REPORT

OF THE

ELEVENTH MEETING

OF THE

Australasian Association for the Advancement of Science,

HELD AT

ADELAIDE, 1907.

EDITED BY

WALTER HOWCHIN, F.G.S.

Adelaide:
PUBLISHED BY THE ASSOCIATION.

ADELAIDE:
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1908.

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OFFICERS FOR THE ADELAIDE SESSION.

JANUARY, 1907.

Patron:

His Excellency Sir George R. Le Hunte, K.C.M.G., Governor of South Australia

Vice-Patron:

The Right Honorable Sir Samuel James Way, Bart., P.C., LL.D., D.C.L., Chief Justice and Lieutenant-Governor of South Australia.

President:

A. W. Howitt, C.M.G., D.Sc., F.G.S.

Retiring President:

Professor T. W. Edgeworth David, B.A., F.R.S., F.G.S.

Past Presidents:

H. C. Russell, B.A., C.M.G., F.R.S., Sydney (1888).
Baron Ferd. von Mueller, K.C.M.G., Ph.D., F.R.S., Melbourne (1890).
Sir James Hector, K.C.M.G., M.D., F.R.S., Christchurch, N.Z. (1891).
Sir Robert G. C. Hamilton, K.C.B., LL.D., Hobart (1892).
Professor Ralph Tate, F.G.S., Adelaide (1893).
Hon. A. C. Gregory, C.M.G., F.R.G.S., M.L.C., Brisbane (1895).
Professor A. Liversidge, M.A., F.R.S., Sydney (1898).
R. L. Ellery, C.M.G., F.R.S., F.R.A.S., Melbourne (1900).
Captain F. W. Hutton, F.R.S., F.G.S., Hobart (1902).
Professor T. W. Edgeworth David, B.A., F.R.S., F.G.S., Dunedin, N.Z. (1904)

Permanent Hon. Secretary:

A. Liversidge, M.A., LL.D., F.R.S., Professor of Chemistry, University of Sydney.

Hon. General Treasurer:

David Carment, F.I.A., F.A.A., Sydney.

Hon. General Secretaries:

W. Howchin, F.G.S., Lecturer in Geology and Palæontology, University of Adelaide.

J. P. V. Madsen, B.E., B.Sc., Lecturer in Electrical Engineering, University of Adelaide.

Hon. Local Treasurer:

W. H. Bragg, M.A., Professor of Mathematics and Natural Philosophy, University of Adelaide.

Hon. Local Secretaries:

New South Wales: A. Liversidge, M.A., LL.D., F.R.S., Professor of Chemistry, University of Sydney.

Queensland: John Shirley, B.Sc., F.L.S., Department of Public Instruction, Brisbane.

New Zealand: G. M. Thomson, F.L.S., F.C.S., Newington, Dunedin.

Victoria: T. S. Hall, M.A., University of Melbourne.

Tasmania: Alex. Morton, F.L.S., Curator Museum, Hobart.

South Australia: W. Howchin, F.G.S., and J. P. V. Madsen, B.E., B.Sc., University of Adelaide.

Council.

By Rule 6 the Council consists of—(1) Present and former Presidents, Vice-Presidents, Treasurers, and Secretaries of the Association, and present and former Presidents, Vice-Presidents, and Secretaries of the Sections; (2) members of the Association delegated to the Council by scientific societies; (3) secretaries of Research Committees appointed by the Council.

Trustees (Permanent).

R. L. J. Ellery, C.M.G., F.R.S., F.R.A.S.
Professor A. Liversidge, M.A., LL.D., F.R.S.
H. C. Russell, C.M.G., B.A., F.R.S., F.R.A.S.

Auditors:

R. Teece, F.I.A.
R. A. Dallen.

Publication Committee:

A. W. Howitt, C.M.G., D.Sc., F.G.S.
Professor E. H. Rennie, D.Sc.
Professor W. H. Bragg, M.A.
Professor W. Jethro Brown, LL.D.
Professor W. Angus, B.Sc.
Dr. T. Borthwick
J. P. V. Madsen, B.Sc.
Professor A. Liversidge, M.A., LL.D., F.R.S.
Professor E. C. Stirling, C.M.G., M.D., F.R.S.
R. W. Chapman, M.A., B.C.E.
W. Howchin, F.G.S.

Recommendation Committee:

A. W. Howitt, C.M.G., D.Sc., F.G.S.
Professor A. Liversidge, M.A., LL.D., F.R.S.
Professor E. H. Rennie, D.Sc.
Dr. Greig-Smith
J. P. V. Madsen, B.Sc.
A. Gibb Maitland
Professor T. W. E. David, B.A., F.R.S. F.G.S.
Professor W. H. Bragg, M.A.
Professor F. Anderson, M.A.
W. Howchin, F.G.S.
E. F. J. Love, M.A.
J. H. Maiden, F.L.S.

Reception Committee:

(The Reception Committee consists of members of the Local Committee, together with representative gentlemen resident in the city and suburbs elected by the Local Committee.)

Chairman: His Honor the Chief Justice.

His Worship the Mayor of Adelaide
Hon. Sir Langdon Bonython
Sir E. T. Smith, K.C.M.G.
R. Kyffin Thomas, J.P.
T. Gill, I.S.O., Under Treasurer
A. B. Moncrieff, M.I.C.E., Engineer-in-Chief
S. Dixon
Professor E. H. Rennie, D.Sc., Chairman of the Local Committee
The Honorable the Premier
Professor E. C. Stirling, C.M.G., M.D., F.R.S.
F. Bevan
J. C. B. Moncrieff, Resident Engineer, S.A.R.
D. Mawