiments are : Comparison of the rates at which water passes down through various soils; comparison of the rates at which water passes up through various soils; comparison of the rates at which air passes through various soils; determination of percentage of humus in various soils; determination of some of the effects of the presence of humus.

5. *Ecology.*

(1) Water plants.
(2) Fresh-water marsh plants
(3) Sea-shore plants { Pebble beach, Sand dune, Salt marsh.
(4) Heath and moorland plants.
(5) Plants of oak wood.

The botany gardens include a pond, fresh-water marshes, a pebble beach, a sand-dune, a salt marsh, a heath, and an oak wood, and in these the above plants are studied. In addition to the study of the structure of characteristic plants in these ecological gardens, many interesting problems are taken, and original investigations can be made For example, experiments are being made in the oak wood to investigate the gradual changes in the character of the soil, in the total evaporating power of the atmosphere, and in the light intensity as the trees develop more leaves; and observations will be made of the effects of these changes on the ground vegetation.

VII. SUGGESTIONS FOR A COURSE OF PRACTICAL FOOD STUDIES.

By Henry E. Armstrong

(The following suggestions for a series of practical food studies are very similar in form and purpose to those given in the schemes accepted by the Association in 1889 and 1890. This scheme was offered to the Association, precisely in the form in which it is now printed, at the Norwich meeting in 1907; the Committee of Section L suggested that it should be published in full but this recommendation was not adopted by the Committee of Recommendations My object was to aid teachers, especially in girls' schools, who desired to develop a logical, comprehensive laboratory course of instruction based upon food materials At the time I stated that the scheme was not half complete: it needs elaboration, especially on the physical, botanical and biological sides; and had the slightest encouragement been given, I should have developed it. Its present belated appearance may perhaps serve to stimulate a few teachers to take up a line of work which is certainly of promise, if only it be pursued in a proper scientific spirit. My desire has been to see a scheme of instruction gradually introduced into girls' education which will make them scientific observers and thinkers in relation to all home matters: if this position were gained, they would stand on an intellectual plane far higher than that they now occupy.)

Study of Food.

At the outset, children might be asked what they know about food—what people take as food—to draw up a list of foods, arranging the different kinds together according as they are vegetable, animal, etc.—to think what infants live on (*milk and air*); what is the simplest food we can live on when we have teeth (bread and water and air); that if butter or dripping (fat) be added to bread, it becomes improved both to taste and as food; and that bread and butter together with milk and water and air are a thoroughly satisfying food.

After much talking about such matters, they should be led to write simple accounts of what they know or can find out by observation and inquiry about foods under heads similar to the above. It would be well to let them find out what animals generally live on, so that they may understand the distinction between carnivorous and herbivorous animals.

As it is possible to live on bread, air and water, bread may be studied thoroughly as a typical solid food. The answer to the question 'What is it made from?' 'Flour or wheat'—would lead to the further question 'What is flour?' Flour should then be made by each child—practically, as it is still made by savage races and as it was made before flour mills were invented—by pounding wheat in a mortar or crushing it with a rolling pin. The exercise should be carried out seriously and with scrupulous care, each child being made to weigh out a certain quantity of wheat, then to powder or crush it and to separate the flour from the bran by sieving through book muslin; the flour and bran should then be weighed separately and the percentage of each calculated and the loss. A record in writing of this work should be kept by each child.

In the course of the lessons, the production of wheat should be discussed—where and how it is grown. This would give an opportunity for geography teaching and for economic teaching, which might well be utilised: diagrams might be made to illustrate the consumption, yield per acre, price, imports and exports, etc.

The children should be set to examine and describe wheat—the average size and weight of the grains, their appearance, density, etc. They should also be set to grow it—to plant it in different ways, in dry and wet sawdust, in sand

and in soil and also just dipping into water on muslin tied over the mouth of a bottle. Wherever possible, wheat should be grown as a crop in the school garden.

A regular account of all that went on should be kept.

To return to bread—having made flour (or before this, if desirable) they should assist in actually making a batch of bread in the kitchen and be led to observe (not be told merely, by the teacher) and record everything that happened and was done.

Wheat having been thus dealt with, barley and oats and even maize and rice should be studied in a similar way—and cakes should be made by the children (and afterwards eaten) from barley-meal, oatmeal, maize-meal and rice-meal, in order that the value of cereal grains generally as foods might be impressed upon them. A valuable lesson would be given if cakes were made, at this stage, from various kinds of meal.

Study of Flour.

It would be learnt in the kitchen that flour forms a paste which is scarcely sticky when mixed with not too much water, but that more water makes it sticky; the question arises—What does water do to flour? Some things—salt and sugar, for instance—dissolve in water: does flour? Each child should work a pellet of flour paste between its thumb and two fingers under water (in a common tumbler). It would then be discovered that something is washed away from the sticky mass and that at last a peculiar stringy rather than sticky mass remains from which nothing more can be washed away even by running water. From the turbid water in the tumbler, a white solid gradually settles down which is not in the least sticky. The experiment should be repeated on a larger scale by each child with say 30 grams of flour. This should be put into a basin and mixed, by means of a short stout glass rod or stick, with about half its weight of water. The paste should then be kneaded between the fingers under a tap from which water trickles, the washings being collected in a basin over which a square of muslin is spread, so as to catch any sticky particles which may be broken away. When the washings are no longer milky, the stringy mass should be dried by rolling it on the palm of the hand, constantly drying the hand with a towel, just up to the point at which it shows signs of sticking—but no longer; then it should be placed on a 2 or 3 inch square of grease-proof paper and dried in a water oven. When dry it should be weighed.

The washings should be poured into a large pickle-jar or cylinder and allowed to settle. After an interval, as much as possible of the clear liquid should be syphoned off and the residue collected on a filter, dried and weighed.

In this way, the flour would be separated into *gluten* and *starch* and a fair estimate would be made of the amounts of each

On treating barley-meal, oatmeal, maize-meal and rice-meal in the same way, it would be found that they did not yield the sticky substance (gluten) when kneaded with water. One reason why wheaten meal is more suitable for kitchen purposes than other kinds of cereal meals would then be made clear.

Study of Starch.

Starch is in common use—for what purpose? For stiffening articles of clothing—collars, cuffs, shirt fronts, etc What is it like and how is it used? Examine samples and describe it. Prepare a quantity for starching by mixing . . . grams with . . . cubic centimetres of cold water, using your forefinger to stir them together, then pour the paste in a thin stream into . . . cubic centimetres of boiling hot water contained in a dish or saucepan of suitable size, stirring constantly, as you pour in the paste, with a wooden spoon or rod. Set the liquid aside to cool but cool a portion rapidly in a test tube under the tap Taste it and solid starch. Describe the appearance of the liquid and everything that happens to it as it cools. Dilute a small portion considerably, to a known extent; then add a drop or two of a solution of iodine to a litre of the diluted liquid. You will thus become acquainted with the characteristic test for starch.

Carry out a like series of operations with the starch you have prepared from flour.

Examine starches from different sources under the microscope—note the effect of iodine.

Test arrowroot, sago, tapioca, macaroni, vermicelli, for starch ; also try if you can extract gluten from these materials.

The presence of starch, in considerable quantity, in important food materials, having been thus established and something learnt of its properties, the part it plays in cereal grains may be considered.

What happens to the seed when it germinates and a plant grows out of it? Some information will have been gained already on this point. The gradual disappearance of the starch will have been noted. By tasting grains which have been soaked in water and then kept for various periods, the development of a sweet taste will be noticed. Malt may then be introduced and an account given of the way in which it is made and what it is used for. Malt should be made by steeping barley in water during . . . . hours, then keeping it and allowing it to germinate until the young plantlet is about . . . . inches long, after which it is dried at a temperature not exceeding . . . . C. The appearance of the starch grains of the malted and unmalted barley should be noticed under the microscope. Then equal quantities of barley and of malt which have been ground in a coffee mill should each be mixed with about . . . . times their weight of ordinary water and the mixture allowed to stand . . . . hours. It would then be discovered that in one case the starch disappears. The liquids should be examined and the weights of equal volumes (the relative densities) contrasted with that of water. Known quantities should be evaporated in weighed dishes on the water bath, in order that the weights of matter in solution might be determined. It would thus be discovered that the starch is changed into a soluble sugar-like material and the disappearance of the starch from the seed during germination would be explained.

Foster's 'Primer of Physiology' (Macmillan & Co., Ltd., 1s.) might be studied at this stage with advantage and the nature of the stomach and intestines made clear. At some time also the stomach and the intestines of a freshly killed rabbit should be laid bare before the class and their character and arrangement fully explained.

The children might then be asked—What happens to the starch in our food ? What is done with it?—It is first chewed in the mouth and becomes mixed with spittle or saliva, is it not? Does this latter produce any effect on it? Try! Spit freely into a test tube half full of solidified starch paste prepared as directed; mix the starch and saliva well together with the aid of a light wooden rod which you have made for the purpose. Plunge the tube into a water bath kept at about . . . C ; examine it at intervals. Repeat the experiment but first spit into the test tube and then plunge it into boiling water; after about five minutes' heating add the starch and digest the mixture : at the same time digest a mixture of starch with similar unheated saliva. Also make comparative experiments in a similar way with unboiled and boiled malt-extract.

It would then be discovered that starch is rendered soluble by something which is present both in malt-extract and in saliva—something, moreover, which is rendered inactive by heating to near the boiling point of water. This substance has been named *Diastase*.

The importance of the change thus undergone by starch when 'digested' with the aid of the diastase either in malt-extract or in saliva would be more obvious when it is realised that starch *diffuses* with extreme slowness into water and that it does not pass through wet bladder or vegetable parchment, whereas the sugar which is formed from it on digestion, like ordinary sugar and salt, diffuses readily.

Our starchy food is cooked either by baking or by boiling it—what is the effect on the starch of baking and boiling ?

When heated in the oven, as in baking bread or pastry, flour is browned and may easily be burnt; but flour is more than starch—what happens to

starch when it is heated alone ? Study the effect of heat on starch very carefully, at gradually increasing temperatures.

At an early stage, vapour is given off—what does this look like ? Steam—that is to say, water vapour. Perhaps the starch was not dry—dry it carefully at a temperature at which wet things are easily dried and repeat the experiment. Vapour is still given off when the dried starch is heated—is it water vapour ? How can you find out ? What happens when water vapour meets a cold surface? Try! The vapour becomes liquid—it condenses. See if the vapour from starch can be condensed. You find it can and that the liquid is like water—is it water? Would not the discovery that it is water be of interest and importance as an indication that water is in some way contained in starch? Try therefore to prove that the liquid is water. Heat . . . grams of starch in a vessel from which the vapour can only escape through a cooled tube (a condenser), and when you have sufficient of the liquid, contrast it carefully with water

But water is not the only product on heating starch: as the heating is continued, the starch becomes more and more burnt or charred, at last, it is converted into a mass of very light charcoal, which easily takes fire and burns away to nothing! Are not these strange changes—who would suppose that in white starch there are hidden away in some mysterious manner both black charcoal or *carbon* (to give it its Latin name) and water?

How comes it that starch is useful to us as food—has the presence of carbon and water in it anything to do with its value as a foodstuff? We certainly cannot eat charcoal as such but what *can* we do with it? What is it used for? In England, we no longer use it as fuel, as it is too expensive; in France and Japan, however, it is still much used in cooking and also for warming rooms. And have you not heard through the newspapers of people being killed by the fumes of burning charcoal? Does not this show that it must not be assumed, because nothing is seen to escape, that charcoal gives nothing when burnt?

What does food do for us? It makes us grow, you will say! But does it not also keep us warm—may not perhaps the warmth be produced at least in part by the burning of the carbon which is in the starch we eat? Is not the suggestion one which it is well worth following up—will it not be well to study burning? What are the things we burn or which we know will burn? Make out a list.

Combustibles.

From the domestic point of view, our most important fuel or combustible is coal—what do you know of the way in which coal burns—does it just burn when set fire to? You know it does not. To keep a fire burning, air must be supplied to it; if a fire be low, it is often restored by holding a newspaper in front of the stove or grate in such a way that a draught of air is forced through the feebly glowing embers—very soon these begin to burn brightly; and at any time a fire may be caused to burn brightly by increasing the draught through it: by using bellows, we often make a fire burn up quickly.

Must we not conclude, therefore, that air has something to do with the burning of coal? Is this true of other combustibles? Consider what you know and if you cannot produce evidence one way or the other—but such questions should be settled by trial or by experiment, not by guessing.

Under ordinary conditions, we cannot see what happens to the air during burning—suppose you shut up a burning candle with air so that you can watch the air as well as the candle flame. You will probably think of several ways of making such an experiment; the easiest perhaps is to place a small piece of candle on a block of wood floating on water in a basin and cautiously to invert over the flame a bell jar provided with a stopper which you insert the moment the bell jar is in position; or you may use a small statuette cover. Noting everything that happens, you see that almost at once the sides of the jar become bedewed; the flame grows dim and after a time goes out; at the same time the water rises in the jar, showing that some of the air is used up. It is desirable to paint a line a short way up the jar with Brunswick black, such as is used in blacking stoves, to mark the position of the water at the

start. When the jar is again cool, the point to which the water rises should be marked in some suitable way and the capacity of the jar ascertained above this mark and also between it and the lower mark: the amount of air which disappears is then ascertained.

Similar experiments should then be made with other combustibles—spirit, different oils and gas In every case, the flame soon gives out and some air disappears: less than a fifth. Clearly the air is concerned in the burning—but very partially: does it not seem that it contains something which is active rather than that it is active as a whole?

Solid combustibles are not so easily dealt with: if an electric current be available, you may fire such substances in air, in a bell jar standing over water, by means of a spiral of platinum heated to redness by the current—in every case air disappears; but never quite a fifth.

But why does some of the air disappear—is it because it is in some way changed into water vapour which condenses on the jar and on contact with the water used in shutting up the air in the bell jar? Do all combustible substances give water when burnt? Can water be condensed from the candle flame and other flames? Try the effect of exposing a cold surface (a flask full of cold water) to each At once it is bedewed but except in the case of the spirit flame it is soon smoked or coated with soot, which looks like charcoal or carbon in a fine state of division—so there seems to be carbon in combustibles, as there is in starch Although the liquid which bedews the flask looks like water, you have no proof that it is water: as nothing is to be taken for granted, you must burn the several combustibles in such a way that you can collect enough of the liquid from each to contrast it with water.

Having done this, you feel sure that water comes from each of the liquid combustibles when they are burnt in air. But what of solid combustibles such as wood, charcoal, coal, coke? It should not be difficult to make observations over fires made with these and to convince yourself that charcoal and coke give practically no water although indications are obtained that it is formed on burning wood and coal

What becomes of carbon when it is burnt, therefore, remains a mystery to be solved only by further inquiry.

Although there is yet much to learn as to what happens when things burn, it is now at least clear that starch may be burnt with the aid of air and that much heat is given out: knowing as we all do that we must have air to live, may it not be that the air we inhale serves to burn part, at least, of our food, quietly and in such a way that we are kept warm by the process? If so, the fact that it is an indispensable article of food meets with an explanation.

Before taking up fresh subjects, it is worth while to take stock of the knowledge gained by studying flour and starch experimentally: Flour has been resolved into starch and gluten; the latter, however, has been set aside temporarily while starch was being examined It has been ascertained that although wheaten flour has certain advantages, owing to the peculiar properties of its gluten, other cereal grains give flours which are also mixtures of starch and gluten-like substances; potatoes, however, have been found to consist almost wholly of starch. Starch, it has been discovered, contains both carbon and water, associated apparently in some strange way which altogether masks their ordinary properties. Itself insoluble but convertible into a peculiar jelly-like material (starch paste) by heating with water, starch is changed by diastase (a constituent of barley and of human saliva) into a soluble diffusible sugar. A little reflection will show that these properties give starch its peculiar value. It occurs in the seed of cereals and in the potato tuber—the resting parts of the plants: if it were soluble, it could not well be stored up; and unless it could be rendered soluble by digestion, it could not pass into circulation and serve as food—in fact it has just the attributes which are required of a substance occupying the position it holds in the plant world. Starch is a substance which is easily burnt: in studying it from this point of view, it has been discovered that burning is a process in which air is concerned—not air as a whole but an active portion in it.

THE KITCHEN.

Books are usually divided into chapters: when the story is carried to a certain point it is broken off and a new chapter is begun, in which some other set of characters is considered. It will be well to leave the study of food for a time and pass to the kitchen, where the stove and fender and fire irons are to be found. All these are made of iron and, like steel knives, must be carefully looked after and kept bright. Why? Why too is so much care taken to paint ironwork out of doors? We use many other metals and leave them unpainted—at most they are tarnished, but iron rusts and spoils. What happens to it—what makes it rust? Water, you say—if water be dropped on the fender and be allowed to remain there or if knives are left wet, rust soon appears. You must not be hasty in your conclusions—you will soon find out if you are that your conclusions are often wrong If water be the cause of rust, should not iron rust if corked up with water, say, in an ordinary medicine bottle? Get some bright iron nails (wire or French nails) and try the experiment; at the same time expose some nails in a saucer along with a little water—not enough to cover them Scarcely any rusting takes place in the bottle, while outside the bottle the nails rust considerably Why is this—what was the difference between the two experiments? If air were present in the one case and not in the other and in some way play a part, it may be possible by watching the air to find out if it be concerned. Shut some air up over water along with some wetted iron Some of the air disappears—how much—is the amount definite?—make sure by repeating the experiment several times. What is the remaining air like—is it unchanged air—how will you try! Think of a test. Have you not made a great discovery about air when you take into account what you had previously learnt in your experiments on burning? What will you call this active part of air—may it not, for the time, be called *Fire air*—the air which, in some way, gives rise to fire; or rust air, if you will? In the latter case, however, the name has reference to a less striking property of the air or gas; it is less significant though appropriate in its way. What becomes of the 'Fire air' as the iron rusts—it changes the iron into rust, is it in the rust? If this be so, what must happen as the iron rusts—iron rust, when you handle it, seems to be a much lighter substance than iron (find its exact density as well as that of iron), but is the rusted iron lighter or heavier than the unrusted? Try!

The result of this experiment should leave no doubt in your mind that iron rust is formed by the association or *combination* of the active gas in air with the iron—that it is a *compound* of iron with the active gas. It is clear also, is it not? that in some way the water plays a part—as the rusting only takes place when the air and water act together—what that part is cannot be determined at present, however.

Probably you never suspected that the kitchen range, the fender and the fire irons were in any way to be associated with your food except that they were of use in preparing it—that they could be brought into relation with it through air and water cannot well have entered into your thoughts. Is not the lesson a very valuable one—is it not one that teaches you that no opportunity is to be neglected—that eyes must always be open and willing to see, willing also to send messages to the brain?

Is not the formation of a substance such as iron rust from the metal iron very remarkable? Compare them carefully in every way you can and consider the nature or properties of the two substances. The one, like metals generally, is bright or lustrous when polished and is relatively heavy; it can be bent and beaten and drawn out without breaking—its strength being one reason why it is so useful. Rust, however, is quite unlike a metal—it has no strength and is easily powdered. What does it most resemble, especially when powdered? Red earth, does it not? It may be best described as an earthy substance—in fact, in some parts of our country, in Devonshire particularly, the soil looks just like iron rust and red soils are frequently met with. You may have noticed too that burnt clay is not unlike iron rust. Burn some clay, if you have not.

What is iron itself—is it found anywhere; if not, how is it made? It is

well worth while to inquire what is known of the early use of iron and to consider how, probably, the way to make it was first found out. It is made from ironstone—from iron ores as they are called, some of which are very like iron rust and others like hardened clay. It is made from an earth, in fact—by smelting or heating the earth together with charcoal or coke. You know that carbon burns in air—in the active part of it (Fire air) that is to say: does it perhaps associate with the Fire air as the iron does in rusting and does it release the iron in the ore when it is smelted with it by depriving it of Fire air? Questions such as these are not to be answered without further study.

Study of Burning

As food and fire seem to be closely connected, it may be well now to study fire a little more fully and carefully. How do we produce fire—in the morning when lighting the fire; or at any other time? You say at once—by striking a match. What is a match?—nothing is more commonly used and yet few know anything about it.

The easily inflammable substance—that which is fired by the heat developed by friction in drawing the match over the rough surface of the box—is *phosphorus*. What does the word mean—what language is it derived from? Phosphorus is made largely from animal bones. From bones, you say: can't we get away from ourselves and our food even in studying the matches used in lighting the fire with the aid of which our food is cooked? Do all things move in a circle?

Phosphorus, you will see, when it is put before you, is a yellow wax-like solid; it is always kept under water and must be handled with extreme care and only kept in the fingers during a short time, as it takes fire very easily and the burns it produces heal with difficulty. Why should it inflame sooner or later when taken out of water and not in water? Does this behaviour suggest anything to you? If so, make an experiment to verify your idea. What has this experiment taught you—does it not serve also to bring the match more closely into relationship with the iron stove than you before thought to be likely?

Very little phosphorus is used in matches—how does it burn alone? Carefully dry a small piece, first on a duster and then on porous paper, place it on a brick or tile and touch it with a warm wire: at once it takes fire and burns brightly; as it burns, dense white smoke is given off. Try to stop the smoke from escaping by covering the burning phosphorus with a glass shade. Note what happens—describe the product.

In burning other substances, you have found that the air is concerned—that, in part, it is 'burnt' as well as the inflammable substance: is the air concerned in the burning of phosphorus? Try.

But as phosphorus takes fire so very easily, will it not be well to try to burn it alone to make sure that the air is concerned? It is possible to remove the air from a vessel by means of an air pump. Let us put a piece of carefully dried phosphorus into a strong globular flask, provided with a tightly fitting rubber stopper to which a glass tap is fitted: having exhausted the air by means of the pump and closed the tap, let us now cautiously heat the flask, where the phosphorus lies, over a small flame, sufficiently to melt the phosphorus: nothing happens. Now let us repeat the experiment with a strong flask full of air closed by a simple rubber stopper: the phosphorus takes fire but soon ceases to burn and apparently some remains unburnt. There was not much air in the flask—was any or all of it burnt along with the phosphorus? Think what happened when the phosphorus was exposed in air over water. What then will happen if the stopper be withdrawn from the flask while the neck of the flask is under water? See!

It is clear therefore that whether it be merely exposed in air or burnt in air, the phosphorus kills, as it were, very nearly one-fifth of the air—its behaviour is much like that of all other burning substances, except that, to be precise, it is more like that of iron—which also gives a solid product, unlike the other substances which were burnt. But the air behaves alike to iron and phosphorus, seeing that one-fifth disappears under the influence of each. This

fact would seem to indicate that the same constituent of the air is concerned in both cases—try to place this beyond doubt by experiment.

How does the phosphorus act—does it associate with the active gas in air—is the white snow-like product a rust? How will you ascertain? You must prevent the smoke from escaping, must you not, if you wish to contrast its weight with that of the phosphorus—how will you do this—how is smoke to be held back or screened off—what is a respirator used for? Very well, then; fit up a suitable respirator to prevent the smoke from escaping from a tube in which phosphorus is burnt.

From the result, it is clear, you see, that the phosphorus and iron behave alike towards air, withdrawing and combining with the same proportion—very nearly one-fifth; and it seems probable, does it not, that this one-fifth about (the Fire air, as we have called it) is a special constituent present to this extent in air? You have thus discovered what of air—that air is a mixture of at least two kinds of air, have you not?

Where does the fire come from? It seems to have its origin in the act of association, does it not? What becomes of the fire or heat produced on associating phosphorus with Fire air? It escapes, does it not? The flask in which the phosphorus is burnt becomes unbearably hot in places but soon cools—the heat is soon lost: does it, the heat that is lost, weigh anything? Try!

You have thus made the discovery—the wonderful discovery—that fire is weightless—something unsubstantial, unmaterial—but consider what strange changes attend its production: the metal iron and Fire gas give rise to the earth-like rust; the phosphorus and the Fire air to phosphorus snow; the various ordinary combustibles, whether gaseous, liquid or solid, seem to afford water and something which has escaped our notice hitherto and which probably therefore is an air-like or gaseous substance: but if so, it must be quite soluble in water, must it not, as nearly one-fifth of the air disappears when the various substances are burnt in it? But stay, do you know that all substances burn at the expense of one and the same constituent of air? Will it not be well to try whether, in all cases, the inactive four-fifths left after exposing iron or phosphorus in air be inactive also towards all ordinary combustibles? In this work, nothing must be taken for granted. And do you know that when iron and phosphorus 'rust' in air heat is produced as when phosphorus actually burns in air? Is heat given out when the phosphorus is merely exposed in air? Make the experiment in a really warm room, using a thin rod of phosphorus lashed to a wooden rod.

You thus obtain evidence that even when the Fire air is absorbed slowly, heat is produced; and you can believe that whether the phosphorus burn visibly or not is merely a question of the rate at which the change takes place—whether the heat have time to get away or not.

You may ask: Is the rusting of iron a case of slow burning? The reply is—Can iron burn? How were fires lighted before matches were known—how were guns fired before percussion caps were invented? With the aid of a flint and steel. Try the effect of striking pieces of flint and of iron together. If you can find a smithy, watch the blacksmith at work at his forge; or still better, go to a steelworks where iron is rolled into bars and plates. Examine a new horseshoe and contrast its surface with that of one which has been in use. Examine the ground near the smith's anvil. Heat a piece of bright iron to redness for some time and notice the effect; or prepare some coarse iron filings and heat them in a muffle furnace on a clay support, weighing them before and after heating.

Having thus ascertained that iron can be burnt, you will be prepared to regard rusting also as a case of slow burning—whether it rust slowly or burn rapidly, it equally combines with Fire air and becomes converted into a pulverulent, earthy substance: a red earth in the one case, a black earth in the other.

You will perhaps ask—do other metals burn? Do other metals give earths when burnt? Metals are so commonly used in household practice that it will be well to know something about them. Copper vessels are commonly used—does copper combine with Fire air and burn? Try! Does lead, does zinc, does

tin? You can easily try. Magnesium, in the form of ribbon, burns very easily—study the change carefully. And try if silver can be burnt.

Having previously contrasted iron with iron rust by determining their densities, it will be well in the case of other metals to contrast each of the products with the metal from which it is formed and to draw up a tabular statement of the results arrived at. It will be well, instead of making all the substances, to inquire if you cannot obtain the various burnt metals and at the same time to collect information as to the use that is made of them and of their market value in comparison with that of the metals. At the same time, it will be well to inquire how the metals are made.

Such a comparison affords most instructive results—in every case, the metal affords an earthy product: some of the earths are relatively light, others heavy—some are coloured, others colourless; how do they behave towards water—have they any taste?

All this time, the snow formed on burning phosphorus—which is certainly not at all like a metal—has been left out of consideration: it should therefore be compared with the earths formed from the metals. You have already learnt that its behaviour is somewhat peculiar—what became of it when the phosphorus was burnt over water? If you did not notice, repeat the experiment. What happened to the snow which fell on the tile when the phosphorus was burnt under the glass shade? Can the snow be kept in a closed bottle? Has it any taste?

It seems then that earths are produced when Fire air is combined with metals—what other combustible substances yield when combined with it is not yet clear: only in one case, that of phosphorus, have you learnt that a sour or acid-forming substance is produced.

To understand what becomes of food when it is burnt, it is clearly desirable to extend the inquiry—carbon is certainly not a metal and there is no evidence yet that any earthy substance is formed when it is burnt, apart from the small quantity of ashes which remains.

Has it not struck you as remarkable, when you were hearing of the ways in which the various metals were made, that in most cases carbon in the form of anthracite, coal or coke, was used to separate the metal? The metallic ores are mostly earthy substances and most of the metals are converted into earths by roasting them in air—what then is perhaps the nature of the action which the carbon exercises in separating the metal? Will it not be well to try experiments with the earths prepared from the metals or with those which afford metals and to heat them with charcoal? In some cases, you obtain the metal easily—what else? Nothing solid or liquid—perhaps an air or gas is produced. Try; and if one be obtained collect it and examine it in comparison with air by determining its density, &c. Then see what happens on burning starch in a similar way. After these experiments, there can be no doubt that the carbon in starch is of value as a combustible.

Plants and Soils.

Although our food is partly of animal and partly of vegetable origin, excepting fish, poultry and game, the animals we use as food are entirely vegetable feeders: directly or indirectly, therefore, we are dependent on plants for our food—we could not live on air and water and the soil as they do. The knowledge gained from the experiments you have made enables you already to ask of what use is air to plants—do they breathe as we do? They are not warm, as we are—nevertheless, it may help them to burn some of their food slowly. What is their food—where do they obtain the carbon which is contained in starch and which we must suppose is a chief constituent of plants, of wood and of all vegetable materials, as they all give more or less charcoal when heated sufficiently strongly? The use to them of water we can understand to some extent, as they are full of watery juices, like ourselves. Of what use to them are roots—do they suck all their food out of the soil with their aid? As roots are peculiar to plants, it does not seem unlikely that this is the

case. Considerations such as these make it desirable to know something of the soil.

To grow plants properly, they must be cultivated; all soils are not equally good. What is soil? The surface crust of the earth. Even in those regions which consist of hard rock, the surface is usually soft soil formed by the gradual decay of the rock under the influence of the weather. What kinds of soft rock or soil do you know—what kinds of hard rock?

The soft soil everywhere is either sand or clay or a mixture of these (loam). You probably know both kinds and are well aware that they are very different, but it is better that you should examine them carefully. Take grams of each, examine them—if possible with a magnifying lens; describe them, contrast their behaviour, also their behaviour with water, both when wetted with it and when stirred up with a considerable quantity. Afterwards examine some garden and field soil and see what you can separate by stirring up the soil with water and decanting off the water before the lighter particles have settled.

The separation of sand from clay is always going on in rivers and in many places along the sea-coast: and it is on this account that sand-banks are formed in rivers and that the sea-shore more often than not consists of sand

Sandstone.—Sand is found in many places mixed up with pebbles of various sizes—how are such rounded pebbles produced, do you suppose? If you have been on the sea-coast where there is a shingle beach, you will probably be able to account for the rounding of the pebbles. What are gravel pebbles like inside—do they in any way resemble sand?

Hard rocks are of frequent occurrence which are obviously formed of sand particles stuck firmly together—these are commonly known as sandstones; they are usually coloured more or less—yellow, brown, or even bright red Flint, chert and quartz are solid, somewhat glass-like rocks, which when broken into small pebbles give a material like sand

Clay —In many places, soft rocks are found which are more or less easily split up into slabs or sheets; these are known as shales or slate rock. If the fine powder formed by grinding them be mixed with water, it forms a more or less sticky, clay-like mass.

Limestones.—Rocks which yield lime when burnt are very generally met with together with sand and clay; they vary much in character according to the district, some being soft like chalk, others hard and crystalline like mountain limestone. The limestones are always full of fossils; chalk under the microscope appears to consist almost entirely of shell-like remains.

Igneous rocks —Sandstone, clay and limestone are known as sedimentary rocks—there being complete proof that they have been deposited as sediments from water.

A fourth class of rock includes all rocks which have cooled down from the fused state. Granite is one of the most characteristic of these rocks and is well known, as it is much used as an ornamental stone for building.

Everyone should be familiar with the common rocks and take some interest in their history: and the wonderful story they tell when properly interpreted: but this should be made almost entirely an outdoor occupation.

Nature of Limestone.

In studying starch, we have taken into account things which were known about it and have based experiments on these: the results have enabled us to arrive at certain conclusions: our discovery that starch contains carbon and perhaps water was based on the study of the changes which it undergoes when heated and when burnt in air. We were led on to study the changes which metals undergo when burnt and to discover that the earthy substances into which they are converted are compounds of the metals with Fire air. We were able to take away the Fire air from the metal in some of the earths by means of carbon. In every case a change was effected—we arrived at our knowledge of the nature of the subject by studying a change in which it was concerned. Can this method be applied to the study of soil materials—in appearance they resemble closely the earths obtained by burning metals—are any of them known

to undergo change in any characteristic way? What is done with sand? It is used along with lime in making mortar and when fused with soda forms glass.

Clay in admixture with sand is used in making bricks and when burnt with chalk yields cement.

Limestone when burnt is changed into lime; in the form of soft chalk or preferably of lime, it is applied to the soil as manure.

Apparently, all undergo change; limestone, however, is changed when heated alone and therefore seems to offer the simplest case for study.

A series of experiments might follow, on lines like those indicated on pp. 355-359 and 444-448 of my 'Teaching of Scientific Method' (Macmillan & Co., Ltd.), leading up to the discovery of the compound nature of limestone. Limestone has thus been resolved into two substances—solid lime and a gas: although not itself an earth like any of those formed on burning metals, the lime obtained from it is very similar in appearance at least to the earths which are formed from some of them; as to the gas, being colourless, it is not easily compared with other gases What are the properties of the gases you have dealt with thus far? Of the two gases in air, one, you know, promotes combustion, the other does not; the gas you obtained by burning carbon by means of red lead and copper scale was heavier than air and more soluble in water than air and a taper would not burn in it. On testing the gas from limestone, you find that it resembles the latter gas rather than air. But you have discovered that the gas from limestone can be reconverted into limestone stuff. Does the gas prepared from carbon at all resemble it in this respect? On making the experiment you find it does; indeed you cannot distinguish between the two—they are the same material. Think what a momentous discovery you have made! That carbon is an important constituent not only of vegetable and animal matter but also of the earth limestone—it seems to be everywhere, in some cases in an unburnt, in others in a burnt state. You may ask, how comes it to be in limestone—in a burnt state? What is limestone composed of? Chalk, the form which you have examined, consists of the remains of minute shells—shells are of animal origin—are all shells alike in composition? Such reflections should lead you to study a variety of shells, salt-water, fresh-water and land shells, the shells of birds' eggs.

In the course of the experiments with limestone, it has been discovered that the gas which is a constituent of limestone stuff is present in minute proportion in the air How does it get there? You know that it is formed by the combusion of coal, wood, &c But as we are kept warm by our food and it is probable that it is more or less burnt up in our bodies and that the air we breathe in is used for the purpose, may it not be that the gas is also given out by us? Try to find out by contrasting ordinary air with expired air. See also if the gas be given off by animals, such as mice, by caterpillars feeding on green leaves, by snails, &c, by keeping these under a bell jar through which air is passed after scrubbing it free from the gas by means of lime. Also endeavour to find out if air be concerned in the germination of seeds by ascertaining if they germinate in air over water and whether the air be affected, and also whether as germination takes place the gas be given off.

Study of Acids

Are you not surprised that you have been able to find out so much—and especially that whatever you do you are always led, sooner or later, to discover something of interest in relation to yourselves? No doubt you are anxious to continue your inquiries now that you begin to understand what wonderful changes are going on everywhere.

The gas obtained by burning carbon resembles the product from phosphorus and differs from the earths derived from the metals inasmuch as they are both formed from substances which are clearly not metals—but one being a gas and the other a solid they are not directly comparable as are the products from the metals. Have they any property in common? What property is characteristic of the phosphorus snow? Its taste, is it not? Has the gas an acid taste? Try! Acids stain coloured clothes, do they not? The colours of flowers are very sensitive—make coloured solutions from a variety of flowers and see whether they are affected by solutions of the two substances which you are

studying and by the common acids. You find that the product from carbon has only a weak action but it seems to act in the same direction as the acids. Things which are similar may sometimes be substituted for one another, may they not? You know that limestone contains the gas which is derived from carbon and that the common acids in some way turn the gas out—will the acid product from phosphorus have a similar effect? Try! You thus discover that the two substances have similar properties, although not alike in strength —both are acidic substances. Are there any other non-metallic combustibles which you can study to ascertain if they yield acidic products? Although sulphur matches are not much used nowadays and almost the only occasion when sulphur is used in the house is when it is put into the dog's water, you perhaps know the smell of burning sulphur. Burn some sulphur, pass the fumes into distilled water; taste the solution, test it with colours and add some chalk to it You thus become acquainted with a third acidic product of combustion derived from a non-metal: the probability that non-metals form acid compounds and metals earths when associated with Fire air is therefore increased Years ago, when it became desirable to give significant names to substances, the great French chemist Lavoisier introduced the name *oxygen* for the gas we have spoken of hitherto as Fire air; it retains this name to the present day, except among the Germans, who call it *Sauerstoff*, or sour-stuff—the stuff of which acids are made; but this is the meaning of the word oxygen, which is derived from two Greek words, *oxus*—acid and *gennao*—I produce The compounds of oxygen are termed oxides and it may be mentioned here that the terminal *ide* is always restricted to substances which like those in question consist of only two others.

Thus far you have been led to conclude that there are two kinds or classes of oxides—metallic and non-metallic: oxides of metals and oxides of non-metals. The latter it is found are acidic—they form acids when dissolved in water; except that the former are more or less earth-like in appearance, nothing has been observed which seems to be characteristic of these oxides as a class. Have you not noticed, however, that lime resembles the metallic oxides—is it perhaps a metallic oxide—what is characteristic of it: is it not its power of combining with carbonic gas and other acidic oxides—if then it be a metallic oxide, the metallic oxides generally may be expected to resemble it in combining with acidic oxides, may they not? You have found that not only is limestone acted upon by the common acids (muriatic acid, aquafortis and vitriolic acid) but lime also: in what way are they acted upon—comparing the effect of heat on limestone with that produced by acids, does it not seem that the lime in it is acted upon by the acid and the carbonic gas just let go? Does it not therefore seem desirable to study the action of the common acids on the metallic oxides generally in comparison with lime?

But you will ask: what are these acids: how are they obtained? Surely, if we are to use them, we should know something about them.

[Sketch history of the discovery of oil of vitriol—pyrites used by palæolithic man—decay of and conversion into green vitriol and rust—distillation of green vitriol, production of oil of vitriol—strong sulphur smell, pyrites combustible, burning like sulphur but giving rust-like earth as well—preparation of vitriolic acid by burning sulphur, later with the aid of aquafortis]

Knowing what happens to sulphur when burnt, you will at once reason that vitriolic acid is in some way connected with the oxide you have prepared from sulphur—but you are told that it is formed from this oxide with the aid of air, water and aquafortis; or nowadays by passing the gas formed by burning sulphur together with air over heated finely divided platinum. Suppose you try this experiment.

You will now realise that vitriolic acid consists of sulphur, oxygen and water, and that it is derived from an oxide which contains more oxygen than is contained in that formed on merely burning sulphur in air; this latter is a colourless gas, whilst the former is solid and forms a dense white smoke. To distinguish the two oxides, one is called sulphurous oxide, the other sulphuric oxide; whilst the acid formed from the one is called sulphurous acid and that formed from the other sulphuric acid. You know that you can associate sulphurous

oxide with lime and that you can displace carbonic gas from limestone by sulphurous oxide and also by phosphoric oxide; and as you know that sulphuric acid acts on limestone, you will be prepared to argue that sulphuric oxide can also combine with lime Phosphoric oxide has proved to be stronger than sulphurous oxide—try whether sulphuric or sulphurous oxide be the stronger, in a similar sense.

Contrast sulphurous with sulphuric acids. The fact that sulphuric oxide proves to be the stronger is clearly of interest in justification of the name sour-stuff, or oxygen : the stronger and more pronounced acid being that which contains the major proportion of oxygen.

Aquafortis.—There is no doubt that, in early times, as soon as the alchemists found a new substance, they tried its effect on all the substances with which they were acquainted. In this way, when they discovered oil of vitriol, besides finding out more or less by accident if not by carelessness that it was very corrosive and destructive of their skin and clothes, they probably very soon tried what action it would have on substances such as nitre or saltpetre and sea salt. The former often appears in the form of crystals on the soil in the neighbourhood of manure heaps; saltpetre occurs in large quantities in Chili in certain districts where there is no rain to wash it away Both kinds of saltpetre are very valuable as manures When vitriolic acid is added to saltpetre and the mixture is gently warmed in a retort, a very volatile and acid liquid distils over, the retort becoming full of brownish vapour This liquid is very corrosive, staining the skin a deep yellow. Of course, the alchemists tried the action of this acid on everything at hand, metals such as gold, silver, copper, lead, tin, zinc and iron, and found that it dissolved all but gold : as it was much stronger than the other acids they knew, they called it aquafortis. To the present day, the jeweller uses aquafortis to distinguish spurious from real gold

Aquafortis—or nitric acid as it is called on account of its formation from nitre—you have learnt, is used in converting sulphurous into sulphuric acid; it must therefore be capable of giving off oxygen and must contain an oxide. Nitre, or villainous saltpetre, as Hotspur calls it in Shakespeare's 'Henry IV.,' has been used for centuries past in making gunpowder—a mixture of charcoal, sulphur and nitre; also in fireworks The modern explosives—gun-cotton and nitroglycerin—are also made with the aid of nitric acid. What happens when gunpowder is fired—in what way do charcoal or sulphur and nitre interact? Try to find out.

Muriatic acid.—We get back to the kitchen and our own food once more when we come to salt. Oil of vitriol acts upon it at once—fizzing takes place and an acid fume escapes—spirit of salt, the old alchemists called it. They were clever enough to find out that this fume is very soluble in water and the solution is known to the present day by the oil-and-colour man, the plumber, and in kitchen regions, as spirit of salt It is used in cleaning and removing scale from baths, closet pans, etc. You will find that it is very acid and that it stains the clothes but is not corrosive like oil of vitriol and aquafortis. The plumber uses it in soldering, after 'killing it' with zinc—everyone should learn to solder, and it may be worth your while to take the hint given by the plumber and see if you cannot follow up the clue What is the action of the oil of vitriol on the nitre and salt? You know that it displaces the carbonic gas from limestone stuff—is its action on the salt and nitre a similar one—are they comparable with limestone stuff?

The zinc, you find, is readily acted upon by the muriatic acid—examine the product and compare it with similar substances which you have prepared previously; it will be well to fit up apparatus which will enable you to prepare it at will, at any desired rate. Contrast it with coal gas and determine very carefully what is formed from it when it is burnt.

When this inquiry is complete, you should recognise that you have made a discovery of the greatest importance with reference to your previous work and to the nature of foodstuffs such as starch. Again, you have an illustration of the fact that information is to be gained from the most unexpected quarters —who would suppose that the plumber could help you to determine the composition of starch?

Nature of Water.

You believe that you have obtained this clue to the composition of water—that it consists of the gas which is called water-stuff, or hydrogen (because it affords water when burnt) and oxygen: as you know that all other things which you have burnt combined with the oxygen. But nothing must be taken for granted in our work: it is possible that the oxygen in air is not alone concerned; cannot you devise some method of using oxygen in a form in which there can be no doubt that if water is obtained it is formed from oxygen and hydrogen alone? How did you burn carbon with oxygen alone?

You are now satisfied that you have established the fact that water consists of hydrogen and oxygen. Is it not worth while to submit the oxides generally to the action of hydrogen? Will you not be able to test lime if you find that they all give up their oxygen to hydrogen? The results enable you to classify the metallic oxides in two groups; although you have not yet solved the problem regarding lime, have you not narrowed it—is it not clear that if it be a metallic oxide it is the oxide of a metal of a particular kind?

Perhaps by studying the action of spirit of salt, which dissolves oxides, it may be possible to obtain further information of assistance in solving the problem as to the nature of lime. Where does the hydrogen come from which is obtained when zinc is dissolved in muriatic acid? As this is a solution of spirit of salt in water, obviously it might come from the water in the solution, since this is known to contain hydrogen; it might come, however, from the dissolved gas. How shall we decide whether or no this be the case? We must eliminate the water, must we not? Try the experiment without water.

There are still two ways possible in which the gas may be formed—it may be present either in the metal or in the gas. Can any argument be adduced in favour of the one view or the other? Zinc oxide is produced on a large scale for making white paint (zinc white paint) and it should be possible to ascertain if water be formed on burning the zinc; if not, the experiment must be tried.

As there is reason to suppose that the hydrogen is contained in the spirit of salt, it is probable that the zinc displaces it, combining with whatever is associated with the hydrogen How does the oxide behave towards the acid—like lime? It dissolves quietly. What then becomes of the hydrogen, supposing this to be in the spirit of salt—is not its disappearance to be accounted for, if it combine with the oxygen in the oxide? The product in solution will be the same, will it not, according to this view, whether zinc or zinc oxide be dissolved: in what will the difference consist? Is water formed when zinc oxide is acted upon by the spirit of salt? Experiment shows that a liquid is formed—can this be water? As the water will be in presence of the gas, it will be saturated with it—the gas must be got rid of from the liquid to obtain proof that water is formed.

Having ascertained that water is formed when zinc oxide is acted upon by spirit of salt, the production of water becomes a proof of the presence of oxygen—you are able now to test lime—again water is obtained It is therefore established that lime is an oxide—probably the oxide of a metal like magnesium or zinc. Limestone stuff is therefore a distinct type of earthy substance, different from the earthy metallic oxides, formed by the association of a metallic oxide with a non-metallic oxide You have yet to extend your experiments to the other metallic oxides to ascertain whether they all form compounds similar to limestone stuff.

If a course of experiments with the metals and metallic oxides (iron, copper, zinc, lead, magnesium, etc) and acids (muriatic, nitric, sulphuric) were introduced here, there would be considerable opportunity of cultivating preparative skill.

Literary Work.

In carrying out such a course attention must ever be paid to the literary side of the work. Rough but clear notes, of the arguments used, of the things done and of the observations made, must be jotted down, from time to time,

as each experiment proceeds: on no account must this be done at any other time. A reasoned account of the work should then be written out at leisure, in flowing language, with due regard to style, never in the inexcusable form of a statement in advance of the conclusion to be arrived at ultimately, nor in the graceless hackneyed form of Experiment, Observation, Inference. It should never be forgotten that the prime object in view is to develop habits of logical thought and logical statement, together with the habit of inquiry. The clearest possible distinction must be drawn, therefore, between an experimental, reasoned inquiry into an undetermined issue and the practical demonstration or verification of a stated fact. It must be made clear that an experiment is an act performed with the definite object either of finding out something novel in the experience of the worker or of testing an assumption—that the mere demonstration or verification of the truth of a statement is not an experiment The accounts should be fully illustrated by drawings and photographs.

In order to teach the use of books and develop the habit of purposed, serious reading, as wide a course as possible of reading should be associated with the experimental work The books used should be mainly of general interest, and informative—books of reference, books of travel, &c—though technical books may be consulted occasionally with advantage.

APPENDIX I.

A. Tabulated Statements on Salaries of Teachers in the Aided and Maintained Secondary Schools of England, and other Details.

—	Average Salary	Average Number of Years of Service
	£	
England and Wales .	175·52	12
England alone . . .	177·27	12·34
Wales alone . . .	158·42	11

B Salary Scales Reaching a Maximum of:

—	County Councils	County Boroughs English)	Other Scales (Published)	Wales
Over £250 . . .	1	1	2	—
£250 . . .	4	4	3	1
£211–£250 .	2	4	1	3
£210 . . .	—	4	1	1
£200 . .	7	12	11	2
£181–£199 .	3	6	2	1
£180 . . .	—	11	7	3
Under £180 . . .	—	3	19	7

There is only one authority which publishes a scale in which the ordinary maximum salary (after 15 years' service) is £300

In County and County Borough areas a salary of £200 is regarded as a fitting reward for a successful life's work. In one case Honours Graduates can look forward to £190 after 16 years' service. In another the maximum is £160 after 10 years. There are ten schools with a maximum of £150—one of which announces an initial salary of £140 rising by annual increments of £5 to a maximum of £150—while 5 go below even that figure.

C. Percentage of Masters Receiving ·

—	Less than £200 p.a.	£200 to £250	£251 to £350	£351 and over
England	71·2	24·2	4·2	0·4
Wales	88·	11·16	0·84	—
England and Wales .	72·8	22·99	3·82	0·39

D. Percentage of Schools in which the Highest Salary is:

—	Less than £200 p.a.	£200 to £250	£251 to £350	£351 and over
England	51·8	36·8	10·1	1·3
Wales	68·7	28·9	2·4	—
England and Wales .	54·	36·11	8·79	1·1

The smallest salary is £30 and the largest £500. A Headmaster may receive £2,000, whilst his Senior Assistant has a salary of £230.

Number of cases are included of Graduates and even Honours Graduates with long service, having salaries of about £200, and in Wales as little as £70 is paid for an Honours Graduate.

E. Salaries and Prospects in Careers Considered by many Boys from the Secondary Schools.

—	Entrance Age	Salary	Probable Salary at 22–23 Years	Prospects	Conditions
A. Intermediate Civil Service	18–19	£100, rising to £350	£160 . .	£850–£1,000 .	Pension and tenure secure.
B. Second Division Civil Service	17–20	£70, rising to £300	£130 . .	Possible transfer to other class	Ditto.
C. Banking .	16–18	£60 to £80, rising to £300	£130 . .	Transfer to higher position if successful	Ditto.
D. Teaching .	22–23	£120 to £150, rising to £190	£120 to £150	Indefinite possibility of headmastership	No pension, tenure insecure.

F. Model Scale Suggested by the Assistant Masters' Association before the War

Initial Salary, £150 per annum.

Increments of £10 per annum to £300, and then £15 per annum to a maximum of £450.

Additional allowances in centres where the cost of living is higher.

More complete details will be found in :—

1. The Conditions of Service of Teachers in English and Foreign Secondary Schools. Published by Messrs. Bell and Sons for the Incorporated Association of Assistant Masters.

2. Statistics of Salaries of Assistant Masters. Published by the Incorporated Association of Assistant Masters.

APPENDIX II.

Science Subjects in Typical Girls' Schools.

(The figures indicate the number of schools teaching a specified subject at a given age.)

Leaving Age, 16. Grant Aided. 36 Typical Schools.

Age .	8 10 +	11 +	12+	13 +	14+	15+	16+	17+
Nature Study . .	25	18	6	3	—	1	—	
General Elementary Physics . .	—	11	26	18	9	4	2	
Elementary Chemistry . . .	—	1	9	16	17	9	4	
Systematic Chemistry . . .	—	—	—	1	7	9	9	
Mechanics . .	—	—	—	—	1	1	1	
Heat	—	—	—	3	3	2	—	
Light . . .	—	—	—	—	—	2	2	
Botany . . .	—	6	9	11	21	30	28	
Hygiene . . .	—	1	3	4	3	2	2	
*Domestic Science .	—	—	4	6	8	8	3	

* In some cases this means actual cookery, &c.

Leaving Age, 18. Grant Aided. 103 Typical Schools.									
Age:	8–10+	11+	12+	13+	14+	15+	16+	17+	18+
Nature Study	90	70	21	7	1	—	—	—	—
General Elementary Physics	3	31	78	78	31	11	8	5	—
Elementary Chemistry	2	8	27	50	54	30	11	4	—
Systematic Chemistry	—	—	1	3	16	28	35	47	4
Mechanics	—	—	—	3	1	1	6	16	2
Heat	—	—	1	8	10	11	7	16	3
Light	—	—	—	3	6	3	7	13	3
Botany	3	17	31	33	57	83	87	80	2
Biology	—	—	1	2	—	2	3	11	—
Hygiene	1	3	8	6	10	10	7	7	—
*Domestic Science	3	9	10	19	24	23	16	13	—
Physiology	—	—	—	—	—	1	2	2	—
Physiography	—	—	1	—	—	—	—	—	—
Zoology	—	—	—	1	—	—	1	3	1
Mag. and Elec.	—	—	—	—	1	1	—	—	—
Sound	—	—	—	—	—	—	1	2	—
Geology	—	—	—	—	—	—	—	2	—

Leaving Age, 18. No Grant. 19 Typical Schools.									
Age:	8 10+	11+	12+	13+	14+	15+	16+	17+	18+
Nature Study	17	13	6	3	1	—	—	—	—
General Elementary Physics	—	3	11	11	9	1	—	—	—
Elementary Chemistry	—	—	4	7	10	8	4	1	—
Systematic Chemistry	—	—	—	—	1	5	7	11	1
Mechanics	—	—	—	—	1	1	—	5	1
Heat	—	—	—	—	3	1	3	7	—
Light	—	—	—	—	1	1	2	5	—
Botany	—	3	4	2	8	14	14	11	1
Biology	—	—	—	—	—	—	1	4	—
Hygiene	—	—	—	—	1	5	4	4	—
*Domestic Science	—	—	—	2	2	2	1	1	—
Physiology	—	—	—	—	1	1	1	1	—
Sound	—	—	—	—	—	—	1	2	—
Elem. and Mag.	—	—	—	—	—	—	—	—	1
Zoology	—	—	—	—	—	—	—	—	1

Private Schools. 13 Typical Schools.								
Age:	8–10+	11+	12+	13+	14+	15+	16+	17+
Nature Study	8	7	4	4	1	—	—	—
General Elementary Physics	—	1	4	3	5	3	2	1
Elementary Chemistry	—	—	1	1	4	5	4	1
Systematic Chemistry	—	—	—	—	—	—	1	1
Mechanics	—	—	—	—	—	—	—	1
Heat	—	—	—	2	2	1	—	—
Light	—	—	—	2	1	1	3	1
Botany	1	4	6	7	8	8	9	7
Biology	1	1	2	1	2	2	2	3
Hygiene	—	—	—	3	3	5	5	4
*Domestic Science	—	—	1	2	3	4	2	2
Physiology	—	—	—	1	—	—	—	—
Geology	—	—	—	—	1	1	1	2

* In some cases this means actual cookery, &c.

APPENDIX III.

Laboratory Accommodation and Staffing in Girls' Schools.

Laboratory Accommodation.

89 Typical Girls' Schools.

No. of Girls in School	No. of Schools	1 Lab.	2 Labs.	3 Labs.	4 Labs.
100–200	38	35	1	1	1
200–300	28	20	7	1	0
300–400	13	10	1	2	0
400–500	10	—	4	5	1

Staffing.

146 Typical Girls' Schools.

No. of Girls in School	No. of Schools	No. of Science Staff							
		1	1+	2	2+	3	3+	4	5
100–200	59	46	7	5	—	1	—	—	—
200–300	42	19	9	8	2	4	—	—	—
300–400	30	3	2	16	4	4	1	—	—
400–500	—	—	—	3	6	2	—	2	2

1 + means that there is one full-time and one part-time science mistress, and so on.

APPENDIX IV.

Academic Qualifications of Headmasters and Headmistresses

A. Schools Represented on the Headmasters' Conference.

Number, 118. Boys, 36,393.

—			—	Per cent	Boys	Per cent
Classical . .	82	Literary	95·33*	80·8	30,245	83·1
Theological Pass Degrees	13·33	Mathematics	15·83	13·4	4,103	11·3
		Science	6·83	5·8	2,045	5·6

* The fractions originate from the fact that a few headmasters possess more than one qualification. Three headmasters (two mathematical and one classical) also possess an additional scientific qualification.

B. Non-State-Aided Schools in England Represented on the Headmasters' Conference.

Number, 73. Boys, 23,269.

—			—	Per cent	Boys	Per cent.
Classical . .	50	Literary	61·33	84	20,300	87·2
Theological Pass Degrees	11·33	Mathematics	9·33	12·8	2,189	9·4
		Science	2·33	3·2	780	3·4

C. Qualifications of 200 Headmistresses of Public Secondary Schools for Girls.

			Number	Per cent.
Classics	34			
History	40			
Mediæval and Modern Languages	34	Literary	131	65·5
English Language and Literature	18			
Mental and Moral Science	5			
		Mathematics	48	24
		Science	21	10·5

In the case of the B.A. and B.Sc. London, only the Honours Degree is included, as the subjects of the ordinary degree are not specified in the calendars.

The schools have been taken from the 'Girls' School Year Book,' and the majority are represented on the Headmistresses' Association.

Corresponding Societies Committee.—Report of the Committee, consisting of Mr. W. WHITAKER (*Chairman*), Mr. WILFRED MARK WEBB (*Secretary*), *the* Rev. J. O. BEVAN, Sir EDWARD BRABROOK, Sir H. G. FORDHAM, Dr. J. G. GARSON, Principal E. H. GRIFFITHS, Dr. A. C. HADDON, Sir THOMAS HOLLAND, Mr. T. V. HOLMES, Mr. J. HOPKINSON, Mr. A. L. LEWIS, Mr. THOMAS SHEPPARD, *the* Rev. T. R. R. STEBBING, *and the* PRESIDENT *and* GENERAL OFFICERS. (*Drawn up by the Secretary.*)

THE Committee regrets that the Institution of Mining Engineers has withdrawn from affiliation.

The Conference will be held in the apartments of the Geological Society, Burlington House, London (by kind permission of the Council), on Thursday, July 5, and Friday, July 6.

The President, Mr John Hopkinson, will take as his subject 'The Work and Aims of our Corresponding Societies.' Dr. F. A. Bather has consented to act as Vice-President of the Conference.

The following subjects will be discussed: 'Regional Surveys' (suggested by the Letchworth and District Naturalists' Society), to be introduced by Mr. C. C. Fagg; 'Weights and Measures,' to be introduced by Mr. Thomas Sheppard; 'The part to be played by Local Societies after the War in the application of Science to the Needs of the Country' (suggested by the Selborne Society), to be introduced by Mr. Wilfred Mark Webb.

The Corresponding Societies Committee has accepted, on behalf of the delegates, an invitation from the Selborne Society to a meeting on July 6, when Professor R. A. Gregory will speak on 'The Popularisation of Science,' and Professor H. E. Armstrong will give a lecture on 'Fuel Economy.'

The Committee asks to be reappointed and for a grant of £25.

Report of the Conference of Delegates of Corresponding Societies held in London on Thursday, July 5, and Friday, July 6, 1917.

President . John Hopkinson, F.L.S., F.G.S., Assoc.Inst.C.E.
Vice-President Dr. F. A. Bather, F.R.S.
Secretary . Wilfred Mark Webb, F.L.S., F.R.M.S.

By the courtesy of the Council of the Geological Society the three meetings of the Conference were held in its rooms at Burlington House, and at the first meeting the President took the chair and delivered the following Address:—

The Work and Aims of Our Corresponding Societies.

It is nearly forty years since I suggested that the Delegates from provincial societies should hold a Conference at each meeting of the British Association, subsequently arranging for the first Conference to be held at Swansea in 1880. Although sanctioned by the Council of the Association it was not an official Conference, being the first of five managed and supported financially by the Delegates only. Having then been in the Chair I accept with the greater satisfaction after so many years the honour conferred upon me to preside at the present Conference.

It was not at first, nor was it for several years, the custom for the Chairman to give an address. A few remarks were made by Dr. J. G. Garson on opening the Conference at Nottingham in 1893, but the first formal address from the Chair was delivered at Ipswich in 1895 by the late Mr. G J. Symons, who took for his subject certain systematic meteorological work which might be done by members of provincial societies.

At the Conference held at Swansea in 1880 the following resolution was passed: 'That this Conference recommends that at future meetings of the British Association the delegates from the various scientific societies should meet with the view of promoting the best interests of the Association and of the several societies represented.' With this end in view it seems to me that Mr. Symons' address was particularly appropriate, for it is surely in the best interests of the Association as well as of its Corresponding Societies that concerted systematic work should be done.

The main object of our Societies is, or should be, to undertake local scientific investigation, and we are here assembled chiefly to discuss the best means of doing so and of obtaining the most valuable results. While all should work to the same end, that end, whatever it may be, can best be achieved by all working in the same manner, or at least on some definite plan, so that the results may be comparable.

It is not, however, to stimulate and direct scientific investigation only that this Conference should aim; there is also for it the wider field of influencing public opinion on the importance of far greater attention than at present being given to scientific education and to many problems concerned with the future welfare of our nation in which science may lend a fostering hand. There is no other country in the world which has nearly so many scientific societies as we have There are on our list 120 Corresponding Societies (ninety Affiliated and thirty Associated) with an aggregate membership exceeding 46,000, subject to a slight reduction, as some of these societies are represented individually as well as by the Union to which they belong, and some have members who are also members of other societies on our list; but we may, I think, estimate the number of individual members represented as not less than 45,000, while Principal Griffiths, in his address at our Cambridge Conference in 1904, estimated the total number of scientific societies in the kingdom as about 500 with a membership approaching 100,000 If we could all agree upon some beneficial project what an immense influence we might have!

The 'Circular referring to subjects recommended for investigation by Local Scientific Societies,' issued by our original Committee in 1882, had good results, enlisting observers and investigators in the study of the various subjects on which information was desired, and an extended list with instructions published in 1891 in the 'Transactions of the Hertfordshire Natural History Society' (vol. vi , pt. 2, pp. 40-44) may still be consulted with advantage.

In the Report of the Council of the Association for the year 1881–82 it is stated that in respect of a resolution referred by the General Committee the Council recommended (*inter alia*) 'The appointment of a Committee in order to draw up suggestions upon methods of more systematic observation and plans of operation for local societies, together with a more uniform mode of publishing the results of their work. It is recommended that this Committee should draw up a list of societies which publish their proceedings' The Committee was appointed, and its first report was printed in the Report of the Association for 1883 (pp. 318–345). The list, drawn up by Mr. (now Sir) H. George Fordham,

gives in tabular form the most important particulars of 175 publishing societies, while appendices give less full information on eleven societies of which the Cumberland Association for the Advancement of Literature and Science then consisted, of twenty-one which formed the Midland Union of Natural History Societies, and of thirty-eight also included in the Yorkshire Naturalists' Union, with the exception of twenty in the two Unions, appearing in the main list. This was the origin of the official Corresponding Societies Committee, which presented its first report in 1885, giving in it a list of thirty-eight Corresponding Societies and appending to it an 'Index of Papers referring to Local Scientific Investigations published during the past year' by those societies. Such an index has since then been annually appended to the report of the Committee. The first official Conference of Delegates was held in the same year at Aberdeen, reports of that and of every subsequent Conference appearing in the annual Reports of the British Association. The last unofficial Conference having been held at Montreal in 1884, the official Conferences followed without a break.

In the report of the Corresponding Societies Committee printed in the Report of the British Association for 1902, there is (pp. 852-853) a list of Committees of the Association which desire the co-operation of the Corresponding Societies, and one of subjects selected by the Delegates for investigation which are not included in that list. The two lists embrace all the Sections of the Association except A, Mathematical and Physical Science; F, Economic Science and Statistics; I, Physiology; L, Educational Science; and necessarily M, Agriculture, that being a Section formed since that date. In the following remarks I dwell most fully on some subjects which are within the scope of the omitted Sections, except that of Physiology, a science which does not appeal for concerted action by our Corresponding Societies.

Section A, MATHEMATICAL AND PHYSICAL SCIENCE, ought to be divided as it is in the French Association, which has a Section dealing with the Meteorology and Physics of the Globe. Meteorology in our Association is almost ignored, and yet there is no other science to which assistance can be so easily rendered by the members of our Corresponding Societies, nor one in which uniformity of observation is so important. Observations need only be taken once a day, at 9 A.M., and are mostly only taken at that hour, but may also be taken at 9 P.M.; if three times a day, the other hour is 3 P.M., in 'summer time' necessarily an hour later by the clock.

The chief object for which meteorological observations are taken, apart from that of forecasting the weather, is to arrive at a knowledge of the climate of a place, and we can only compare the climate of one place with that of another from the results of observations taken at the same local time at each place—that is, at the same interval of time after sunrise. This does not vary so greatly within the area of the British Isles but that Greenwich time gives satisfactory results, and with rainfall only the difference is of no moment. Suggestions for certain meteorological observations were given by Mr. Symons in the address referred to, but with evident intent he does not specially treat of the subject to which he gave his greatest attention — rainfall. Although since that address was delivered observers of rainfall have increased in number in the British Isles from about 3,000 to 5,500, the variations in rainfall from place to place are so great that many more observers are still required, especially in Ireland, in the western counties of Wales, in Shropshire and Staffordshire, and along the east coast of England. Each delegate should see to it that his own neighbourhood is adequately represented. A knowledge of the mean and extreme rainfall in any district is most important in relation to water-supply and agriculture, and it can only be gained from the records of a great number of rain-gauges taken for many years. Dr. H. R. Mill, Director of the British Rainfall Organisation, has twice brought this subject before the Conference of Delegates, and has added to records of rainfall more records of bright sunshine as urgently required. Observations with a Campbell-Stokes sunshine-recorder give little more trouble than those of rainfall with a Snowdon rain-gauge, but it is not so easy to measure the records, and the instrument is expensive.

At the Conference held at Leeds in 1890 I suggested the formation of a

Committee on meteorological photography; the idea was approved, members of the Committee were chosen, and I was requested to endeavour to secure the appointment of the Committee through Section A. This was done by reading a paper on the subject before the Section, the Committee appointed presenting ten reports. Its work was eventually restricted to experiments by the Secretary, Mr. A. W. Clayden, with the object of devising the best means of ascertaining the height of clouds, his method being the taking of photographs by two cameras in electric connection at a great distance apart. A collection of meteorological photographs of various kinds was also made and presented to the Royal Meteorological Society, forming the nucleus of a very fine collection of lantern-slides available for lectures. Additions will be welcome.

Closely related with meteorology, or a branch of it, is phenology — the study of the relation between the weather and the dates of flowering of plants, arrival and departure of migratory birds, and appearance of insects, and also its effect upon our field- and garden-crops Here again more observers are urgently required, for it is only with a very large number of observers that we can feel confident that first appearances, whether of flowers, birds, or insects, have not been overlooked. Forms for recording may be obtained from the Royal Meteorological Society.[1]

For Section C, GEOLOGY, much good work has been done by the Corresponding Societies, especially for the Committee on Geological Photographs, which was formed by the joint action of the Section and the Conference of Delegates at the Bath meeting in 1888. The photographs (a very large number) are deposited in the Geological Museum in Jermyn Street, where they may be seen; also numerous lantern-slides which are lent for lectures. The Committee is still in existence and photographs are acceptable.

Other important geological subjects which have been brought before our Conference are earth-tremors, underground water, and coast-erosion, in the investigation of one or other of which all our Corresponding Societies can help

The subjects embraced in Section D, ZOOLOGY, are by far the most attractive to members of our natural history societies, to whom we owe nearly all our knowledge of the distribution of animal life in the British Isles, far more perhaps of that of the Invertebrata than that of the Vertebrata, about which much was known in very early days. It should be the aim of all such societies to compile and publish lists of the animals inhabiting their areas, recording their localities, carefully noting their habitats, and studying their habits and life-histories. Increasing attention is being paid to our Invertebrate fauna, but there is still very much to be done, especially in the collection and study of the microscopic forms of life in our rivers, lakes, ponds, and ditches, on our stately trees and humble mosses, and even in our soils. Almost every tuft of moist moss teems with animal life which will well repay microscopic examination.

There is another aspect of the subject which has frequently been brought before us, that is the preservation of our native fauna. In endeavouring to prevent the destruction of rare animals or of those approaching extinction all may help. We cannot well make sure of the presence of a rare moth or butterfly without capturing it, but there is never need to take a large series, as is the practice of some entomologists; with birds and mammals it is different; they can mostly be identified by the practised naturalist without shooting them. There are birds, such as the rook and the wood-pigeon, which should be reduced in number, as they are so destructive to our field- and garden-crops, but such birds as hawks and owls, which are persecuted by gamekeepers, are our farmers' best friends, and their extermination ought not to be allowed. The same may be said of all insectivorous birds. Hawks may occasionally kill a partridge or even a pheasant, the beautiful kingfisher may take a few fish, but the food of the owls, with the exception of a few rare species such as the eagle owl and the snowy owl, consists almost entirely of small rodents.[2] With regard

[1] Copies of a list with instructions, printed for the Hertfordshire Natural History Society, were distributed.

[2] Taken out of a barn-owl's tree at Keswick in Norfolk in April, 1911, were 114 'pellets' containing the skulls of 10 very small rats, 126 long- and short-tailed field-mice, 69 shrews, and 3 small birds (perhaps greenfinches), but no game.

to the species which should be protected, the ornithologists in a natural history society can render County Councils valuable help. An order for the protection of certain birds was issued by the Hertfordshire County Council in 1895 on the representation of the Hertfordshire Natural History Society, the schedule being drawn up by ornithological members of the Society and accepted by the County Council.

The next Section is Geography, but it will be better to take here Section K, Botany, especially as most of the remarks on zoology apply also to botany. Such is the duty of compiling a flora, as well as a fauna, of each Society's area; of recording the habitats of plants, with special reference to the study of ecology or plant-associations; of studying their life-histories, and protecting the rarer species from extermination. As with animals, so with plants, it is the distribution of the microscopic forms, such as the desmids and diatoms, about which we know least, and although they cannot lay claim to such beauty of form and coloration as the freshwater rhizopods and heliozoans, they will well repay far more attention than they have hitherto received. The study of fungi has several times been brought before our Conference, and I will only add that we know least and ought to know most about our leaf-fungi as being of great economic importance More frequently still have we discussed the question of the preservation of our native plants.

The action of some societies in providing reservations for plants and animals, as the Selborne Society has done in its Brent Valley Bird Sanctuary, or in urging other bodies to acquire sites for such purposes, is much to be commended. So also is that of endeavouring to retain wild spots in their primitive state. The Hertfordshire Natural History Society has done something towards this end. In 1892 an attempt was made to carry out a scheme for the 'regulation' of Bricket Wood Common, between Watford and St Albans, by the sale of certain outlying parts of the common and the building of houses thereon in order to provide funds for making gravel-paths over it, draining it, and providing a park-keeper to look after it The Society devoted part of two of its meetings to a discussion of the scheme, the Lord of the Manor and some of the copyholders being present at the second meeting, when the opposition to curtailing the common by selling outlying portions as building-land was so strong that a resolution protesting against it was carried by a large majority, and the scheme was dropped, a vigilance committee being appointed to report any attempt to revive it, for if such an attempt were carried out we should lose the greater part of the interesting flora and fauna of the common and its scrubs and woodland. More recently, when part of Cassiobury Park was sold for building and it was proposed that Watford should purchase from the buyers a portion of the part acquired, they building houses round it and leaving the enclosed space as a public park, our Society, in conjunction with its offshoot, the Watford Field-Path Association, called a public meeting which made a recommendation that no houses should be built between the proposed public park and the remaining private park, which, being acceded to, was so gratefully and courteously accepted by the original owner, the Earl of Essex, that he consented to his park being divided only from the public park by an open iron fence. Thus the public secured a sight of the whole of the old park, which Lord Essex secured from being overlooked by houses. These instances are given as examples of the good which can be done by scientific societies in their corporate capacity, outside the scope of their usual activities, and which could not be done by any of their members individually.

Taking now Section E, Geography, it is not a science which can be much advanced by the concerted action of our societies, except by urging its efficient teaching in schools. With the branch of it called Topography we have more concern. It should be our first aim to define the area of our operations precisely and in accord with neighbouring societies, so that there may be no overlapping in our investigations, and to work that area thoroughly. For this purpose our 6-in. to the mile Ordnance Map is essential. The methods of our Ordnance Survey have been severely criticised at our Conferences, especially with regard to the inch-to-the-mile maps, now much improved but too dear for a ready sale.

Section F, Economic Science and Statistics, might well have occupied the

whole of this address, being of such very great importance at the present time. It is difficult, however, to treat of it in relation to the well-being of our Nation, in furtherance of which the members of our Corresponding Societies could exert by their concerted action a most valuable pressure, without trenching upon the forbidden sphere of party politics. The question of tariffs against so-called 'free trade,' surely a false term for allowing other nations to put a prohibitive duty on the import of our manufactures while we let them dump their surplus products into our country free, ought to have no connection with politics. Had it been considered in the past a purely economic question we should not have been in our present unfortunate position of dependence upon other countries for nearly all the necessities of life. Britain, once a great producing country, then became a manufacturing one, importing raw material and exporting the finished products, but latterly has been degenerating into a mere commercial country, importing finished articles to the detriment of the products of our soil and of the output of our factories This has brought us to our present critical state. Not only have we encouraged the importation of goods we can well make ourselves, and of food we can now in part produce, and shall in future have to produce to a much greater extent, and so keep our workers, whether out-door or in-door, busy, but we have freely exported our very life-blood, that which (with iron) made England a manufacturing country, our coal, the exhaustion of which would reduce us to abject dependence upon the resources and good-will of countries beyond our seas Germany has been fighting us with coal from South Wales for the motive power of her ships and with toluol from our gasworks for her most explosive munitions, having imported from us vast quantities of both during many years. Should there be no other result of the present war than to bring about a radical change in our fiscal system, the loss of men and money which it has occasioned would be greatly compensated I repeat that this ought not to be a question for politicians, and there are signs that soon it will not be considered one. It ought to be vigorously taken up as a scientific and economic question by all the members of our Corresponding Societies, for all must have the future welfare of our country at heart.

In Section H, ANTHROPOLOGY, the work of the 'Ethnographical Survey of the United Kingdom,' a Committee of the British Association, has frequently been brought before the Conference, and I believe that great assistance has been given to it by our Corresponding Societies The Committee is no longer in existence, but of lasting importance for continued vigilance is that branch of it entrusted with the recording of monuments and other remains of ancient culture. It is rather the preservation than the recording of such remains that is now of greatest importance, and in this most of our societies could help by appointing vigilance committees to report any attempts at vandalism. Much good has resulted from the 'Ancient Monuments Act,' but it does not go far enough, being permissive only, not compulsory. At present the most pressing need of protection seems to be that of Kent's Cavern, near Torquay, in the exploration of which Mr. William Pengelly spent the best years of his life, and an endeavour should be made to get it placed under the protection of this Act, if a prehistoric cave can be considered a monument, or under the National Trust [3] I visited it last autumn and found that the custodian had relics for sale.

To treat adequately of Section L, EDUCATIONAL SCIENCE, would require several addresses. It embraces the teaching of the various subjects already discussed and many others. As to the vexed question of a classical against a scientific education, I would give almost equal weight to each, but let the balance preponderate towards science I doubt if there is a single naturalist amongst us who would consider a little knowledge of Latin and Greek unnecessary. We ought to know sufficient of Greek to devise from it, for instance, a name for a new genus, and when we see a name derived from the Greek to be able to ascertain its meaning; we must know sufficient of Latin to give a suitable name to a new species and to be sure that we give it a correct

[3] Resolutions to this effect should be passed by all our Corresponding Societies, and made widely known.

termination, to know why a certain name has been bestowed and to give in Latin a brief diagnosis of a genus or a species A certain knowledge of Latin is also important for the profitable study of our own and several other languages, so many words being derived from it; but I consider it almost a criminal waste of time to spend the best days of our school or college life in so mastering any dead language that we could give an oration in it, except for those who aim at a classical professorship. It is more necessary that we should have a better acquaintance with one or other of such modern languages as French, Italian, or Spanish, for any of which some knowledge of Latin is most helpful, or of German, so replete is it with biological information, but still more so that we should have a thorough knowledge of that most neglected language in the teaching curriculum of our own country, English, at least in higher education.

With reference to Latin, I will just touch upon one point in my own education. Of course I was first put to Cæsar's 'De Bello Gallico.' I utterly failed with it, owing probably to complete lack of interest. In a higher class I was given Virgil's 'Georgics' to translate and soon took an interest in it—in its four books treating of the cultivation of the soil and the management of fruit trees, of cattle, and of bees. The moral seems to be that the teacher should first learn the bent of mind of his pupils and should modify his teaching accordingly

I presume that most of you have, or may some time have, children to send to school, and may have some influence over their education. You are more likely to know their capabilities than are the teachers to whom you send them, and you should make use of this knowledge for their benefit.

With regard to the teaching of science, all books should at first be eschewed and the child should be taught to make some simple experiments. Every child, out of curiosity almost from its babyhood, wants to experiment, even if it may only be to take its doll to pieces to see what is inside it, and this desire of experimenting, though not of destroying, should be fostered. The natural desire to know all about the things around one is preliminary to the desire to know why certain things are as we see them; that is, to a knowledge of causes and their effects, which is science. The scientific teaching of the present day in our elementary schools is generally the mere imparting of a knowledge of the names and properties of things, and does not develop the intellectual powers. It is only when properly taught that the reason lately given by Professor D. Fraser Harris why a knowledge of science is useful to the general community truly applies. He said, in an address to the Nova Scotian Institute of Science (printed in 'Nature' of May 17): 'Apart altogether from the way in which science makes for technical efficiency, it is a means second to none in the training of the intellectual powers. It trains us in accuracy of observation, in the power of drawing trustworthy conclusions, in habits of precise thinking generally; and these are not small things Science, the true, is the patient, loving interpretation of the world we live in; it is a striving to attain not merely to an understanding of the laws whereby the world is governed, but to the enjoyment of the beauty and order which are everywhere revealed.'

The Rev. Hilderic Friend, in reviewing the last report of the Rugby School Natural History Society (in the same number of 'Nature'), says, with special reference to the Society's work in ornithology: 'Such studies are of inestimable value to young people. They develop the powers of observation, teach patience, sympathy, endurance, and kindness, divert the mind from base pursuits, and open out a fairy realm of beauty and delight, which cannot fail to ennoble, as well as entertain, those who pursue them.' This Society is doing excellent work, so also is the Marlborough College Natural History Society; the latter on our list of Affiliated Societies. The formation of such scholastic societies should be greatly encouraged

The subject of museums comes, I think, most appropriately under this Section, for they are of very great educational value. One of the most important committees of the Association was that appointed in 1886, by the co-operation of Sections C and D and the Conference of Delegates, for the purpose of preparing a report on the provincial museums of the United Kingdom. The Committee was very expeditious, thanks to the energy of its

Secretary, Mr. F. T. Mott, presenting in the following year a valuable report which appeared in the Report of the Association for 1887 (pp. 97–130) and a further report the next year (Report for 1888, pp. 124–132). In the first report there are tables (I) giving particulars of 211 provincial museums under headings extending across two pages, (II) an approximate estimate of the number of specimens contained in these museums, and (III) a list of collections of special interest indicating the museums in which they are preserved. A large portion of this report is occupied with 'Discussion of Details' under thirty-six heads. The second report considers 'the ideal to which provincial museums should endeavour to attain,' and suggests 'practical methods for approaching that ideal.' It is not too much to say that these reports are invaluable, not only to those who have the management of museums, but also to all scientific workers who wish to know where, apart from our national museums, the materials for study in their own branch of science are to be found.

The Hertfordshire County Museum at St Albans—the only one with which I am connected—was not then founded, but I may mention that it is visited largely by children from the Board Schools in the neighbourhood, who take an intelligent interest in the exhibits, quickly find out accessions, and collect and bring to the Curator objects they wish to know the names of, presenting to the Museum any worthy of acceptance. To young children there is one drawback in a museum, which has been felt at St Albans: they wish to handle the specimens, rightly judging that by so doing they can learn more about them than by merely looking at them Every museum should, if possible, have duplicates of the commoner objects, accurately named, to lend to schools.

The last Section, M, AGRICULTURE, is at the present day the most important of all, at least economically. It ought, I think, to be extended to include Forestry. But what, it may be asked, have the members of our Corresponding Societies in general to do with agriculture or forestry? Perhaps not much collectively, but they will have a great deal to do individually when more labour is available on the conclusion of the present war. We must no longer look down upon our farmers. One consequence of our present fiscal system is that the social status of our workers is now generally in an ascending scale from producers, through manufacturers, to merchants, being in relation to the amount of money each class makes; but we must reverse this, even to the extent of placing our tenant-farmers on a social level with professional men, such as doctors. The medical profession, rightly, stands high; doctors look after our health, but we are dependent upon farmers for our life. We cannot exist without food; we cannot get food except by the tillage of land, and it is going to be, as it once was, chiefly by the tillage of our own land Many of our soldiers, after living much in the open air, improved greatly in physique, will not go back to office work We must welcome them to the land; give them a real hearty welcome, and not an empty one, for their comfort will have to be looked after and their companionship will have to be sought, not avoided. Of course the necessary raising of the social status of our farmers cannot come altogether from without; it implies a higher education, and that implies a longer school-life, followed, if possible, by special training in an agricultural college;[4] and this again implies a sufficiency of income. There are not many of our landowners who can afford materially to reduce the rent of their farms; their tenants will have to pay higher wages to their labourers, and they must earn an increased income Thus we are led to the conclusion that there must be a better husbandry, implying an education in which chemistry and biology will play an important part; a more economic distribution of the products of the farm, which might be achieved by co-operation; and that we must be content to pay more for our food by import duties keeping up the cost of supplies from abroad to that of production and distribution at home. The extent of arable land has greatly decreased. From the address of the President of this Section at the Manchester meeting of the Association in 1915, Mr. H. R. Rew, we learn that the acreage under wheat in England and Wales has been reduced nearly half since 1808, while the population has nearly

[4] There should be a Chair of Agriculture and Forestry at each of our Universities supported by the State; or of Rural Economy, as at Oxford.

quadrupled; but we are now getting four quarters of wheat per acre, whereas then we only got three quarters, the result working out at eight and a half bushels per annum per head of the population in 1808, and one and a half in 1914, between one-fifth and one-sixth of our needs.

Here is much lost ground to be regained, and all of you can help to regain it, especially those who live in or near agricultural districts, by helping the farmers with your sympathy and with your support in all legislative measures for their benefit. Then in time, as a powerful writer has recently said: 'Sturdy sons of hill and dale shall till the soil which in years gone by gave us the stout yeomen and the bowmen of old England; agriculture, the purest of all industries, shall resume its rightful sway over the labours of mankind, and, come what may, our granaries and barns shall be stored with the rich harvests of God's generous earth.'

In the heart of the New Forest there is, or was last summer, a small Portuguese colony, its home a hut in a valley, its handiwork a large gap in the adjoining woodlands. In five weeks 26 men cut down and prepared for use in the trenches in France 26,000 pine trees. Not far off, Irishmen, and soldiers called up but found unfit for foreign service, had then cleared some 300 out of 450 acres of Scotch fir. These are only two of several lumber camps in various parts of the forest where saw-mills have been set up worked by Canadian and English sawyers. This depletion of forests is going on in various parts of the United Kingdom; I have seen whole mountain-sides in Wales so depleted, while little is being done to replenish them. Afforestation on a very large scale will be necessary on the conclusion of the war unless we are content to let our country become an arid waste. There is plenty of land available, unfit, or nearly so, for agriculture, but few will go to the expense of planting trees which may yield no return during their lifetime. No return can be expected for 30 years or so, and it may be 60 or 70 years before the profit overtakes the original cost with (say) five per cent. per annum compound interest. Moreover the planting must be done on too large a scale for private individuals, however wealthy and patriotic, to do more than a small fraction of it; it will have to be done by the State. It will not interfere with agriculture, for most work is required in the winter when least is required on the farm, and no valuable agricultural land need be taken. As with agriculture, there will be men for the work, soldiers returned from abroad who will not go back to sedentary occupations.

In walking over the Welsh hills I have repeatedly come across roots and stumps of trees in the peat-mosses which frequently cover them; they are evidences of former forests. The land is worthless except for the value of the peat, the removal of which would, for its valuable by-products, not only as a fuel, well repay the expense, and the ground would be rendered suitable for planting coniferous trees. It is true that most of our peat-covered mountain-land is above the elevation at which it is generally considered that trees will flourish (1,500 ft.), but if they did so in the past there seems no reason why they should not do so in the future, for it is far more likely that our climate has become warmer since trees grew on that land than it is that it has become colder. We have also large areas of waste land at lower elevations, extensive slopes which are too steep for ordinary cultivation between, and on sheep-farms much very poor grazing land which would be more profitably used in growing timber. As to the best trees to be planted at different elevations and on different soils, at least by private landowners, no doubt there are many botanists in our societies who could greatly help with their advice. In the last half-century we have doubled our imports of timber and now do not produce more than a tenth part of our requirements, although our climate is admirably suited to the production of nearly the whole.

We are far behind most European countries in the relative area of our timbered land. For instance, nearly half the area of Russia and of the Scandinavian countries is wooded, about 26 per cent. of the area of Germany, about 17 per cent. of that of France, and the same of Belgium, the most densely populated country in Europe until its devastation and depopulation by the Germans, but only about four per cent. of the area of the United Kingdom,

which will probably be reduced, owing to the requirements of the war, to not more than two or three per cent.

Next to fostering agriculture let it be your aim, individually as well as collectively in your capacity as members of societies working in harmonious co-operation, to promote to the best of your ability the re-afforestation of our country. By encouraging these two industries you will help to secure its future safety and prosperity.

I have said nothing about three Sections of the British Association: B, Chemistry; G, Engineering; and I, Physiology. In them concerted action is not so much required as in those which I have brought before you, but I hope that I have given, for a single address, a sufficient number of examples of good work done by our Corresponding Societies in the past and a sufficiency of hints of what their aims should be in the future. I will only add that it should be the chief aim of each of us

> 'To make the world within his reach
> Somewhat the better for his being,
> And gladder for his human speech.'

A vote of thanks was passed to the President on the proposition of Mr William Whitaker, Chairman of the Corresponding Societies Committee, seconded by Sir Edward Brabrook, and afterwards the following discussion took place.

Mr. WILLIAM WHITAKER (Croydon Natural History and Scientific Society) said: I heartily agree with the President in pretty nearly the whole of his address. That he was the President of the first unofficial Congress of the British Association interests me especially, as I happen to have been that of the last.

It is a great thing that all societies should know of the slides mentioned by the President, and that they can be borrowed. I should like to emphasise what the President says of Topography. It is very important that this particular branch of Geography should be studied, not only by observation in the field, but by the consideration of its literature, which is an exceedingly large and important one. I am not going to defend the Ordnance Survey; it is their business, not mine; but there is a good deal to be said for them in regard to prices. If any societies want a large number of maps for their use as a society—not for sale—they can get them at a ridiculously low price. We in Croydon have done it. We not merely got a map at a low price, but got the copy printed as we wanted it—that is, with Croydon as a centre; five hundred copies, and I think the cost was about a penny a copy. Of course they cannot be sold to members, but they can be given to them for use in marking scientific areas and sites. In Croydon every subject of importance we put on a map.

The President says that Economic Science should be separated from Politics. But you cannot, the two sciences go together. Economics is a very important part of political science; in fact, political science cannot get on without it. There is one economic law you cannot get rid of, and that is simply to buy in the cheapest market. In the end it comes to this, that the law will conquer. I need not go into the reasons Of course the war is making us think of these things, rightly in many cases, wrongly in others.

I am not inclined to go so far as the President in favour of classical languages, but I heartily agree with him in what he said about English. We have in this country one of the finest languages, if not the finest, that ever was invented, and we ought, instead of neglecting it, to make it one of our chief studies. It is one of those things in which we English, as we generally do, depreciate our own things, and make out that the English people are doing wrong and other people doing right. One of the changes wanted in English education is the proper study of the English language.

The President has rightly put to the front the Hertfordshire County Museum. One of the societies I represent is the Essex Field Club, and we have two museums to look after. I do not know whether any other society can go as far as that. One museum is managed in concert with what I venture to call the enlightened Borough of West Ham, with a Council which does not mind

spending a little on scientific purposes. If anything is going at a fair reasonable price it will get it. Another point which our societies will have to study is working in concert with municipal and county authorities, with which they should be more connected.

There is one thing our President has not noticed: the need of some alterations in our land laws. You will not advance very much without this. The farmers do not want our sympathy: they want the power of doing what is right. In Essex there are, or were, square miles of uncultivated land.

The Rev. J. O. Bevan (Woolhope Naturalists' Field Club) spoke as follows: I joined the Association in the year 1879. The first meeting I attended was at Swansea in 1880, and I did not understand at that time that such a mountain was in labour. One is delighted to find that, although the mountain was in labour, it has not brought forth a ridiculous mouse; it has brought forth the Conference we have the pleasure of attending to-day.

One cannot fail to notice that we have, and have had, some very eminent meteorologists at our meetings. I especially remember Mr. Symons, whose personal qualities were as high as his scientific attainments in the department which he had made his own Another that occurs to me is Dr H R. Mill.

Not only in our own country, but throughout the entire Empire, afforestation is of interest. When, as one of the members of the Association, I visited Canada in 1884 and 1897 I was saddened by the consideration of the great destruction that is going on in the forests in that wonderful portion of our Empire I was told that the timber was cut day by day to make paper-pulp for a New York paper. What one complains of is that a simultaneous effort was not made to supply the waste. In the United States there is Arbor Day, and on that day every person who is able is required to plant a tree Our societies would be very well advised to suggest that a day of that sort should be inaugurated throughout the British Islands. Those who have really wanted to study forestry have had to go to Germany. This is not only unfortunate; it is disastrous. It is in line with the policy which the President has touched upon with regard to our dependence upon Germany and foreign countries for things for which we ought to depend upon ourselves

It is a kind of irony of fate, when Kent's Cavern has been so handsomely and wonderfully worked for so many years by Mr. Pengelly and others, that it should have been allowed to pass out of the hands of scientific people and scientific associations. A certain measure of blame, I dare say, is to be attached to local associations, and perhaps to our great Association. But the thing is done, and ought to be amended as soon as possible. It is a feature of our Association and our Conference, that much of our effort is spent in simple talk; the matter ends with talk. I hope that something may be done at this Conference of Delegates to set matters in train whereby the working out of the cavern shall be carried on by scientific people in a scientific way. There is very little doubt that considerable elements in the past history of our globe are now enthroned in that cavern which in existing circumstances will not be brought up.

Sir Edward Brabrook (Balham and District Antiquarian and Natural History Society) stated that the matter of Kent's Cavern was brought before the Council, and they expressed their entire sympathy with the object, but the Ancient Monuments Act, unfortunately, does not apply to objects of natural formation, such as Kent's Cavern. Therefore he was afraid, after having inquired of the best authority on that subject—that is, the Chief Inspector of Ancient Monuments—that nothing could be done for it.

The Secretary reported that the Council had officially informed him of the facts which Sir Edward had put before the Conference, and he alluded to what Mr. Mark Sykes said at Newcastle that he was prepared to do. It is now up to the Conference, as Mr. Bevan has said, to try to carry the matter further.

The Rev. J. O. Bevan said that he would be very glad to formulate a proposal.

Mrs. Forbes Julian (Torquay Natural History Society) was very grateful for the remarks that had been made about her father (Mr. Pengelly) The working of Kent's Cavern was a great work in any man's life When the cavern was offered for sale her husband knew nothing about it. She would be very glad if anything could be done, because it was a very great loss to science, as

not only could one not make further investigations there, but it was difficult to trace even those of the past.

The Rev. T. R. R. Stebbing (South-Eastern Union of Scientific Societies) was bound to say that his nephew, E. P. Stebbing, a lecturer on forestry in the University of Edinburgh, would be happy to give instruction to anyone particularly interested in that industry.

Miss Layard (the Prehistoric Society of East Anglia) pointed out that there were few English caves or caverns available for research, and that they were extremely valuable, especially with regard to surface flints and the discussions which arise with regard to whether these are of neolithic or late palæolithic origin. There is also a danger of the site of the Anglo-Saxon cemetery which was discovered at Ipswich several years ago being lost sight of, as it would probably be soon built over. She asked whether a suggestion could not be made by the British Association that some kind of small monument should be placed there.

Mr. A. W. Oke (the Brighton and Hove Natural History Society) then made further suggestions, and asked whether a committee, consisting of Sir Edward Brabrook, Mr Whitaker, and others, could not be formed to deal with the question.

Dr. F. A. Bather (Museums Association, and Wimbledon Natural History Society) pointed out that everything that was made by man went to the British Museum as historic; the animals with which man was associated went to the Natural History Museum. It was obvious, therefore, that the main interest in Kent's Cavern was historic; certainly it should come under the National Trust for Places of Historic Interest In further remarks, Dr. Bather said that as they met in London it might be of interest, at all events to those in London, to know that the John Evelyn Club for Wimbledon, the parent of the society that he represented, was instrumental in saving to the public a very large tract of land that had recently been added to Wimbledon Common. The great advantage of saving this land was that having it built over would have spoilt the view from Wimbledon Common. Also the smoke would have added to the damage. It was the hope of the Natural History Society to try to form out of a portion of this something like a sanctuary. The other body which he had the honour to represent was the Museums Association. The President had alluded to a very valuable report on museums drawn up in 1887 by the British Association. Of course that was long ago, but years afterwards the Museums Association produced a Directory to the Museums in this country which would be found more up to date, and rather more complete, than the old report. Also there was at the present moment sitting a British Association committee which was discussing the educational aspect of museums. The work had been held up because a good many of its members were otherwise engaged. He hoped a valuable report might be issued, but education does not, or should not, cease when we leave school. Education by museums was not confined to school children, but they had the opportunity of educating the whole of the public, and during this time of war some of our museums had recognised their duty as educational media. There were so many ways in which museums could educate the public, if only people would utilise the museums, which would be only too ready to help.

He was very strongly in favour of Latin and Greek, but would remind them that 'a little knowledge is a dangerous thing' He studied Latin and Greek for a number of years, and though he thought he knew enough to construct names correctly and make new specific names he found he was mistaken. The ability to look up a lexicon and a dictionary and some knowledge of inflections and so forth was not enough, and it was generally advisable to take counsel with a real classical scholar.

He did not wish to discuss the question of Free Trade, but he did wish to say he agreed with Mr. Whitaker. As to saying that economics should be divorced from politics, he would rather go to the other extreme, and say that not anything that interests us as human beings and citizens of the British Empire should be divorced from politics. The trouble was, we had allowed politics to be divorced from us. We ought to keep a hold on politics; to keep up our interest; to take part in all affairs, and to take care that we did not draw distinctions between certain subjects and politics, and then blame politicians

because they did not understand us. They could not go very far, even in the pursuit of science, before they found it necessary to begin to talk to the politicians.

The SECRETARY, speaking as Secretary of the Selborne Society, added his testimony to that of the others as to the pleasure he had received from hearing Mr. Hopkinson's address.

With regard to Arbor Day, the Society for the Protection of Birds had for some years had an Arbor Day. It was also a matter not entirely lost sight of in this country by individuals, such as Mr. Till, of Eynsford, but it should be instituted by the State or as it was in America The ordinary landowner was supposed to be in difficulties when he cut down the trees, but this was not always the case One of Lord Yarborough's ancestors looked at the bare hills round his house, and thought it would be a very good idea to plant trees, and he planted hundreds and hundreds of acres. The present Lord Yarborough came to the conclusion that it would be a rather good idea to treat the trees as if they were corn, and cut down a number of acres every year; but he planted several times as many trees as he cut down. Speaking of a visit paid to Lord Yarborough's estate, Mr Webb said the forester told him that instead of having a difficulty to part with timber he had a regular market every year for the best; the poorer wood they kept and creosoted for their own use. This was a sort of thing that might be done all over the country.

The President had said that one of the difficulties was that children could not handle things in museums He (Mr Webb) had the pleasure a year or two ago of devising a museum which might be made for the use of children, and he had shown one at the Children's Welfare Exhibition. The exhibits which were not living were changed according to the season and time of the year, and there were specimens that anybody could pick up and examine, specimens chosen because they could not be easily damaged.

If Mr. Bevan would give them a resolution with regard to Kent's Cavern, asking them to go forward, he would, as the Secretary of the Corresponding Societies Committee, see what he could do in the matter He did not think they could appoint, as Mr Oke suggested, a definite committee, because it was not within the power of the Conference, but they might nominate representatives to serve on any outside committee that could be brought into existence.

Mr. HENRY BARNES (Worcester Naturalists' Club), speaking on the subject of museums and their educational value, said this was very much weakened by reason of there being no guide, either in the person of the curator or some assistant, who could point out to the many persons visiting them the various objects and their classification and relation People wander in the vaguest way through a museum, not knowing what they are looking at If the curator observed an interested visitor who did not appear to know much about the object he was looking at, and could just put in a word and give some information which would arouse interest and curiosity, the educational value of museums would be very much enhanced. If there were anyone present belonging to the Museums Association, a suggestion in that direction would not do any harm

The PRESIDENT, replying on the debate, said: I was very pleased to hear what Mr. Whitaker said about Ordnance maps. I was not at all aware that maps could be had at less than the published price, and I hope that that fact will be made widely known, so that local societies can get them at a very greatly reduced rate.

A society's journal is an encouragement to members to contribute papers to the society. I have been editor of one since 1875; members have given us good papers who had never written anything before, and probably never would have written anything had it not been for the society. I have found that members who had never had any previous scientific training and had not had a college education have written better English than some highly educated scientific men

As to meteorology being almost ignored in the Association, I have a personal experience of the difficulty of bringing forward meteorological papers, finding that they are nearly always relegated to the very last place, when there are only two or three minutes left.

It would be an excellent thing if we could settle upon an Arbor Day and induce all our societies to get all their members to plant a tree on that day. It could be initiated perhaps better from this Conference than in any other way.

Perhaps, instead of politics, I ought to have said party politics, for I used the word in its usual restricted sense as the art of forwarding the interests of a political party.

Mr. FAGG then read the following paper upon

Regional Surveys.

At the Conference of Delegates of Corresponding Societies held at Newcastle-upon-Tyne last year, your President, Professor Lebour, chose for the title of his address 'Co-operation.' I might very appropriately preface my remarks on Regional Surveys by some quotations from that address, but I will reserve these until the end, when you will be better able to see that the regional survey provides the means for carrying into effect, systematically and in detail, Professor Lebour's suggestions. The regional survey is in fact the materialisation of the spirit which animated his address, which itself gave voice to the spirit of the times in matters of local research, and indeed in matters of far wider interest.

The same is equally true of your present President's stimulating address

The subject of regional surveys is a very large one, and we must concentrate our attention on one or two aspects of it. I cannot do better than tell you of the regional survey activities of three societies with which I am connected, namely, the Croydon Natural History and Scientific Society, the South-Eastern Union of Scientific Societies, and the Regional Survey Association. The two former are Corresponding Societies of this Association, and the third, which is a newer society, will probably shortly apply to be admitted as such.

I will commence by describing the methods we have adopted in conducting the survey at Croydon; next I will give an account of the scheme for co-ordinating all surveys in the South-Eastern Counties, which is being developed by the Regional Survey Committee of the South-Eastern Union; and finally say something of the activities of the Regional Survey Association, which exists for the purpose of promoting regional surveys throughout the British Isles. In so doing, I shall of necessity repeat to some extent what I have said in former papers, but I will avoid this evil as far as possible, and for the sake of brevity refer you especially to two of these papers, namely, 'Regional Surveys and Local Societies'[1] and 'Regional Surveys and Public Libraries,'[2] in which I have briefly traced the history of the movement and dealt with some points at greater length than is here possible

A regional survey may be described as the organised study of a region and its inhabitants, plant, animal, and human, from every aspect, and the correlation of all aspects so as to give a complete picture of the region, both in its past history and its present features, and from these to indicate its probable future development. Such a survey is a very comprehensive task, providing activity for every class of research student, and opening up problems of methodology and technique such as Committees of the British Association delight in solving. If Regional Survey is proper to one section of this Association more than another it is the Geographical Section, but the equipment of the Regional Surveyor, or collectively of the Regional Survey Society, must include some knowledge of the subjects dealt with by every section. The Croydon Survey was the outcome of some suggestions made by myself in April 1912, in which the following reasons for undertaking it were advanced: 'The survey will give the society a concrete scheme of work which will last for many years and provide activities for every section. It will revive the life

[1] Trans. S.E. Union of Scientific Societies, 1915, p. 21.

[2] Read before the Library Association and Library Assistants' Association, March 15, 1916; abstract in 'The Library Assistant,' May 1916.

of some of the sections which are now slumbering and give greatly increased interest to others. By relating the work of all the sections to a common scheme these will be brought into more vital contact with one another and become mutually dependent in a variety of ways. All this means that new life will be brought into the society, and the results in a few years' time should be of great scientific interest and educational value.'[3]

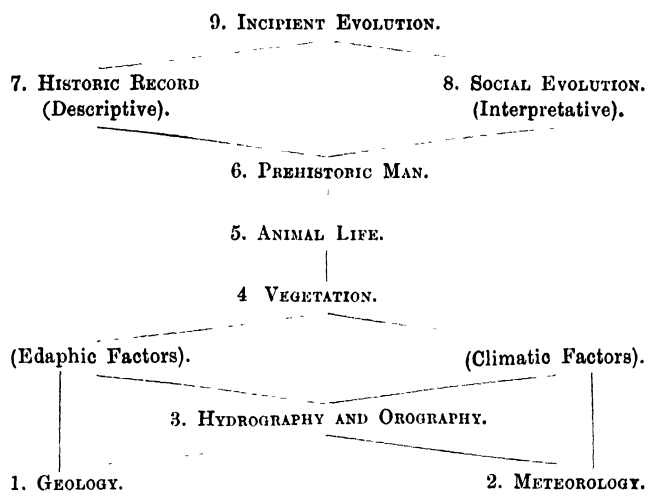
The work of making a survey may be conveniently divided into three branches: observation and record, interpretation, and exhibition. In recording regional observations the aims should be conciseness, ease of reference, and suggestiveness in arrangement, and the most concise, convenient, and suggestive means of making records is on a map. The basis of our records, therefore, will be a large series of maps. But we must not overlook the limitations of the map nor forsake other methods of recording data, and in most cases our maps will be freely supplemented by written descriptions and photographs, statistical tables and diagrams. But maps will form the foundation of the survey, and it will be necessary for this reason to set geographical limits to the area to be surveyed. I shall return to this question of defining the limits of the region when speaking of the South-Eastern Union. For the present suffice it to say that at Croydon we have chosen a rectilinear area sixteen miles long and twelve miles wide. I need not enter into our reasons for this choice, much less describe the area itself, my sole object being to demonstrate the methods we adopt. Having defined the area, we must procure a number of maps upon which to make the records. The 1-inch scale will be large enough for most general records, but not for use in the field nor for some special records. For field work the 6-inch maps are indispensable. The best way to obtain the 1-inch maps is from the Ordnance Survey Department, which issues for educational purposes lightly printed maps, with any heading we may choose, at very greatly reduced prices. This privileged issue of maps is in abeyance during the war, but I am informed that it will be resumed when the present pressure on the department due to war work is over.

(A specimen of the Croydon map, of which 500 copies were procured, and a number showing different features of the district in manuscript, *e.g.*, geology, rainfall, population, &c., and a selection of photographs, were exhibited to illustrate the paper from this point onward.)

There are many maps which can be prepared without leaving the study, from material already available. The mere transference of written records to maps is often very enlightening. At the least it helps us greatly in visualising them. The Ordnance maps themselves contain data for several maps (*e.g.*, contours, parish-boundaries, rivers), and it is only necessary to accentuate each set of data by coloured inks or washes upon a separate map. In most cases, however, the work of compilation will need supplementing to a greater or less extent by field observations. Concurrently with the field-work and map-making a systematic hunting up of all existing records of the region under survey will be carried out. A classified bibliography capable of indefinite expansion will be prepared, and a collection made of books, pamphlets, old maps, and manuscripts dealing with the district. In this search we shall rediscover many useful items which have been buried away in back numbers of our societies' publications.

Let us next pass briefly in review from the regional standpoint the various sections of the survey, and in so doing endeavour to arrange them so as to bring out their relations to and dependence upon one another. The diagram will help us in this. From our point of view it would be difficult to over-emphasise the importance of the geology of the region. It is the foundation upon which all else is built. Palæontology is a subject not to be ignored, but except in the Pleistocene beds or as an aid to zoning it has little regional significance. The same is true of *past* geological history. It is the present disposition of the strata and their physical and mineralogical characters that determine the topography of the district and profoundly influence all life

[3] Proc. Croydon Nat. Hist. and Sci. Soc. 1912, p. cxxxvii.



upon the surface, from the types of vegetation to the occupations and habits and even the ideals of the human inhabitants.

In geology a century of survey-work has been accomplished, and we have the Geological Survey maps and memoirs and much valuable amateur work to start with We may commence by copying on two of the maps the Drift and solid geology from the official maps. Where only the old inch maps are available it will be found impossible satisfactorily to transfer the geology to the new editions of Ordnance maps without some field observations. Many districts are more fortunate in having the new series of inch geological maps, while some parts have been surveyed on the 6-inch scale, and the manuscript maps are available for reference at Jermyn Street.

The geological map is one of those which, like the contour and other leading maps, should be prepared in outline as a transparency for the purpose of placing over other maps for comparison. In this way many interesting points will be brought out. A geological model and vertical sections should also be prepared.

Although so much has been done in geology, there is still plenty of scope for the local worker. Several lines of investigation open to him were mentioned by Professor Lebour in his address last year.

Next in importance to geology is meteorology or climate—that is, the rainfall, temperature, sunshine, wind, &c. The charting of meteorological records will add greatly to their value, and other branches of the survey will make good use of them. The Croydon Society has for many years made and published daily rainfall observations for about 100 stations under the direction of Mr. F. Campbell-Bayard, and in transferring some of these to maps we were fortunate in obtaining the help of Dr. Hugh Robert Mill, who very kindly had three of our maps prepared for us from his British Rainfall Organisation charts—namely, the average annual rainfall, and a very wet and a very dry year (1903 and 1898). One of our members is engaged in working out a further series of rainfall maps.

Meteorology competes with geology as an influence upon life, and the two sets of phenomena act and react upon one another The rainfall playing upon the geological strata determines the hydrography of the region—that is, the surface and underground drainage, which, with the other atmospheric agents of erosion, gives us the orography or contour.

These three branches together form the physical environment, and directly dependent upon them all is the vegetation or plant-ecology. The geology and the hydrography on the one hand give us the edaphic ecological factors, while

the meteorology and orography together constitute the climatic factors. In the local study of vegetation in this country there is little left to do in making floras. We have our local floras complete, except for occasional new records. The distribution of some important or interesting species may be shown on our maps, but it is to the study of the plant formations and associations and to the preparation of vegetation maps that the botanists of the regional survey will devote most attention. Vegetation maps have been published for a few districts. Those of the Peak District by Dr. Moss are excellent examples. Other vegetation surveys have been made by members of the British Ecological Society, but their publication is in many cases held up on account of expense.

Dependent again upon the vegetation and physical environment, and reacting upon them in a variety of ways, is the animal life of the region, which is capable of treatment similar to that given to the vegetation.

Finally, we have mankind dependent upon his whole environment, physical and organic, and to an ever-increasing extent master of it. It is in mankind and his contemporaries that we find regional links with recent palæontology, and we have to follow his career from his advent in our regions through the realms of archæology and history to that of modern sociology.

Prehistoric man is worthy of a place to himself. We shall have to deal with his implements, weapons, earthworks, and other remains, paying special heed to locality, and to reconstruct as far as may be the picture of his life in our regions.

From the dawn of history the human survey may well be divided into two parallel branches, which in the preceding diagram I have provisionally called 'Historic Record' and 'Social Evolution' The former will be an analysis and record to any degree of minuteness of all human institutions and activities in each historic period; the latter a synthesis and interpretation of the records, its aim being to show what each successive period has stood for in the region, and in particular what heritage it has handed down to the complex of our present civilisation.

The object of all research is to establish relations of cause and effect, and to enable us to foresee events and, if necessary, to deal with them in advance. The most valuable result of our surveys, therefore, apart from their great educational value to the surveyors themselves, will be to enable us to detect and understand the tendencies of our times, and put us in a position, as citizens, intelligently to encourage good and discourage evil ones. For this reason, in the above outline scheme, I have given a special heading to what I have called 'Incipient Evolution.' By so doing we are not so likely to overlook this all-important aspect of the survey We shall find, indeed, when the survey is in progress, that this branch will often give temporary direction to our efforts.

The above primary classification is, by accident, ninefold, and therefore well adapted to a decimal system of notation for indexing, the cipher being left free for methodology.

When we commenced to get to work at Croydon we found there were many questions of technique to be settled, and that the whole scheme of work needed carefully thinking out, and it appeared to us that many things could be better settled by a larger body representing a number of societies which might in the future be undertaking surveys. Such an organisation, for instance, as the South-Eastern Union of Scientific Societies would, it appeared, be able to encourage, co-ordinate, and secure some measure of uniformity in survey work by its constituent societies. Accordingly I introduced the subject to the South-Eastern Union at its Brighton Congress in 1915, and as a result a Regional Survey Committee of members of the Union, with Professor G. S Boulger as its Chairman, was formed. After some preliminary work this committee has settled for the present upon four lines of action. I will deal with each of these separately.

1. *The partition of the south-eastern counties into areas suitable for local surveys.*—This involves the question, 'What is a region?' Strictly speaking, the term used in this connection is a centre of civilisation (a city, town, or even a village) and its natural environs. It is not always easy to define the limits of such a region, and the task of the committee, which aims at covering the whole of the Union's area by a mosaic of small regions, is not a light one.

We have decided that for many reasons the civil parish will form the most generally suitable unit of area, and that a local survey should deal with at least one parish, or more often with a group of parishes around a civic centre. The grouping of parishes into survey areas, and of these again into larger natural regions, is a piece of work that will take some time, and will depend for its success largely upon the help of local societies.

2. *The preparation of an outline scheme or 'conspectus' for local surveys.*—This will be a general and detailed analysis of the whole field of survey, with suggestions for the maps to be made and work to be done in each section. Appended to the committee's report in the forthcoming volume of Transactions of the South-Eastern Union will be some notes on a method of surveying rural parishes which will be useful to anyone engaging in survey work in country districts

3. *A regional survey bibliography.*—This will contain references to books, pamphlets, maps, manuscripts, &c., dealing with any part of the Union's area and with any subject, and its arrangement will follow that of the conspectus

4 *The preparation of a series of maps of the Union's area showing different features of interest* —This will be on a small scale (¼ inch) series to serve as an index series to the larger scale maps prepared by the local societies

Since the formation by the South-Eastern Union of a Regional Survey Committee some of its affiliated societies have taken up survey work. After the war we expect several others will do the same, and possibly in some unrepresented districts new societies for carrying out surveys will be formed.

I may now appropriately repeat what Professor Lebour said in his Presidential Address to this Conference last year, and I may claim that the regional survey offers to local societies a means both practical and thorough of carrying out the spirit of his suggestions

'The above are some only of very many directions in which the clubs and societies, working on pre-arranged lines with each other, may, in the field of our branch of science alone (geology), induce their members to take part in wide-reaching research with the certainty that no bit of work, however small, will, so long as it is honestly and carefully done, be lost, but will find its place as a stone in some worthy edifice erected by the joint efforts of many others. Co-operation of the kind I have in mind should be so planned that the maximum value in useful results will be obtained from the maximum number of co-workers . . The machinery to carry out such schemes must be left to those in whose hands lies the management of the different societies.'

In conclusion, let us take a brief glance at the Regional Association. This Association has wider contacts than either the Croydon Society or the South-Eastern Union, inasmuch as it covers the whole of the British Isles and takes an active interest in the application of regional survey to education, to town-planning, and to civic development generally It was formed as the Provisional Committee for the development of Regional Survey at a conference held at the Outlook Tower at Edinburgh in 1914, and having done much good work under that title is now preparing its constitution as the Regional Survey Association Professor Geddes, to whom, perhaps, more than anyone else the Regional Survey movement in its wider sense owes its inspiration, is the President of the Association It is an itinerant Association, holding one or two meetings annually at different centres and an annual meeting in London. In the three and a half years of its existence it has held meetings of a week or more duration at Edinburgh, Dublin, Aberystwith, Ludlow, and Newbury.

The Association has, among its several committees, a Publication Committee, which, in addition to obtaining reprints of regional survey contributions to other societies' publications for distribution, has issued three leaflets with suggestions for starting regional surveys written respectively from the physiographical, natural history, and humanistic standpoints [4] Others are in the course of preparation.

Finally, what shall we do with our accumulating survey material? It is not in the spirit of the movement that we should hide it away in cupboards at our

[4] Obtainable from Geo Morris, B.Sc, 18 West Road, Saffron Walden, Essex.

societies' headquarters. At Croydon we deposit the maps, photographs, and other material at the public library, where they are available for public reference and are of great use to local teachers. The ideal to aim at, however, is the formation at each centre of a regional museum. Such museums, and there are some in existence, with regional surveys behind them, become very living institutions in the districts, and help both visitors and inhabitants to understand what the places have been in the past, what they now stand for, and what are their possibilities for the future.

Mr. GEORGE MORRIS (of the Regional Survey Association, a visitor) said: I should like to point out the rather wider aspect of the Regional Survey as we consider it in the Regional Survey Committee. During the last twenty years a great deal of change has taken place in the teaching of geography and in the teaching of history. As regards archæology, the practical end of the teacher's work is gradually to reach out to taking the child from the confines of the schoolroom, and putting him in his education in contact with actualities. That is one of the things we of the Regional Survey are out for, and it is almost impossible for the average school-teacher, who comes from a hundred miles away and knows very little about the surroundings, to effect this. We should like to see every secondary school in England, both teachers and pupils, undertaking a regional survey on the lines Mr Fagg has put before us. The history, the geography, and the archæology would be indicated on maps The zone where the school is would be the regional zone, and the map would show the local applications, where the local remains or the local specimens and so on are. To do this we have an Educational Sub-Committee which is trying to institute such surveys. Then we have a sub-committee which is endeavouring to register at any rate and obtain the interest of the scientific societies in local work of the kind; and also we have a Museums and Local Societies Sub-Committee We hold meetings to which we invite teachers from the different schools. We invite scientific men who have special knowledge to join us, and we ask the local people who are interested in archæology or geology, and so on, to give us help. Then we devote a week to study and the reading of papers This has been done with success. We have invited the co-operation of various bodies, specialist association bodies, and an inter-committee has been formed I should point out that this Regional Committee is endeavouring to synthesise in different directions the various branches of inquiry and make them available for general reference. The underlying idea of the whole of the Regional Survey is that you have a community which is an organic entity, and, like every organic being, is dependent on its surroundings for its being and for its present condition. In other words, I define it as the study of the Ecology of the Human Community.

Mr J. OSCAR PARKER (Chairman of the Council of the Selborne Society, a visitor) said: I do not know how I can convey a better impression of the scheme which has developed than by suggesting that if a second William the Conqueror took up his residence in England at some shortly future day, he would, if this work has been completed according to the lines which Mr Fagg has presented to us, find a Domesday Book ready to his hand He would be able to gather into his autocratic hand all the estates, all the woods, all the lands that exist to-day, without appointing a commission to go about the country. Why, then, should it not be of tremendous interest to ourselves? If this work is carried out throughout the country we shall have a remarkable survey of the whole of our beloved country right at hand

Miss LAYARD said that some years ago, when she was making excavations on the site of conventual buildings in Ipswich, she made use of the Ordnance Survey map, and distinguished in colours the buildings of the convents, priories, and so on

The Rev. J. O. BEVAN said they wanted specialists for carrying on a survey of this kind: persons specially trained in other matters (ethnological, for instance) that are involved in a survey of this sort, so as to secure that one series of facts will not interfere with another. It is oftentimes a danger when you get persons partially educated involved in such work

Mr. HARRY SOWERBUTTS (Manchester Geographical Society) referred to regional surveys that were being carried on for the improvement and replanning

of towns. This work was sanctioned by Government, and was being carried out by local architects and surveyors. A diagram of the road traffic would be imposed on the Ordnance Survey maps, depicting very clearly the widening of the roads, and by different colours the detailed volume, and different classes of traffic passing over main roads at a fixed hour of the day. The great value of a plan of this sort was that it showed fairly accurately to a local authority from which direction the greatest volume of trade entered its town, and in the case of the through traffic how it could easily be diverted in order to lessen the congestion in the centre. Mr. Sowerbutts mentioned maps showing by different colours the growth of Manchester from 1650 to 1885. All the different periods were shown by different colours, and the different stages were clearly seen. It was intended to let the plans give details of the growth as affected directly by manufactures and by position as a distributing centre Then there was a plan dealing with the accessibility of the area by trams and by trains, and how better communication could be obtained. A third plan showed the two systems superimposed Two maps showing the rainfall might be very instructive when associated with rain statistics; the first one to give the average rainfall for a period, the second the number of days in which more than 01 inch fell. It was almost impossible to describe adequately the value of this work: surveyors, medical officers, and other officials had testified to its usefulness; in fact, some had gone so far as to suggest that a permanent department on the lines of the Ordnance Survey should be established Mr Sowerbutts advocated regional surveying in connection with those matters so vital to trade after the war. The point that struck him was, How was it going to be carried on? At present the Government was paying for it, supplying architects with work during the war

Dr. BATHER was very much puzzled about the architects, and wanted to know what Department was paying them

Mr FAGG: The Local Government Board is paying them

The PRESIDENT spoke of the duty of societies to the best of their ability making a survey of their own locality or their own town and district As an example, he handed round a pamphlet which was brought out by the Hertfordshire Natural History Society for the South-Eastern Union at its St Albans Congress in 1911. Members of the society took particular divisions of the subject, and the area was restricted to a radius of five miles. Topography, geology, hydrology, climate, flora, fauna, and archæology were given divisions. They also added an account of the County Museum. If societies would do this in their own districts, and hand the result to the Regional Survey, he thought it would help considerably in a much larger scheme With regard to the survey of the footpaths, they thought it would be better to have a separate association, and one was formed with a small subscription of 2s 6d. a year—now no longer required They were now in the fourth thousand of their map, and something like a thousand must have been bought by soldiers.

Mr. FAGG said, with regard to Mr. Bevan's remark about specialists, that quite a number of maps have been prepared for them by specialists, and in all the survey societies they made use of all the specialists they could get together. On the other hand, he still maintained that a vast amount of work in these surveys can be done by people who are not specialists. With regard to the civic surveys, those who were instrumental in getting them carried on did not intend them to stop after the war. He had not the slightest doubt that all this work would sooner or later get Government recognition He had brought together a number of pamphlets dealing with the Regional Survey Some of them they had in the transactions of the societies; those they had not got he thought might be of interest for their library.

The PRESIDENT said that the great advantage of their library was that every paper published by their corresponding societies and indexed in their report could be seen in it at the offices of the British Association.

Second Meeting.

At the meeting held in the afternoon of Thursday, July 5, it was decided to ask the Council to add the name of Dr. Bather, the Vice-President of the Conference, to the Corresponding Societies Committee.

The Conference appointed Mr. Whitaker, Mr. Webb, and Mr. Mark Sykes to confer with others who might be interested in Kent's Cavern.

Mr. Thomas Sheppard then read the following paper upon

Money-Scales and Weights.

Terrible as the present war is, there is no doubt that it has had, and will have, many good results. It has demonstrated that the British nation is more united than was ever dreamed of, and that the people, rich and poor alike, are prepared to give everything, to make the greatest sacrifice, for the common good. We do not hear much to-day of the 'idle rich,' nor of the Piccadilly 'nut.' They have done, are doing, and will do their share for their country. The working classes are not *pushed* by the rich into the battle line, they are *led* by them. Men and women of all grades have come to understand each other in a way which would have been very difficult, it not impossible, without a war. The formation, training, equipment, and upkeep of one of the greatest armies on record is a feat of organisation and management which would have been unbelievable a few years ago The manner in which those at home, both women and men, have helped the war by working, or by grappling with the food problem, is nothing short of miraculous Many expensive luxuries which had almost become necessities with the wealthy are now cheerfully discarded. To the members of the British Association it must be more than gratifying to find that at last the value of science is recognised, albeit that armies of educated people are devoting their scientific work to inventing, perfecting, and manufacturing various machines and materials for the destruction of humanity, or perhaps I should say for the destruction of 'inhumanity' The co-operation and friendship of the Allies, now so thoroughly cemented, will be rigidly maintained after the war, and it is certain that many schemes which have been under discussion for years will be shortly carried out The war brought home to us the great economical advantages of the Daylight Saving Bill, against which the disadvantages have been proved to be practically nil. The necessity for a Channel Tunnel has been more than demonstrated, though we believe the scheme would have been carried out years ago had it not been for the opposition of a military expert. The present war would certainly have been considerably shortened, and thousands of precious lives and, what may appeal to many, enormous sums of money, would have been saved, had the Channel Tunnel been carried out when the idea was first mooted.

In many minor ways the war will result in numerous needed reforms; among these (though possibly the word 'minor' is hardly accurate) is the general adoption of the metric system for weights and measures. The advantages of such a system are so obvious that it is hardly complimentary to an audience such as this to attempt to point them out. In our stubborn, what-was-good-enough-for-our-grandfathers-is-good-enough-for-us sort of way, we have adhered to a series of complicated systems of weights and measures, such as no other civilised country in the world would tolerate We estimate aluminium by avoidupois weight, silver by troy, peas by the peck, potatoes by the pound, fowl and pheasant by the couple or brace, fish and flesh by the pound, oranges and whisky by the dozen, stockings by the pair, pears by the pound, and beer by the gallon. But these absurdities are as naught when compared with other measures and weights. A draper sells most of his things at 11¾*d.* or 2*s* 11¾*d.* or 4*s.* 11¾*d.* Books are sold at two shillings or three shillings or seven shillings and sixpence. A car or a house realises so many pounds, but a picture or a horse realises guineas or half-guineas. Cotton is sold by the yard, wool by the pound, land by chain, rod, or perch, cloth by the ell, timber by the standard.

The question of the origin and evolution of the various systems of weights and measures is of engrossing interest, but is hardly the subject of these notes. I propose therefore to refer to one small branch of the subject, a branch that has been considerably neglected—I mean to money-scales and weights. The subjects brought before the delegates from the Corresponding Societies have varied considerably, but as a rule an effort is made to suggest lines in which work might be accomplished by them. In the first place, I would like to urge upon the delegates the necessity of every care being taken, preferably in the local museum, of objects which are going out of date or out of fashion; objects which come under the heading of 'bygones.' It is amazing how soon a once common thing becomes scarce as the inevitable result of evolution and improvement. Should anyone doubt this, let him try to obtain a tinder-box, a flail, or a 'bone-shaker' bicycle; yet all of you have probably seen them used. Other objects once common, which can yet be picked up, are the various forms of boxes of scales and weights for dealing with money. No one seems to have made a particular study of these. In most museums perhaps two or three can be seen; but even the National Museums in London contain very few examples The following notes are based upon a collection of over 200 specimens, each of which has some particular characteristic, now in the museum at Hull. These, with the help of Mr J F. Musham, I have been able to get together during the past few years The majority of them date from the seventeenth to the nineteenth centuries, though a few are much earlier and others later. In addition to showing ways in which local societies can do good by preserving relics of the past, the necessity for the first manufacture of these scales and the extraordinary variety of the weights, which varied from time to time, demonstrate the desirability of still more simplifying the complicated though relatively simple system now in vogue.

The necessity for money-scales and weights arose long ago, but was accentuated in this country and on the Continent, in the Middle Ages, in consequence of the interchange in the process of trade of an enormous number of varieties of coins; so much so that in some sets of English examples as many as twenty or more weights were required, even greater numbers being found in foreign boxes of scales and weights—these foreign sets being frequently used by English merchants to assist them in their financial transactions

Judging from Greek, Roman, Egyptian, and even Chinese antiquities, it is clear that from the earliest times there have been scales and weights, and as the earlier coins were valued by their weight it is obvious there were coin scales to test them.

Though the Romans used boxes of money-scales and weights, it is hardly to be expected that many such things would be preserved in anything like a complete state. In Egypt, however, where the conditions are so eminently favourable, such objects have been found, and Professor Flinders Petrie has kindly permitted me to examine some very interesting examples in his remarkable collection at University College, Gower Street One of these sets is in a wooden box, about a foot in length, and is provided with a tray In the box are round, square, and other receptacles for the weights, scales, balance-beam, &c., with lidded lockers for the smaller weights. Though this set is dated about A.D. 340, it is almost similar in construction and appearance to the boxes of scales and weights so much in vogue in England from the sixteenth to the eighteenth centuries; the construction of the weights (of brass, square and circular) and that of the balance-beam with circular brass pans, &c , are almost alike, though separated in date by something like twelve or thirteen centuries. Frescoes in the houses at Pompeii have also provided illustrations of the money-scales in use in those early times.

In the Metropolitan Museum of Art, New York, is a set, dating from the Coptic period, which even better matches English early Georgian boxes, in the shape of the box, the brass hinges, and the impressed concentric rings decorating the lid.[8]

In Anglo-Saxon times money-scales were in use. In Saxon graves in Kent

[8] Egyptian Weights and Balances. *Bulletin of the Metropolitan Museum of Art*, vol. 12, No. 4, April 1917, pp. 85-90.

have been found sets of these scales and weights, the weights being sometimes made from Roman coins rubbed down to the required size.[6]

All the early forms of money-scales are of the well-known type, with a balance-beam and two suspended brass pans, somewhat similar to the familiar copper scales in use in grocers' shops to-day, excepting that the coin scales have shallow pans. With very slight variations this type has been in vogue for two thousand years, being in use in this country up to half a century ago. In recent times the difficulty of making counterfeit coins without detection has been so great that testing coins for weight and size is almost unknown The withdrawal of various kinds of foreign coins in England has also assisted in scales being dispensed with. Formerly, however, coiners and coin-clippers were so much in evidence that the Beggars' Litany 'from Hull, Hell, and Halifax, Good Lord deliver us' is said to have originated from the fact that at Hull and Halifax, at any rate, coiners were punished with unusual severity.

The earliest illustration of a pair of English coin-scales that I have been able to trace is dated 1496, and occurs in *Vetusta Monumenta*, vol i. 1747. It is on a plate described as 'The Standard of Antient Weights and Measures, from a table in the Exchequer. From the original Table formerly in the Treasury of the Kings (*sic*) Exchequer at Westminster, and now preserved in the MS. Library of the late Earl of Oxford, anno 12 Henrici Septimi [1496], N B The original Parchment is fix't on an oak table.' On this there are illustrations of various kinds of weights and measures, a view of the Exchequer, a man in the pillory for giving short weight, &c

From the centre of this document we learn that 'By the discrecion & Ordinaunce of or-soueraigne lorde ye kinge & of his lordes spuall & tepall wth ye commons of ye same his realme of England of all manr of weight and measure yt was made by ye grayne of wheate. This is to understande yt xxxjj graynes of wheat taken out of ye middell of ye yeare weieth a starlinge otherwise called a penny & xx starlinge maketh an ounce,' &c

In the top left-hand corner of this remarkable document are illustrations of 'The Whete eare,' with the information that 'Two graynes maketh ye xvj pte of a penny The conage of ye mynte ffower graynes maketh the viij pt of a penny. The iij pte of a penny is a farthinge, xvj graynes an halpeny, the halpeny wth ye peny and halpeny and the farthinge is all poore mens, upon all manner of vitelers of the realme. . . . The cuynars to be sworne in speciallie yt ye thirde pte of ye Bullion be made in halpence & farthings, yt is to saie that one half of the saide third in halpens & ye other in farthings.'

Accompanying this quaint information is a sketch of a pair of coin-scales with a penny (on edge) in one tray, the other being full of grains, presumably thirty-two It is to be hoped that the eccentric fork to the scales is merely an error in the drawing!

It occasionally happens that representations of antique money-scales occur on old pictures. Perhaps one of the most interesting examples of these is 'The Banker and his Wife' by Corneille de Lyon, which was at Antwerp before the war In this case a gold piece is about to be weighed in a pair of scales with triangular pans, the weights being square; on the table is the box for the scales, with twenty-four oblong pans for the weights Similar old sets of scales are shown on the picture by Quentin Matsys in the Louvre, in 'The Misers' at Windsor Castle, and other paintings in the National Gallery and elsewhere.[7]

In the middle of the seventeenth century a 'steelyard' type of scale was in use in Ireland for weighing coins, an illustration of which appears with the following 'Extracts from the Journal of Thomas Dineley, Esqr., giving some account of his visit to Ireland in the reign of Charles II.'[8]:—

'The most usual money and that which passeth in the greatest quantity of

[6] For illustrations see *Inventorium Sepulchrale*, 1856, pp. 22-23, and *Archæologia Cantiana*, vol. vi. 1866, pp. 157-185.

[7] See *Burlington Magazine*, vol. xx. No. 107, February 1912.

[8] *Journ. Kilkenny Arch. Soc.*, vol. ii N.S. 1858-9.

silver in Ireland is Spanish Coyne known here by the name of a cob, or half a cob or a quarter cob.'

'A sort of pieces of eight at 4-6*d* each, which they call plate pieces, Mexicos, and Perues.'

'The cobs that are weight, as well as the french crown, pass at 4*s* 9*d*, but if they want a grain, or turn not the scale or stilyard, they pass but at 4*s*. 6*d*.'

'*None here, either in market or publick-house, but with small scales weigh their silver, as well as their gold, before they take it.*'

'Here are also pieces of Portugall coyne wch go at 7*s* 6*d*, these only, and now and then a piece of English money pass unweighed.'

The early English types of scales were usually in elaborate wooden boxes, with recesses, pans, or lockers, cut out of the solid, for the scales and weights, the latter often being very numerous. Usually the balance-beam was of steel, the suspension-cords of twisted silk, and the pans and weights of brass. Occasionally tin, iron, copper, and even silver were used for pans, beams, and weights. Afterwards the boxes were covered with shagreen, leather, and other materials; still later they were usually of polished rosewood or mahogany; then the boxes were of brass, steel, iron, or tin; the latest of all being made without boxes, on turned wood pillars or standards, and usually in brass.

Early types of scales in boxes, though suitable for the office or counting-house, were rather cumbersome for the purpose of carrying about, and consequently neat scales in boxes with fewer weights, or weights made one to fit within another, were brought into use. These at first were of the ordinary hanging-pan type, but the inconvenience of using separate weights, and the fact that they were liable to get lost, were apparently felt, and less awkward varieties were made At first these appear to have been in the form of a fixed steelyard with a sliding weight, but later were supplanted by the familiar compact folding scales, with all the pieces fixed, the weights of the different coins being ascertained by an ingenious arrangement of hinged weights made to turn over according to the nature of the coin to be dealt with. With some an additional slide indicates slight variations in the weights of the coins; so much so that, according to the directions on some of the boxes and the figures marked on the balance-beams, the loss of even a farthing's worth of gold could be ascertained.

Towards the end of the eighteenth century, and early in the nineteenth, when the Yorkshire coiners were in vogue, scales for testing the weight and thickness of the gold coins, and even of the silver coins, were common, especially in Yorkshire and Lancashire. Names of scale-makers in Ormskirk, Kirkby, Warrington, and Liverpool are frequent. Usually the scales were made by watch- and clock-makers, a fact plainly obvious on an examination of the details of the scales. The boxes were made of a suitable size for carrying in the waistcoat pocket, and averaged five inches in length by one inch in width and three-quarters of an inch in depth. Sometimes they were even less, one in our possession being less than two and a quarter inches in length, three-quarters of an inch in width, and slightly over a quarter of an inch in depth. This is the smallest I have seen. These boxes were made in considerable numbers, so great indeed that the early directories contain entries of 'watch makers and scale makers,' &c.

In Queen Elizabeth's reign a proclamation was issued * (1587-8) giving details of the money-scales and weights issued in her time. The proclamation contains 'a declaration of an order for the making of certain small cases for balances and weights, to weigh all manner of gold coin current within the realm, provided to be sold to all persons that should have cause to use the same, and which had been viewed by the wardens and assistants of the company of goldsmiths in London, by whom it was signed, limiting the sundry prices thereof according to their several quantities; which cases, with the balances and weights, had been made by order of the master of her Majesty's mint in the Tower of London, and viewed, allowed, and set at

* See L. A. Lawrence, 'Coin Weights,' *Brit. Numismatic Journ.* vol. vi. 1909.

reasonable prices by the said wardens of the goldsmiths in London, and thereupon according to her Majesty's proclamation heretofore made for the purpose, now put into print, by order of the Lord Burghley, Lord Treasurer of England, whereof the original forms (so rated and prized) remained in the receipt of the master of the mint, according to their several forms and prices.

The First and Greatest Case.

First, a case of wood with several partitions for xiiij printed weights, iiij other partitions for other weights, and one partition with cover for grains, esteemed at . .	viijd.	iiijs.	vid
The balance of the same case at	xvjd.		
The xiiij printed weights for coins	xviijd.		
The suit of ldwt. from ob. weight to 5dwt. . . .	ixd.		
The suit of grains from di. grain to v grains . .	iiijd.		

The Second Case.

Item, a lesser or second case of wood, having a partition for a balance, partitions for xiiij several weights for coins, and one partition for small grains, esteemed at	vjd.	iijs.	iijd.
The balance of the same case at	xijd.		
The xiiij printed weights at	xviijd.		
The grains at	iijd.		

The Third Case.

Item, a lesser or third case of wood having a partition for the balance, partitions for xiiij several weights for coins and one partition for small grains, esteemed at	iiijd.	iijs.	jd.
The balance of the same case at	xijd.		
The xiiij printed weights at	xviijd.		
The grains	iijd.		

The Fourth Case, being Leather.

Item, a leather case printed and gilded with gold, having in it a partition for the balance, two partitions for weights and grains, esteemed at	xijd.	iiijs.	vjd.
The balance of the same case at	xijd.		
The xiiij printed weights at	xviijd.		
The suit of j dwt. at	ixd.		
The suit of grains at	iijd.		

The Fifth Case, being Latten.

Item, a case of latten for a pair of folding balance, also of latten, at	viijd.	iijs.	vd.
The balance of the same case at	xijd.		
The xiiij printed weights at	xviijd.		
The grains at	iijd.		

This proclamation appears to have been but little attended to, for on February 18, 1588-9,[10] Richard Martin complained to the Lord Treasurer that, notwithstanding her Majesty's proclamation respecting the weighing of gold and silver coins, they still continue to pass without being weighed, and that he had expended above six hundred pounds in providing scales and weights marked with an E crowned, the far greater part of which still remained upon his hands. He proposed, therefore, that the warden of the mint, &c., should have authority to see that the said proclamation be observed, and that all other weights and grains used against the meaning of the same should be forfeited.

[10] The date given, *loc cit.* p 291, is 1558-9; apparently an error for 1588–9.

So far I have not been able to trace a single example of these particular boxes.

An examination of early scale-boxes indicates to what an enormous extent foreign money was in circulation in this country, necessitating the issue of special weights, albeit they bore the effigy of the English monarch. For instance, in the reign of Charles II. weights were known for .[11]

Gold.

	Weight. dwt.	grs.	Value £ s.	d.
The golden rider	6	12	1 2	6
,, half golden rider	3	6	11	3
,, Spanish or French quadruple pistole	17	4	3 10	3
,, ,, ,, double pistole	8	14	1 15	0
,, ,, ,, single pistole	4	7	17	6
,, ,, ,, half pistole	2	3½	8	9
,, double ducat	4	12	18	0
,, single ducat	2	6	9	0
,, Spanish suffrance	7	2	1 8	6
,, ,, half-suffrance	3	13	14	3

Silver.

The ducatoon	20	16	6	0
Half and quarter in proportion.				
The Mexico, Sevil or pillar piece of eight, the rix dollar, cross dollar and French Lewis	17	0	4	9
Half, quarter, and half-quarter in proportion.				
The Portugal royal	14	0	3	8
Half and quarter in proportion.				

Royal proclamations referring to coin-weights, and occasionally to scales, were issued in various reigns; the earliest by King John (1205) stated that for discovering lack of weight 'there was issued from the mint office a penny-poise, wanting one-eighth of a penny, to be delivered to anyone who would have it'

Various other references occur in proclamations issued by Edward I., Henry V., Henry VI, Henry VII, Elizabeth, James I, Charles I, Charles II, and William III.

Returning to the coin-scales, it may be as well to state that the largest collection in the country has been classified in the following series :—(1) Tooled and plain wood boxes; (2) shagreen-covered boxes; (3) japanned iron boxes, usually oval; (4) narrow boxes with automatic balances; (5) brass sovereign-balances; (6) miscellaneous

From the preceding I think it is demonstrated that there have been and still are difficulties in our system of coinage, difficulties which would be immeasurably simplified by the use of the metric system. Similar or greater difficulties exist in all our other weights and measures, and these could be similarly surmounted with equal ease.

(Typical forms of boxes of coin-scales were exhibited in illustration of the paper.)

Mr. G. C. Hart Gordon opened the discussion as follows. I compliment the author on his very interesting paper. As an ardent advocate of the metric system I would have wished for a little more about it; but I feel that Mr. Sheppard has conveyed some very interesting information in showing that in this country great changes have taken place. One thing I would notice is this : he made no reference to an interesting coin, the *Novus denarius*, which was introduced into Europe by Pepin the Short. It was a silver penny which obtained currency throughout Europe. I think it is the only case after the

[11] See L. A. Lawrence, 'Coin Weights,' *Brit Numismatic Journ.* vol. vi. 1909, p. 294.

Roman Empire. It is the extraordinary instance of an international coin, which drove all the Roman coins out of the market, and practically took charge of European trade until Pepin's Government, I suppose, became organised and started making coins that were of different weights. Another thing that is of great interest to us—particularly when we think of decimal coinage and of Mr. Gladstone's celebrated attack on decimal coinage because of the working man's interest in the penny, and what he called the dishonest proposal of decreasing the penny, which would take place, of course, if the sovereign were divided into one thousand parts—I understand that there were no copper coins in use in England (no copper coins made) until the time of the Georges. All the coinage used throughout the country was silver or gold; and the scales business throws a great deal of light upon it. As a matter of fact, coins in those days were in no sense tokens. To-day the coin is a promissory note, to be redeemed by the King in gold. The reason why Pepin's denarius continued was that it was exactly the value in silver that it was represented to be; its purchasing power was according to the silver it contained. Apparently, it was a great thing for a Government to introduce a copper coin; it needed a very powerful Government, and one which had a reputation for redeeming its promissory notes, to issue bronze coins It would be rather interesting to hear from Mr. Sheppard what were the controlling factors which led to the issuing of bronze coinage, which apparently was unknown in the earlier stages of our civilisation. Another thing that was mentioned by Mr. Sheppard was very interesting from a coinage-reform point of view, and that is the use of the Black Art in trade by the assistance or connivance of difficult systems of weights and coinage. The curious custom of the draper of pricing goods at 1*s.* 11¾*d.* is one which is admirably justified by the result. He can produce an effect by 1*s.* 11¾*d.* which is not produced by 2*s.* I have been interested in the fact that at a Congress here in London in 1911 agriculturists decided practically unanimously in favour of decimal coinage, a remarkable thing for farmers The reason given was that a farmer has to study so many things that he cannot be an expert in weights and measures. At Cardiff an enthusiastic flour-miller produced a book in which there were 800 pages devoted to nothing but weights and measures used in the corn trade in various markets in England and Wales When a farmer has not time to study this 600 or 800 page book, another man gets ahead of him. This is one of the reasons from the commercial point of view why it is all-important we should adapt the decimal system to coinage

I have come from Australia, and I have preached the metric system over there; but when I came to this country I got rather a shock. Since then I have been trying to use metric measures everywhere that I can, to see what is the effect. Now after three months I go back to inches, which I had used all my life, with difficulty. A gentleman, our chairman at a meeting in Bath recently, is a jeweller, and he told us a most extraordinary thing. Some three years ago a bolt out of the blue came to the jewellers in the shape of a ukase from the Board of Trade, or something similar, saying that they must no longer use the old carat divided into halves and fourths and eighths and sixteenths; they should use the metric carat, and it should be decimally divided. An indignation meeting was held. Sitting up one night, at the end of fifteen minutes the jeweller had mastered the new system, and at the end of the week he would not have used anything else. His assistants were of the same opinion, and they sometimes look back on the old system as a joke. This shows that once you introduce decimal methods they will drive out the farrago of old weights that has been growing through the centuries in all the different countries. In a little country part of Germany, in Hanover, which at that time was under the Kings of England, they had some coins called groschen. One of the Kings of England tried an improvement, and introduced what was called the new groschen. For something like one hundred and fifty years the new and old groschen existed side by side, and when something else was introduced in 1870 the new and old groschen were gone in two years. I think that is the hope for this country—that the new system will drive out the old. It has not succeeded in driving everything out of France. One of the reasons of that is that we took into France machinery and other things on the old measures, and we purchased from

France on the old measures. The consequence is we preserved it in France. You can preserve anything if you make it profitable for it to be preserved. The man who gains by Black Art will fight for that by which he profits, and will try to make the people believe that if they abandon it they will go to ruin.

Mr. HARRY ALCOCK said: I agree with Mr. Sheppard that it is superfluous to dwell upon the beauties of the metric system before a body of scientific people. We shall have to make up our minds on what lines reform shall be approached. There are two schools. One says you retain our present measures, inch and pound and gallon, and divide them into decimal portions. In that way you will get the advantage of the decimal; but the most superficial examination will satisfy us that this is indefensible. The manufacturer must have his inch, the surveyor and civil engineer his foot, and the navigator his fathom. In addition to that, one has to bear in mind that after you had succeeded in adapting the system of British weights and measures to these alterations you would still have a bad system, because there would be no correlation between the units in the same simple delightful way we have in the metric system. So we find we could not very much improve our system by simply re-arranging existing units on the decimal system. It comes back to this: we must have one universal unit of quantity by which manufacturers and consumers can communicate without any possibility of doubt.

On the question of the metric system becoming uniform throughout the world, the speaker referred specifically to America and Russia as follows:

America's trade is largely a domestic trade. The market for her manufacturers has been until quite recently a domestic market. What happens as soon as a nation aspires to become an exporting nation? People tell you that if you are to cater for the foreign markets you must adopt a new system Comparing Great Britain and America, we depend on the volume of our export trade, and it is therefore very much more to our interest that we should change to the metric system than even America; and once we have taken the plunge here we shall be followed by America.

Russia is quoted as a non-metric country; but it is an interesting fact that, in so far as she is a manufacturing State, work has been for some years conducted on the metric basis. The Russian measures relate to the land measurements, railway measures, and so on, but in trade and manufacture these are already converted to the metric system.

We could not have a suitable discussion of the metric system without paying tribute to the very excellent work done in the interest of the system by Lord Kelvin. He was a stalwart advocate of it; he was in advance of his time; but when the turmoil of the war opens our eyes to the weakness of our national system we shall achieve the reform which Lord Kelvin so strenuously advocated for many years.

At the end of the war we shall be burdened with a huge national debt. The only way to remove the pressure of that burden will be to export produce in enormously increased quantity, and export it throughout the world. We shall be awfully lacking if we continue to use our British weights and measures and absurd arrangements when we attempt to trade with nations abroad who have adopted what we are now advocating

The PRESIDENT said: I am sure we are indebted to Mr. Hart Gordon and Mr. Alcock for their remarks, and also to Mr. Sheppard for his paper. One point that has not been touched upon is the immense amount of saving the metric system would be in education It would take years of school life, or, rather, the children would be able to do so much more in other ways which they cannot possibly now do, because they have to learn our intricate system of weights and measures. I have a good deal of calculation to do myself, and I very frequently put the figures into decimals, and work out my calculations and re-convert them into our system. That would not have to be done if we had the metric system established. Not only in such calculation, but in all commercial transactions, in all book-keeping, an increased amount of work could be done in the same time. I believe there are some here who are not so fully alive to the advantages of the metric system as I am. They will have a good opportunity to-morrow morning of stating their views.

Third Meeting.

At the third meeting, held on Friday, July 6, the discussion on Mr. Sheppard's paper 'Money-Scales and Weights' was continued.

Mr. Whitaker said: Our decimal friends go a little too far. They think decimals a cure for everything It depends on decimal notation, which is a bad one.

Dr. Bather said: If you have read much foreign literature as well as English, you will find there is an extraordinary variety in expression of notation, and it is extremely difficult to say what is meant For instance, we in this country are accustomed to write 33.25m for metres or any other decimal measure or weight If you go to the people who invented the system —the French—they put 33m.25; that is how they do it There is a worse difficulty almost than that. Of course it would be perfectly intelligible to put m 33 25; that can't mean anything but 33¼ metres. But here is a diversity which creates considerable difficulty. Where we wish to put a decimal point we often put a full stop. That is not the French way of doing it. For our 33.251 the French write 33,251. To an Englishman that means 33 thousand and 251. I have found authors using both these forms on the same page. If we are going to use the metric system all over the world, let us see that we all write it in the same way. In this case the least ambiguous form undoubtedly is 33.251 In simple numeration similar questions arise. For a number in the thousands a Frenchman writes 33 251. If he wants to make it longer: 125 103 717. That is not nearly so clear as to put in the comma. When the ordinary person writes, it is a very difficult thing for the printer to tell whether he is to put the hair spaces in or not It is also necessary to indicate the unit in each case. To say that a fish is 2 34 long is meaningless, yet there are British authors who do this with, presumably, the permission of their British editors.

Mr. A L Lewis said: With regard to measures, I have found in some of our stone circles which go back to Neolithic times the Mediterranean measures At Stonehenge there is an old Mediterranean foot, which is somewhat less than our own foot. At Stanton Drew, Somerset, there is the same. In addition to that, at Stanton Drew you have a series of measurements working out with that of the Mediterranean foot In other stone circles, in other parts of the country, I have found measurements not working out to that foot, but to other old Mediterranean measures. This was in prehistoric times. No doubt it was so from influences from the Mediterranean which I take to have been rather personal than tribal. That is, the measurements were brought over here by individuals coming casually—it might be as traders or explorers; it might be as fugitives from justice, or injustice, or even missioners There was no doubt a great deal of travelling about in Neolithic times—much more than we think.

The President said: There is one point with regard to the expressing of decimals to which I should like to refer: that of adopting a uniform method. There is only one way of doing it—that of using the full stop and putting it above the line Everyone would know that this indicates decimals

Mr Sheppard, in reply, said: With regard to Mr. Gordon's suggestion that he would have liked to have heard a little more about the metric system, may I say that the entire object of the paper has been to demonstrate the necessity for the metric system? I felt that it was unnecessary to point out the advantages of such a system to this audience, and the recitation of the difficulties that have existed in the past, owing to the absence of the metric system, is surely the best evidence in favour of a change. One speaker asked when copper coins were introduced. Well, of course, there was the Harrington farthing in the reign of Charles II., but the great circulation of copper coins was in the reigns of the Georges. In the early days we only had the silver penny, which had to be kept up. The introduction of milled edges prevented a good deal of the coin clipping, and as soon as we got the milled edge, which could not be interfered with, the necessity for weighing coin was largely done away with. In Elizabeth's time nearly everybody who could get hold of any money cut a nice respectable portion from the edge.

The President said: We could scarcely have a subject more important for

the advancement of science than a discussion of the metric system, and I think it is well within the scope of the Conference. At the meeting of the French Association for the Advancement of Science one Conference was devoted almost entirely to it. Our Secretary was asked to make inquiries of the British Association as to its opinion on an alteration that was to be made in French units. I am very glad that we have followed it in our Conference.

Mr. WILFRED MARK WEBB then read his paper entitled

The part to be played by Local Societies after the War in the Application of Science to the Needs of the Country.

One of the penalties of making a suggestion nowadays is that one is often forthwith asked to carry it out, and if I had had the pleasure of hearing Mr. Hopkinson's Address when the Corresponding Societies Committee asked me to introduce my present subject, I could perhaps have excused myself by claiming that my remarks would be unnecessary.

The key-note, in fact, of what I had in mind to say was that a force must be generated in this country which will enable us to raise ourselves above party politics There are many matters much less debatable than free trade, which our President mentioned, that could be settled much more satisfactorily on a business, common-sense, or scientific basis

Before going farther, however, in this direction, it may be well to consider the position of science It has certainly played a big part in the war, and several times during this Conference the general feeling has been expressed that it will make itself felt in our everyday life in the near future to a much greater extent than it did in the recent past. That it ought to do so is certain The seed no doubt is sown, but, as is the case with many a choice plant, fruit will not again be ripened to perfection unless conditions are favourable, time and care lavished upon the seedling, when it struggles forth from the soil, unless difficulties are surmounted and enemies warded off.

In order fully to realise that even now an effort must be made, that old methods of advancing science must be improved and new ones devised, let us hark back for a moment to the state of affairs which prevailed before the war began, at the time, I may remind you, when the members of this Conference were the guests of France at Le Havre.

What was the position of a scientific person? That is to say one who had some claim to be acquainted with things and facts, with causes, and effects; not an individual trained to gauge his success by how easily he could for the moment put a complexion upon circumstances which would convince twelve men good and true and unpaid, or prevail upon the mobile-minded members of a constituency, who carry the elections, that he was the right person to go to Parliament and help to swell the majority that would bring emoluments, and ultimately honours, to his party without their being sought

The person we have in mind, if he had been asked five or six years ago what he thought would happen, and the pressing things that ought to be done, would have said, as many have done, that within the next ten years there would be a big war in Europe, and that England and Germany would be involved, and, apart from naval and military matters, it was the duty of those in authority to accumulate stores of food in this country, and to see that we produced as much as possible and bought as little as may be. He might also have added that our educational outlook should be altered, and if he had been tempted to touch on business he would have pointed out the folly of allowing Germans to undersell our own people as clerks, and to learn all our customers' names.

Mr. Whitaker said yesterday that we should always buy in the cheapest market. Doing this has been our curse. It is possible, I believe, sometimes even to get rid of a curse

What could such an individual as we have been considering do to bring about the improvements which he knew were wanted? Practically nothing directly. His vote was one amongst thousands. He had very little time to spare if he had to get his living from science, and perhaps even still less if

he devoted himself to some other pursuit to earn his bread and devoted his leisure to research.

It was only indirectly, by trying gradually to educate educationists, Government departments, and the public, that he could see any hope for the future.

Twelve or fourteen years ago some of us thought that the nature-study movement would do a great deal, but it is not everyone who would take the trouble to understand what was meant Mr. Fagg said of nature-study yesterday that it was responsible for much. To it is due to a great extent the new teaching of geography upon which he commented. Regional Surveys are but one branch of the nature-study which we advocated. A great object was to get plastic minds away from books until these are really useful, and the burden of any bad results which may have accrued lies on those who looked upon nature-study as a new subject or a poor kind of elementary didactic science.

The greatest triumph achieved by the nature-study movement was the decision of the Eton College authorities to accept nature-study in the entrance examination as an alternative to Latin verse.

Another habit of human nature akin to buying in the cheapest market, or possibly the same one in another guise, is the wish to get as much as you can for your money, and I never heard that any boys from the regular preparatory schools offered nature-study instead of Latin verses, their schoolmasters knowing that the latter would count for more in the long run if not immediately.

This brings me to consider some of the reasons why science has not advanced as quickly as it might in the past What we may perhaps still call the ruling classes are brought up as ignorant of science as they often are of business They cannot help looking down upon it, or ignoring it, because they do not understand it They also have been accustomed to see all the most successful boys in their schools put to learn Latin and Greek, leaving the others who counted for little to turn to scientific pursuits.

There is one class of schools which has been an outstanding exception, though unfortunately they do not rank with Eton, Harrow, and Winchester. I mean the Friends' Schools, where natural-history pursuits enter into the curriculum and take the place to some extent of games. Bootham School had a natural-history magazine eighty or more years ago, when the British Association for the Advancement of Science came into existence It was this school which produced men like Silvanus Thompson, a scientific man of the first calibre as a physicist, a clever artist, a polished writer, and an ardent lover of Nature It was he who gave the finest Presidential address that I remember to the South-Eastern Union of Scientific Societies at Woolwich. He took for his text two proverbial sayings, one of which, usually misquoted, Dr Bather mentioned yesterday, 'a little learning is a dangerous thing' and 'a cobbler should stick to his last' These Professor Silvanus Thompson, in his fascinating way, proceeded to show were fallacies, finishing his argument with an instance of a cobbler who lived in Woolwich, where he was speaking, who invented the electro-magnet, which is used in millions of instruments all the world over

Another reason why scientific people have been looked down upon is because many of those who have been successful in science, like their classical brethren, are, to use the late Lord Avebury's words, applied to the latter, only half-educated. They have often picked up their knowledge in evening classes after the business of the day was done, and they have not had time to acquire what we may term literary culture They do not as a rule write with the style that they might, and their social position originally is not of the highest Still, as the President said yesterday, a knowledge of English is lacked by very many of all classes, and one of the column-editors of *The Field* once told me that the writing of many of our country gentlemen was appalling He had had very many years' experience of it.

Then, again, if the classical scholar looks down on the scientific one, the same is true of the business-man. Scientific people, in the past at any rate, have worked for nothing. In the commercial eye a man who does this is a fool, and what you can get for nothing is not worth having.

It is rather a pity that any labour for love should cease, but the man who has a scientific education should get something on his investment, and I feel

sure that no scientific man who really works will ever be repaid from a monetary point of view.

The war has done more than give a greater appreciation of science: it has given a chance to men who would not otherwise have made themselves felt in the work of shaping our destiny, and it will have removed some of those prejudices which I mentioned There is a chance that our ruling classes, as I call them, will not be quite the same in the future.

The Government set up a department of scientific and industrial research in 1915. Two of its publications are in front of me One deals with Industrial Research in the United States of America. This bears out Mr. Whitaker's contention that we always go to other people to see what they are doing, and to hold up their methods as a model. Occasionally it is justified The second publication is a report on the resources and production of iron-ores, and so on, used in the iron and steel industry in the United Kingdom, so that we are beginning to get along.

I have also before me the report of a conference held last year in the Linnean Society's Rooms at the instance of the Committee on the Neglect of Science, which is well worth reading; and, again, I have the Presidential address of Dr W. Martin to the South-Eastern Union, given in the same rooms last month, on 'Science and the Industries.'

There is a conjoint board of scientific societies at work The British Science Guild is extending its sphere of influence, and yet I think that the local societies could play a very important part in the directions mentioned by our President yesterday, and in others. The bodies mentioned above reflect the opinion of scientific men who are already convinced of the importance of science; the principal work is to make others see it The local scientific societies should consist of all scientific men in the neighbourhood to which they belong. They would belong to all political sections if political parties still remain The Sections should be constituted to deal with general questions which will occur in every neighbourhood, and special questions which apply to their own. As a biologist, I naturally think of the same illustrations as Mr. Hopkinson, such as useful birds. If our crops are to be increased one-hundredfold, so should the insect-eating birds, and care should be taken that the species which live at our expense should not increase There should be a body of scientific opinion, backed by evidence, which should be able to prevent the cherry orchards of a district from being rendered worthless by the number of starlings, provided that other and more important crops should not instead be ravaged by caterpillars because the starlings have been eliminated.

It should be the part of the local society to point out the places where trees should be planted, and further than this they could deal with manufactures in urban districts, individually they could bring pressure to bear on municipal bodies and members of Parliament, while by concerted action they might influence the Government on questions of importance which affected the country as a whole. It will fall on a few people in each place, in the beginning, to carry out the work, but if such a scheme could be put into practice the results of their labours would be very far-reaching

Mr. WHITAKER said: Mr. Webb falls a little foul of certain economic notions. England has been able in the most wonderful manner to help the Allies in various ways, largely in matters of money; nearly all our Allies, except America, which has just come in. Why? Because England has followed economic laws far more than any other countries have, and has bought in the cheapest market for many years. The result is that she has had a great reserve, and thereby has helped her Allies How could that be effected if we had not followed economic laws? We should not have been the wealthy country we are. We may have been worse off in some ways. Mr. Webb finds fault with our ruling classes for not understanding science, but I do not know how he can make them. You cannot force them. Education should be so arranged that those children who prefer scientific studies should not be handicapped I do not ask for favouritism for science; give us equality, give us justice. If English people cannot make things as well as the people of some other nations, whose fault is it? If, on the other hand, they cannot make them so cheaply, whose fault is it? Let these faults be remedied. There is no nation in the world, be it ever so humble, that cannot

do something better than other nations. It is a good thing that all nations, Germany included, if you like, should have some point in which they are superior to others. We should look at the world as a whole, and not simply at ourselves as a particular part of it. We do that too little.

Local societies form one point in which England excels. In local societies she certainly has a very proud position, and anything that tends to improve our local societies, and to give them a larger occupation that may bear on the public good and the public interest, is distinctly for the good of the nation as a whole, as well as for that of the local societies. Do not let us think that there is nothing but science in the world. We must recognise that there are other things that are equally important and equally valued by other people. We have a right and a duty to stand up for science, to push science forward, but let us do it in the way that was advocated by the President yesterday as to agriculture and forestry; let us do it side by side, and not antagonistically. Let us work our science with literature, with art.

I am sorry to agree that a great many scientific people are not able to write English; but they are no worse than other people. You may say just the same of some politicians and artists, and even professional writers. Many professional writers write most unmitigated nonsense occasionally Our scientific men must not follow the precedent of other English classes in letting themselves down. I do not say that we are better than other people, but I certainly will not allow that we are worse. Scientific people are just an average of a more or less educated people. Certainly there is a distinct want in all classes of a full English education That is one point that should be considered indispensable, and in the matter of science what we want to see and hope to see is all science, all knowledge, leading up to the perfection of what is really the highest science of all: that is, political science.

The Rev J O Bevan made the following remarks · There is one point in Mr. Webb's paper to which I want to refer, and that is the interest of bird-life. Periodically I talk to our young people about the preservation of bird-life Some few weeks ago a copy of a leaflet was sent to me just published by the Society for the Protection of Birds I am rather sorry to see that this pamphlet is written on lines of special pleading, and it takes up those birds which are insect-destroyers It does not mention the fact that a great many birds are also grain-destroyers It is rather an unfortunate leaflet to put into the hands of farmers They say: 'We know a great many that are insect-destroyers, but we have to deal with a great many that are grain-destroyers We want to know what is the difference between the two classes of birds; between the two classes of sparrows, for instance' I think it is very unfortunate that the society should put forth a pamphlet which in its effect is misleading and creates a certain amount of disfavour amongst the class to whom it would be addressed, that is, the farmers

Miss Crosfield (Holmesdale Natural History Club) said: Local societies should make themselves an influence, by approaching local bodies, occasionally sending resolutions on any subjects on which the local societies feel strongly. The matter of the introduction of the metric system is one on which they might act. Not that they would immediately do very much good, but it would introduce a certain amount of discussion at Town Councils, and so ultimately advance something which would benefit the world

Miss Layard asked whether it would be any good approaching the editors of local papers and asking that they should make room for popular scientific subjects; also when a paper is read, such as one at the Anthropological Institute, it would be good to send the pamphlet to be reviewed by the local paper. That might be brought forward before our local people.

Dr. Bather said: My experience recently, when I have an axe to grind, has been that local papers are only too glad to get an article on a scientific subject written by somebody who knows what he is talking about. I write about a great many subjects I do not know anything about, but I have the advantage of a great many friends who know more than I do, and I endeavour to make sure of my facts by making use of my friends. The thing is to write English which can be understood by the people I find not the slightest difficulty in interesting people, simply speaking in an intelligible way. A good deal might

be done by people interesting the public in this way. What seems to me to be the difficulty is that we have not time. I have not time myself in ordinary circumstances to write popular articles and not be paid for them. I am doing it now as a piece of war-work.

The PRESIDENT: I should like before we part to mention one point and answer one question, about buying in the cheapest market. I will just give you a very simple illustration, which should satisfy Mr Whitaker. Supposing we could get twenty-one nails for a penny of a certain kind of which we cannot in this country make more than twenty for a penny. We buy them from Germany whilst our workers are starving Why can we get twenty-one nails from Germany for a penny? The Germans get their profit out of their home-business, and they keep their works going by dumping their surplus stock on the world. We cannot compete with them because of their heavy duty. We should have to make thirty for a penny to export to them. There is another point. If they want to extend the sale of their goods the German Government subsidise steamers. I know positively a certain thing that will perhaps astonish you You can get a pianoforte from Germany sent by Southampton to any of our colonies, and the freight will be much less than from this country to our colonies. There is no way to get out of that difficulty other than by retaliating, by putting a duty on their goods. Of course I allude to pre-war transactions

With regard to the point mentioned by Mr. Bevan, it is correct that the advice of the Society for the Protection of Birds is not always good. As to sparrows, we know that the sparrow feeds its young with insects such as caterpillars, not with grain. That is the time when the sparrows do the farmer good. They catch the caterpillars and give them to their young. Do not prevent them from doing their work in eating the insects which do us harm.

Another point which has been raised is the inquiry for copies of my address. The proper thing is for every delegate to write a report and get that report printed in the proceedings of his society That is the only way in which we can get a knowledge of our proceedings spread amongst all the members of the societies The delegate should have a copy of our printed report and make an abstract of that for his society. That has been done from the very first by the Hertfordshire Society.

I am sure we have had a very interesting conference, and I do hope it will bear good results I am very much indebted to those who have brought forward papers and to those who have contributed to the discussions.

The SECRETARY: I think Mr. Whitaker is right as to buying raw material in the cheapest market abroad, but I do not see why he should buy in the cheapest market at home. I think English people can make almost anything better than anybody else. If the foreigner wants to get anything from this country very little trouble is taken, whereas the German is at great pains to do business. Mr Whitaker did not notice that I said that anybody might be half-educated, scientific people and classical people alike. Unless the scientific know something of the classics and the classical something of science, they are both half-educated. Miss Crosfield said that local societies might be able to influence municipal bodies I urged that we should bring pressure to bear upon them. The idea of going to local editors would be very good, but hardly now, when they have little room and paper is very dear. With regard to Dr. Bather's remarks, I am a person who has had a classical and a scientific education. I have come to the conclusion that you must write what people want, not what you think they ought to have. I might claim some little success in this matter, and I should say the person who writes the best article from the paying point of view and the popular point of view is one who, like Dr. Bather, does not know anything about the subject, but is steeped in all the things that are round that subject; that is to say, knows enough of the science with which he is dealing not to make any mistakes, and is just in the position to pick out those points which are suited to the public. He is able to treat those things which are interesting and may be fresh to the reader, while the specialist is apt to drag in all sorts of petty points which the public does not care anything about.

The following Delegates attended the Conference and signed the attendance book

AFFILIATED SOCIETIES.

Brighton and Hove Natural History and Philosophical Society	Alfred W. Oke, F.G S.
British Mycological Society	Miss A. Lorrain Smith.
Cardiff Naturalists' Society	Dr. W. Evans Hoyle.
Croydon Natural History and Scientific Society	W. Whitaker, F.R S
East Anglian Prehistoric Society	Miss Nina F. Layard.
Edinburgh Field Naturalists' and Microscopical Society	T. Sheppard, F.G.S.
Edinburgh Geological Society	T. Sheppard, F.G.S.
Essex Field Club	W. Whitaker, F.R.S.
Hampshire Field Club and Archæological Society	W Dale, F S A.
Hertfordshire Natural History Society and Field Club	John Hopkinson, F L S.
Holmesdale Natural History Club	Miss M C. Crosfield.
Hull Geological Society	T. Sheppard, F.G S.
Hull Scientific and Field Naturalists' Club	T. Sheppard, F.G.S.
Manchester Geographical Society	Harry Sowerbutts.
Museums Association	Dr. F. A. Bather, F.R.S.
Northumberland, Durham, and Newcastle-on-Tyne Natural History Society	Prof. A. Meek, F L S.
Selborne Society, London	W. M. Webb, F.L.S.
Sheffield Naturalists' Club	T. Sheppard, F G S.
Torquay Natural History Society	Mrs. H. Forbes Julian.
Woolhope Naturalists' Field Club	Rev J. O. Bevan, M.A.
Yorkshire Geological Society	T. Sheppard, F.G.S.
Yorkshire Naturalists' Union	T. Sheppard, F.G.S.

ASSOCIATED SOCIETIES.

Balham and District Antiquarian and Natural History Society	Sir Edward Brabrook, C.B.
Ealing Scientific and Microscopical Society	J. Stark Browne, F.R.A S.
Lewisham Antiquarian Society	Sir Edward Brabrook, C.B.
Wimbledon Natural History Society	Dr. F. A. Bather, F R.S.

THE CORRESPONDING SOCIETIES OF THE BRITISH ASSOCIATION FOR 1917–1918.

Affiliated Societies.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Andersonian Naturalists' Society, 1885	Royal Technical College, Glasgow. Harry G. Cumming	200	2*s.* 6*d.*	2*s.* 6*d.*	Annals, occasionally.
Ashmolean Natural History Society of Oxfordshire, 1828	Miss A. L. Stone, 2 St. Margaret's Road	260	None	5*s.*	Proceedings and Report, annually.
Belfast Natural History and Philosophical Society, 1821	Museum, College Square. J. M. Finnigan	200	None	1*l.* 1*s.*	'Irish Naturalist,' monthly; Report, annually.
Belfast Naturalists' Field Club, 1863	Museum, College Square	330	5*s.*	5*s.*	'Irish Naturalist,' monthly; Report, annually.
Berwickshire Naturalists' Club, 1831	Rev J. J. M. L. Aiken, B D., Manse of Ayton, Berwickshire	300	10*s.*	5*s.*	History of the Berwickshire Naturalists' Club, annually.
Birmingham and Midland Institute Scientific Society, 1859	H H Whitfield, Birmingham and Midland Institute, Paradise Street, Birmingham	108	None	10*s.* 6*d.* and 5*s.*	Records of Meteorological Observations, annually.
Birmingham Natural History and Philosophical Society, 1858	Avebury House, Newhall Street, Birmingham. W. H. Foxall, F R G S.	207	None	1*l.* 1*s.*	Proceedings, annually.
Bournemouth Natural Science Society, 1903	R. A. de Paiva, 13 Carysfort Road, Bournemouth	406	None	10*s.*	Proceedings, annually.
Brighton and Hove Natural History and Philosophical Society, 1854	Henry Cane, 9 Marlborough Place, Brighton	120	None	10*s.*	Report, annually.
Bristol Naturalists' Society, 1862	Dr. O V. Darbishire, The University, Bristol	150	5*s*	10*s* and 5*s.*	Proceedings, annually.
British Mycological Society, 1896	Carleton Rea, 34 Foregate Street, Worcester	140	None	10*s.*	Transactions, annually.
Buchan Club, 1887	J. F. Tocher, D.Sc, Crown Mansions, Union Street, Aberdeen	180	5*s*	5*s*	Transactions, annually.
Burton-on-Trent Natural History and Archæological Society, 1876	A. Slator, D.Sc., 174 Ashby Road, Burton-on-Trent	120	None	6*s.*	Report, annually; Transactions, occasionally.
Canada, Royal Astronomical Society of, 1884	Canadian Institute Building, Toronto. J. R. Collins	550	None	2 dollars	Journal, monthly, Handbook, annually.
Caradoc and Severn Valley Field Club, 1893	H. E. Forrest, 37 Castle Street, Shrewsbury	175	5*s.*	5*s.*	Transactions and Record of Bare Facts, annually.
Cardiff Naturalists' Society, 1867	G. D. Shepherd, Gresham Chambers, Kingsway, Cardiff	500	None	12*s.* 6*d.*	Transactions, annually.
Chester Society of Natural Science, Literature, and Art, 1871	Grosvenor Museum, Chester. G. P. Miln	850	None	5*s.* and 2*s* 6*d*	Report and Proceedings, annually.
Cornwall, Royal Geological Society of, 1814	The Museum, Public Buildings, Penzance. F. H Uren	82	None	1*l.* 1*s.*	Transactions, annually.
Cornwall, Royal Institution of, 1818	Henry Jenner, F.S.A., County Museum, Truro	191	None	1*l* 1*s.*	Journal, annually.
Cornwall, Royal Polytechnic Society, 1833	E. W. Newton, Pendarves Road, Camborne, Cornwall	300	None	10*s.*	Report, annually.
Cotteswold Naturalists' Field Club, 1846	Roland Austin, Public Library, Gloucester	114	1*l.*	1*l.*	Proceedings, annually.
Croydon Natural History and Scientific Society, 1870	Public Hall, Croydon. G. W. Moore	114	None	15*s.* 10*s*, 5*s*, and 2*s.* 6*d.*	Proceedings and Transactions, annually.
Dorset Natural History and Antiquarian Field Club, 1875	Rev. Herbert Pentin, M.A., St Peter's Vicarage, Portland	400	10*s.*	10*s.*	Proceedings, annually.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No. of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Dublin Naturalists' Field Club, 1885 . .	Mrs. Long, 4 Palmerston Villas, Upper Rathmines, Dublin	64	5*s.*	5*s.*	'Irish Naturalist,' monthly, Report, annually
Dumfriesshire and Galloway Natural History and Antiquarian Society, 1862	R. Wallace, Ewart Public Library, Dumfries .	350	None	5*s.*	Transactions and Proceedings, annually
Durham, University of, Philosophical Society, 1896	J. A. Smythe and J. W. Bulierwell, Armstrong College, Newcastle-on Tyne	200	None	10*s.* and 5*s.*	Proceedings, half-yearly.
East Anglia, Prehistoric Society of, 1908 . .	W. G. Clarke, 12 St. Philip's Road, Norwich .	250	None	5*s.*	Proceedings, annually.
East Kent Scientific and Natural History Society, 1857	A Lander, J.P , 17 High Street, Canterbury	60	None	10*s* and 5*s.*	Transactions, annually.
Eastbourne Natural History, Photographic, and Literary Society, 1867	Miss Jay, Technical Institute, Eastbourne .	220	2*s.* 6*d.*	5*s.*	Transactions and Journal, quarterly.
Edinburgh Field Naturalists' and Microscopical Society, 1869	Allan A. Pinkerton, 20 George Street, Edinburgh	208	None	5*s.*	Transactions, annually.
Edinburgh Geological Society, 1834 . . .	Synod Hall Buildings, Castle Terrace, Edinburgh. J. J. McBeath	170	10*s* 6*d.*	12*s.* 6*d*	Transactions, annually.
Elgin and Morayshire Literary and Scientific Association, 1836	H. B. Mackintosh, The Museum, Elgin .	110	None	5*s.*	Transactions, occasionally.
Essex Field Club, 1880	Essex Museum of Natural History, Romford Road. Stratford. W Cole	300	None	15*s.*	'Essex Naturalist,' half-yearly.
Glasgow, Geological Society of, 1858 . . .	Peter Macnair, F R.S.E , and H. R. J. Conacher, 207 Bath Street, Glasgow	197	None	10*s.*	Transactions and Proceedings, annually.
Glasgow, Natural History Society of, 1851 . .	Alex. Ross, 409 Great Western Road, Glasgow .	230	None	7*s.* 6*d.*	'Glasgow Naturalist,' quarterly.
Glasgow, Royal Philosophical Society of, 1802 .	Prof. Peter Bennett, 207 Bath Street, Glasgow .	1,000	1*l* 1*s.*	1*l.* 1*s.*	Proceedings, annually.
Hampshire Field Club and Archæological Society, 1885	W. Dale, F.S.A., F.G.S., The Lawn, Archer's Road, Southampton	250	5*s.*	10*s.* 6*d.*	Proceedings, annually.
Hampstead Scientific Society, 1899 . . .	C O. Bartrum, B.Sc , and R. W. Wylie, M.A , 32 Willoughby Road, Hampstead, N W	294	None	Minimum 5*s.*	Report and Proceedings, annually
Hertfordshire Natural History Society and Field Club, 1875	John Hopkinson (Librarian), Weetwood, Watford	155	None	10*s.*	Transactions, one or two parts annually.
Holmesdale Natural History Club, 1857 .	Mrs. Perrin, Olears Corner, Reigate . .	73	None	10*s* , 5*s* , and 3*s.*	Proceedings, occasionally.
Hull Geological Society, 1889	J. W. Stather, F.G S., Newland Park, Hull . .	60	None	5*s.*	Transactions, occasionally.
Hull Scientific and Field Naturalists' Club, 1886 .	T. Stainforth, B A., The Museum, Hull . .	140	None	5*s.*	Transactions, annually.
Ipswich and District Field Club, 1903 .	Miss M. Fletcher, Sproughton, Ipswich . .	129	None	2*s* 6*d.*	Journal, occasionally.
Ireland, Statistical and Social Inquiry Society of, 1847	W Lawson, Dr. N. M. Falkiner, and Herbert Wood, 93 Stephen's Green, Dublin	80	None	1*l.*	Journal, annually.
Leeds Geological Association, 1873 . . .	E. Hawkesworth, Cross Gates, Leeds . . .	106	None	5*s.*	Transactions, occasionally.
Leicester Literary and Philosophical Society, 1835	Corporation Museum. F. B. Lott, 7 Stoneygate Avenue, Leicester	263 Membs. & Associates	None	Members 1*l.* 1*s.*; Associates 10*s* 6*d*	Transactions, annually.
Lincolnshire Naturalists' Union, 1893 . . .	Arthur Smith, F.L.S , City and County Museum, Lincoln	110	None	5*s.*	Transactions, annually.

Liverpool Biological Society, 1886 .	J A. Clubb, D.Sc., Free Public Museum, Liverpool	80	None	1*l.* 1*s.*	Proceedings and Transactions, annually.
Liverpool Botanical Society, 1906 . . .	E. Horton, Common Hall, Hackens Hey, Liverpool	123	None	5*s.*	'Lancashire and Cheshire Naturalist,' usually monthly
Liverpool Engineering Society, 1875 .	T L. Miller (Acting), 325 Royal Liver Buildings, Liverpool	582	None	1*l.* 1*s.*, 10*s.* 6*d.*, and 5*s*	Transactions and Report, annually.
Liverpool Geographical Society, 1891 . . .	A. Ellis Cookson, 5 Hargreave's Buildings, Liverpool	560	None	Members 1*l.* 1*s* ; Associates 10*s* 6*d*	Transactions and Report, annually.
Liverpool Geological Society, 1859 . . .	T. A. Jones, 27 Rockfield Road, Anfield, Liverpool	78	None	10*s.* 6*d.*	Proceedings, annually.
London : Quekett Microscopical Club, 1865. .	Jas. Burton, 8 Somali Rd ,West Hampstead, N.W 2	450	None	10*s.*	Journal, half-yearly.
London : Selborne Society, 1885 . . .	Avenue Chambers, Bloomsbury Square, W.C. 1 W. M. Webb, F L S.	2,000	None	5*s.*	'Selborne Magazine,' monthly.
Man. Isle of, Natural History and Antiquarian Society, 1879	Miss Margaret Cannell, 118 Buck s Road, Douglas, Isle of Man	280	2*s* 6*d.*	7*s.* 6*d.* and 5*s.*	Proceedings and Transactions, annually.
Manchester Geographical Society, 1884 . .	E. Steinthal and H. Sowerbutts, 16 St. Mary's Parsonage, Manchester	648	None	Members 1*l.* 1*s* ; Associates 10*s.*6*d*	Journal, quarterly.
Manchester Geological and Mining Society, 1838	5 John Dalton Street, Manchester. Noah T. Williams	402	None	2*l.* 2*s* , 1*l* 5*s.*, and 1*l.*	Transactions of Inst. of Mining Engineers, monthly.
Manchester Microscopical Society, 1880 . .	William Dixon, Broadwater, 43 Pine Road, Didsbury, Manchester	148	5*s.*	6*s*	Transactions and Report, annually.
Manchester Statistical Society, 1833 . . .	F. Vernon Hansford, 3 York Street, Manchester	149	10*s* 6*d.*	10*s.* 6*d.*	Transactions, annually.
Marlborough College Natural History Society, 1864	J C. Alsop, M.A , Marlborough College . .	150	1*s.* 6*d.*	3*s.*	Report, annually.
Midland Counties Institution of Engineers, 1871	G Alfred Lewis, M.A., Midland Road, Derby .	330	1*l.* 1*s.*	2*l.* 2*s.* and 1*l.*	Transactions of Institution of Mining Engineers, monthly.
Museums Association, 1889	E. E Lowe, B Sc., Museum and Art Gallery, Leicester	Members (Insts) 117	None	1*l.* 1*s.*	Museums Journal, monthly.
		Associates (Persons) 115	None	10*s* 6*d.*	Museums Directory, occasionally.
Norfolk and Norwich Naturalists' Society, 1869 .	S H Long, M D., 37 St. Giles Street, Norwich .	283	None	7*s* 6*d.*	Transactions, annually.
North of England Institute of Mining and Mechanical Engineers, 1852	Neville Hall, Newcastle-upon-Tyne. Allan Cordner	1,160	None	2*l* 2*s.* and 1*l* 5*s.*	Transactions of Inst. of Mining Engineers, monthly.
North Staffordshire Field Club, 1865 . . .	H V. Thompson, Central Technical School, Victoria Road, Stoke-on-Trent	616	5*s.*	5*s.*	Transactions and Report, annually.
Northamptonshire Natural History Society and Field Club, 1876	H N Dixon, M A , 17 St. Matthew's Parade, Northampton	210	None	10*s.*	Journal, quartorly.
Northumberland, Durham, and Newcastle-upon-Tyne, Natural History Society of, 1829	Hancock Museum, Newcastle-on-Tyne. C. E. Robson and J A Richardson	398	None	21*s.*	Transactions, annually.
Nottingham Naturalists' Society, 1852 . .	Prof. J W. Carr, M.A., University College, Nottingham	100	2*s* 6*d.*	5*s.*	Report and Transactions, annually.
Paisley Philosophical Institution, 1808 . .	J Gardner, 3 County Place, Paisley . . .	549	5*s.*	7*s.* 6*d.*	Report and Meteorological Observations, annually.
Perthshire Society of Natural Science, 1867 .	Tay Street, Perth. S. T. Ellison . . .	314	None	5*s* 6*d.*	Transactions and Proceedings, annually.
Rochdale Literary and Scientific Society, 1878 .	J. Reginald Ashworth, D.Sc., 55 King Street South, Rochdale	227	None	6*s.*	Transactions, biennially.

Affiliated Societies—continued.

Full Title and Date of Foundation	Headquarters or Name and Address of Secretary	No of Members	Entrance Fee	Annual Subscription	Title and Frequency of Issue of Publications
Rochester Naturalists' Club, 1878 . .	Edmund Page, 42 Balmoral Road, Gillingham, Kent	110	None	5*s.*	'Rochester Naturalist,' quarterly.
Sheffield Naturalists' Club, 1870	C. Bradshaw, and A. Brittain, Public Museum, Sheffield	105	None	5*s.*	Report, bi-annually; Proceedings, occasionally.
Somersetshire Archæological and Natural History Society, 1849	The Castle, Taunton. Rev. E H. Bates Harbin, O. Tite, and H. St. George Gray	890	10*s.* 6*d.*	Minimum 10*s.* 6*d*	Proceedings, annually.
South Africa, Royal Society of, 1906 . . .	G M. Clark, South African Museum, Cape Town	207	None	2*l.*	Transactions, occasionally.
South-Eastern Union of Scientific Societies, 1896	H Norman Gray, 334 Commercial Road, E 1 .	about 13,000	None	Minimum 5*s*	'South-Eastern Naturalist,' annually.
Southport Literary and Philosophical Society, 1880	W. Allanach, B Sc, Victoria Science and Art Schools, Southport	186	None	7*s.* 6*d.*	Proceedings, occasionally.
South Staffordshire and Warwickshire Institute of Mining Engineers, 1867	G. D. Smith, 3 Newhall Street, Birmingham .	150	1*l.* 1*s.* and 10*s.* 6*d.*	2*l* 2*s.* and 1*l* 1*s.*	Transactions of Inst. of Mining Engineers, monthly.
Torquay Natural History Society, 1844 . .	Harford J Lowe, F G.S , The Museum, Torquay	158	10*s.* 6*d.*	1*l.* 1*s.*	Journal, annually.
Tyneside Geographical Society, 1887 . .	Geographical Institute, St. Mary's Place, Newcastle-on-Tyne Herbert Shaw, B.A	1,000	None	1*l* 1*s.* and 10*s*	Journal, quarterly.
Vale of Derwent Naturalists' Field Club, 1887 .	J. E. Patterson, 2 East Avenue, Benton, Newcastle-on-Tyne	150	None	2*s.* 6*d.*	Transactions, occasionally.
Warrington Literary and Philosophical Society, 1870	J. S. Manson, M.D., 14 Bold Street, Warrington	130	None	5*s.*	Proceedings, biennially.
Warwickshire Naturalists' and Archæologists' Field Club, 1854	Museum, Warwick. C. West, Cross Cheaping, Coventry	70	None	5*s*	Proceedings, annually.
Woolhope Naturalists' Field Club, 1852 . .	W. E. H Clarke, Cathedral Chambers, King Street, Hereford	200	10*s.*	10*s.*	Transactions, occasionally.
Worcestershire Naturaliste' Club, 1847 .	Education Offices, Worcester. F. T. Spackman, F.G.S.	180	10*s.*	5*s*	Transactions, annually.
Yorkshire Geological Society, 1837 . .	Albert Gilligan, B Sc , The University, Leeds .	184	None	13*s.*	Proceedings, occasionally.
Yorkshire Naturalists' Union, 1861 . .	The Museum, Hull. T. Sheppard, M Sc., F.G.S.	380 and 3,050 Associates	None	10*s.* 6*d.*	Transactions, annually; 'The Naturalist,' monthly.
Yorkshire Philosophical Society, 1821 . .	Museum, York. C. E. Elmhirst.	400	None	2*l.*	Report, annually.

Associated Societies.

Balham and District Antiquarian and Natural History Society, 1897	Miss M. Gardiner, 14A St. James' Road, Wandsworth Common, S.W	70	None	5*s.*	Report, annually; Papers, occasionally.
Barrow Naturalists' Field Club and Literary and Scientific Association, 1876	W. L. Page, 5 Cavendish Street, Barrow . .	150	None	5*s.* and 2*s.* 6*d.*	Report and Proceedings, annually.
Battersea Field Club, 1894 .	Public Library, Lavender Hill, Battersea, S.W. 11 Miss L. B. Morris	48	2*s.* 6*d*	3*s.* 6*d.*	——

Bradford Natural History and Microscopical Society, 1875	Fred. Jowett, 9 Vincent Street, Bradford	75	1s.	4s.	—
Bradford Scientific Association, 1875 . . .	W. Newbould, 34 Burnett Avenue, Bradford .	120	None	5s. and 2s. 6d.	—
Catford and District Natural History Society, 1897	Thomas Coote, 25 Hawstead Road, Catford, S.E. 6	61	None	5s.	—
Dunfermline Naturalists' Society, 1902 . .	Robert Somerville, B.Sc., 31 Cameron Street, Dunfermline	170	None	5s.	—
Ealing Scientific and Microscopical Society, 1877	F. McNeil Rushforth, Coley Lodge, 21 Florence Road, Ealing, W. 5	100	None	10s. and 2s. 6d.	Report and Transactions, annually.
Grimsby and District Antiquarian and Naturalists' Society, 1896	The Museum, Grimsby. A. Bullock (Acting Sec.)	60	None	2s. 6d.	-
Halifax Scientific Society, 1874	J. H. Lumb, 32 Underclıffe Terrace, Halifax .	179	None	2s. 6d.	—
Hastings and St. Leonards Natural History Society, 1893	W. de Muller, B A., 14 St. Matthew's Gardens, St. Leonards-on-Sea	390	1s.	3s. 6d.	Report, annually. 'Hastings and East Sussex Naturalist,' occasionally.
Hawick Archæological Society, 1856 . . .	J. J. Vernon, 81 High Street, Hawick . . .	300	None	2s. 6d.	Transactions, annually.
Inverness Scientific Society and Field Club, 1875	Thomas Wallace, Ellershe, Inverness . . .	160	None	5s.	Transactions, occasionally.
Lancashire and Cheshire Entomological Society, 1877	Royal Institution, Liverpool. William Mansbridge	90	None	5s	Report and Proceedings, annually.
Leeds Naturalists' Club and Scientific Association, 1868	Edward J. T. Ingle, 18 Strattan Street, Leeds .	100	None	5s and 3s. 6d.	Proceedings, occasionally.
Letchworth and District Naturalists' Society, 1908	W. Percival Westall, F.L S., The Museum, Town Square, Letchworth	260	None	2s 6d	—
Lewisham Antiquarian Society, 1885 . . .	J. W. Brookes, Pembroke Lodge, Slaithwaite Road, Lewisham, S E.	73	None	5s.	Transactions, occasionally.
Liverpool Microscopical Society, 1868 . . .	Royal Institution, Liverpool. R Croston . .	63	None	10s. 6d	Report, annually.
Llandudno and District Field Club, 1906 . .	L. S. Underwood, Brinkburn, Llandudno . .	107	None	5s.	Proceedings, annually.
London : London Natural History Society, 1913 .	J. Ross, 18 Queen's Grove Road, Chingford, N.E.	200 Members and Assoc.	2s. 6d.	7s. 6d. and 5s.	Transactions, annually.
London : South London Entomological and Natural History Society, 1872	Stanley Edwards, F.L S , 15 St German's Place, Blackheath, S E. 3	180	2s. 6d	10s.	Proceedings, annually.
Maidstone and Mid-Kent Natural History and Philosophical Society, 1868	Maidstone Museum. A. Barton and J. W. Bridge	66	None	10s.	Report, occasionally.
Newcastle-upon-Tyne, Literary and Philosophical Society of, 1793	Newcastle-upon-Tyne. Alfred Holmes . .	2,961	None	1l. 1s.	Report, annually ; Lectures occasionally.
Preston Scientific Society, 1893	Lecture Hall, 119A Fishergate, Preston. F. Chadderton	400	None	5s.	Papers, occasionally.
Scarborough Philosophical and Archæological Society, 1828	A. J. Burnley, 43 Moorland Road, Scarborough .	80	None	1l. and 10s.	Report, annually.
School Nature Study Union, 1903	H. E. Turner, 1 Grosvenor Park, Camberwell, S.E.	1,580	None	2s. 6d.	'School Nature Study,' quarterly.
Southport Society of Natural Science, 1890 . .	P. H. Christian, 9 Russell Road, Southport . .	168	None	5s.	Report, biennially.
Teign Naturalists' Field Club, 1858 . . .	John S Amery, Druid, Ashburton, Devon . .	120	None	2s. 6d.	Report, annually.
Tunbridge Wells Natural History and Philosophical Society, 1884	Dr D. Davies, 8 Lonsdale Gardens, Tunbridge Wells	84	None	10s. 6d. and 5s.	Report, annually.
Warrington Society, 1898	The Old Academy, Bridge Foot, Warrington. James Richardson	103	10s. 6d	1l. 11s. 6d.	Report, annually.
Watford Camera Club and Photographic Society, 1902	A Dain, 100 High Street, Watford . . .	50	None	—	—
Wimbledon Natural History Society, 1911 . .	Charles H. Tame, 12 Kenwyn Road, Wimbledon, S W 19	150	None	1s.	—

Catalogue of the more important Papers, especially those referring to Local Scientific Investigations, published by the Corresponding Societies during the year ending May 31, 1917.

*** This Catalogue contains only the titles of papers published in the volumes or parts of the publications of the Corresponding Societies sent to the Secretary of the Committee in accordance with Rule 2.

Section A.—Mathematical and Physical Science.

Alsop, J. C. Summary of Meteorological Observations, 1916. 'Report Marlb. Coll. N. H. Soc.' No. 65, 59–80. 1917.

Barnard, E. E. Some Dark Markings on the Sky and What They Suggest. 'Journal Royal Astr. Soc. of Canada,' x. 241–249. 1916

Bassett, Rev. H. H. Tilney. Returns of Rainfall in Dorset in 1915. 'Proc. Dorset N. H. A. F. C.' xxxvii. 198–209. 1916.

Beattie, Prof. J. C. Further Magnetic Observations in South Africa during the years 1913–1915. 'Trans. Royal Soc. of South Africa,' v. 669–670. 1917.

—— True Isogonics and Isoclinals for South Africa for the Epoch July 1, 1913 'Trans. Royal Soc of South Africa,' v. 671–684. 1917.

Bohle, H. The Heating Coefficients of Rheostats and the Calculation of Resistances for Currents of Short and Moderate Durations. 'Trans. Royal Soc. of South Africa,' v. 685–694. 1917.

Brown, Alexander. The Equivalent Mass of a Spring Vibrating Longitudinally. 'Trans. Royal Soc. of South Africa,' v 565–570 1916.

—— The Arrangement of Successive Convergents in Order of Accuracy. 'Trans. Royal Soc. of South Africa, v. 653–657. 1916.

——The Use of a Standard Parabola for drawing Diagrams of Bending Moment and of Shear in a Beam Uniformly Loaded. 'Trans. Royal Soc. of South Africa,' v. 659–667. 1916.

Campbell-Bayard, Francis. Report of the Meteorological Committee, 1915. 'Trans. Croydon N. H. Sci. Soc.' viii. 97–112, and Appendices, 60 pp. 1916.

Cannon, J. B. Orbit of Spectroscopic Binary 125 Tauri. 'Journal Royal Astr. Soc. of Canada,' x. 377–381. 1916.

Chamberlin, T. C. The Planetesimal Hypothesis. 'Journal Royal Astr. Soc. of Canada,' x. 473–497. 1916.

Chant, C. A., and W. E W. Jackson. The Great Aurora of August 26, 1916. 'Journal Royal Astr. Soc. of Canada.' xi. 5–22. 1917.

Clark, G Napier. Sketch of the Life and Works of Rev. Jeremiah Horrox. 'Journal Royal Astr. Soc. of Canada,' x. 523–536. 1916.

Coates, Henry. Meteorological Observations, Perth, 1915. 'Proc. Perthshire Soc. Nat. Sci.' vi. cxxxiii.–cxxxvi. 1916.

—— Floods and Droughts of the Tay Valley. 'Trans Perthshire Soc. Nat. Sci.' vi. 103–126. 1916.

—— Notes on an Old Weather Record found amongst the MSS of the Antiquarian Museum. 'Trans. Perthshire Soc. Nat. Sci.' vi. 126–133. 1916.

Craw, James Hewat. Account of Rainfall in Berwickshire—Year 1915. 'History Berwickshire Nat. Club,' xxii. 403. 1916.

—— Account of Rainfall in Berwickshire during 1916. 'History Berwickshire Nat. Club,' xxiii. 240. 1917.

Creswell, Alfred. Records of Meteorological Observations taken at the Observatory, Edgbaston, 1915. 27 pp. Birm. and Mid. Inst. Sci Soc. 1916.

DeLury, Ralph E Some Measurements of Blended Spectra. 'Journal Royal Astr. Soc. of Canada,' x. 201–219. 1916.

DELURY, RALPH E. The Effect of Haze on Spectroscopic Measures of the Solar Rotation: Explanation of Differences in Values, and Differences depending on the Intensities of Spectrum Lines. 'Journal Royal Astr. Soc. of Canada,' x. 345–357. 1916.

—— The Question of the Presence of Haze Spectrum in the Mount Wilson Observations of the Solar Rotation. 'Journal Royal Astr. Soc. of Canada,' xi. 23–24. 1917.

DENNING, W. F. The Great Meteoric Stream of February 9th, 1913. 'Journal Royal Astr. Soc. of Canada,' x. 294–296. 1916.

—— A Meteoric Shower in June. 'Journal Royal Astr. Soc. of Canada,' x. 446–448. 1916.

FOX, WILSON LLOYD. Report of the Observatory Committee for the year 1915. 'Report Royal Cornwall Poly. Soc,' 3, 14 pp. 1916.

HARPER, W. E. The Swarthmore Meeting of the American Astronomical Society. 'Journal Royal Astr. Soc. of Canada,' x. 421–429. 1916.

—— The Orbits of the Spectroscopic Components of Boss 2484. 'Journal Royal Astr. Soc. of Canada,' x. 442–445. 1916.

HASSARD, A. R. Amateur Work in Astronomy. 'Journal Royal Astr. Soc. of Canada,' xi. 99–102. 1917.

HAUGHTON, J. L., and D. HANSON. Observations on the Transit of Mercury of November 7th, 1914. 'Proc. Birmingham Nat. Hist. Phil. Soc.' xiv. 36–41. 1916.

HAWKE, E. L. Meteorological Report for 1915. 'Report Hampstead Sci. Soc.' 1915–1916, 33–36 1917.

HOPKINS, MARY MURRAY. The Parallax of 61 Cygni. 'Journal Royal Astr. Soc. of Canada,' x. 498–504. 1916.

HOPKINSON, JOHN. The Weather of the year 1915 in Hertfordshire. 'Trans. Herts N. H. S. F. C.' xvi. 125–140. 1917.

HUNTER, A. F., and H. B. COLLIER. A Prismatic Arc. 'Journal Royal Astr. Soc. of Canada,' x. 235–240. 1916.

INNES, R. T. A. On the Development of the Perturbative Function in the Theory of Planetary Motion. 'Trans. Royal Soc. of South Africa,' vi. 19–23 1917.

KLOTZ, OTTO. Location of Epicentres for 1914 and 1915. 'Journal Royal Astr. Soc. of Canada,' x. 302–313. 1916.

—— Magnetic Results, 1913. 'Journal Royal Astr. Soc. of Canada,' x. 314–320. 1916.

—— The Scientific Work of the Government: The Observatory. 'Journal Royal Astr. Soc. of Canada,' x. 449–453. 1916.

—— Constant of Gravitation. 'Journal Royal Astr. Soc. of Canada,' xi. 135–137. 1917.

LAWSON, GRAHAM C. Meteorological Report. 'Trans. N. Staffs F. C.' i. 140–148. 1916.

LOWELL, PERCIVAL. The Genesis of Planets. 'Journal Royal Astr. Soc. of Canada,' x. 281–293 1916.

MCDIARMID, F. A. Gravity. 'Journal Royal Astr. Soc. of Canada,' x. 537–552. 1916.

MCDIARMID, R. J. A Study of the Light Variation of the Star B.D 61°493. 'Journal Royal Astr. Soc. of Canada,' x. 430–441. 1916.

MARKHAM, CHRISTOPHER A., and R. H. PRIMAVESI Meteorological Report. 'Journal Northants N. H. Soc.' xviii. 191–194, 219–222, 243–246 1916, 1917.

MUIR, Sir THOMAS. Note on the so-called Vahlen Relations between the Minors of a Matrix. 'Trans. Royal Soc. of South Africa,' v. 695–701. 1917.

—— Note on Pfaffians Connected with the Difference-product. 'Trans. Royal Soc. of South Africa,' vi 29–36 1917

PATTERSON, ARTHUR H. The January Flood of 1916 at Great Yarmouth. 'Trans. Norf. Norw. Nat. Soc.' x. 162–167. 1916.

PLASKETT, H. H. The Psychology of Differential Measurements. 'Journal Royal Astr. Soc. of Canada,' x. 220–234. 1916.

PLASKETT, J. S. The 72-inch Reflecting Telescope. 'Journal Royal Astr. Soc. of Canada,' x. 275–280. 1916.

PRESTON, ARTHUR W. Meteorological Notes, 1915. 'Trans. Norf. Norw. Nat. Soc.' x. 155–161. 1916.

RAMBAUT, Dr. ARTHUR A. Meteorological Reports for 1915 and 1916. 'Report Ashmolean Nat. Hist. Soc.' 1916, 16–18. 1917.

RIDYARD, G. J. (Manchester Geol. Min. Soc.). Note upon a Flash in the Workings of a Mine at Tyldesley, probably caused by a Lightning Discharge conducted from the Surface. 'Trans. Inst. Min. Eng.' LIII. 135–136. 1917.
RUTHERFORD, JOHN. Weather and other Notes taken at Jardington during 1915. 'Trans. Dumfriesshire and Galloway N. H. A. Soc.' IV. (Third Series), 58–68. 1916.
ST. JOHN, C. E., and W. S. ADAMS. The Question of Diffused Light in Mount Wilson Solar Observations. 'Journal Royal Astr. Soc. of Canada,' X. 553–555. 1916.
STEBBINS, JOEL. The Aurora of August 26, 1916. 'Journal Royal Astr. Soc. of Canada,' XI. 133–134. 1917.
STOBBS, J. T. The Earthquake of January 14th, 1916, 'Trans. N. Staffs F. C.' L. 63–68. 1916.
SWINTON, A. E. Meteorological Observations in Berwickshire for 1915. 'History Berwickshire Nat. Club,' XXII. 404. 1916.
—— Meteorological Observations in Berwickshire for 1916. 'History Berwickshire Nat. Club,' XXIII. 239. 1917.
VAN DER LINGEN, J. STEPH. On the 'Lines' within Röntgen Interference Photograms. 'Trans. Royal Soc. of South Africa,' V. 571–573. 1916.
—— Simple Apparatus for use in Applied Mathematics. 'Trans. Royal Soc. of South Africa,' V. 599–602, 1916.
—— Heating and Cooling Apparatus for Röntgen Crystallographic Work. 'Trans. Royal Soc. of South Africa,' V. 647–651. 1916.
WALFORD, Dr. E. Meteorological Observations in the Society's District, 1915. 'Trans. Cardiff Nat. Soc.' XLVIII. 75–96. 1916
WATSON, ALBERT D. Companions of the Sun. 'Journal Royal Astr. Soc. of Canada,' X. 384–401. 1916.
—— President's Address: Astronomy in Canada. 'Journal Royal Astr. Soc. of Canada,' XI. 47–78. 1917.
WILLIAMS, A. R. The Great Frost, 1917. 'Selborne Magazine,' XXVIII. 49–54. 1917.
YOUNG, J. Earthquakes of January 29 and February 20, 1917. 'Journal Royal Astr. Soc. of Canada,' XI. 146–147. 1917.
YOUNG, REYNOLD K. Orbit of the Spectroscopic Binary Boss 6142. 'Journal Royal Astr. Soc. of Canada,' X. 297–301. 1916.
—— Orbit of the Spectroscopic Binary ψ Aurigæ. 'Journal Royal Astr. Soc. of Canada,' X. 358–374. 1916.
—— Note on the Spectroscopic Binary 12 Lacertæ. 'Journal Royal Astr. Soc. of Canada,' X. 375–376. 1916.
—— Orbit of the Spectroscopic Binary 2 Sagittæ. 'Journal Royal Astr. Soc. of Canada,' XI. 127–132. 1917.

Section B.—CHEMISTRY.

ARMSTRONG, Dr. E FRANKLAND. Modern Explosives. 'Proc. Warrington Lit. Phil. Soc.' 1914–1916, 8 pp. 1916.
ASHWORTH, Dr. J. R. Rochdale Soot-Fall. 'Trans. Rochdale Lit. Sci. Soc.' XII. 50–53. 1916.
BERINGER, J. J. The Physical Condition of Cassiterite in Cornish Mill Products. 'Report Royal Cornwall Poly. Soc.' 3, 56–72. 1916.
DREW, W. NEWTON (Midland Inst. Eng.). The Rectification of Benzol. 'Trans. Inst. Min. Eng.' LIII. 10–21. 1917.
FERGUSON, Prof. JOHN. Some Early Treatises on Technological Chemistry. Supplement V. 'Proc. Glasgow Royal Phil. Soc.' XLVII. 176–228. 1917.
GRAHAM, J. IVON. The Permeability of Coal to Air or Gas, and the Solubilities of different Gases in Coal. 'Trans. Inst. Min. Eng.' LII. 338–347. 1917.
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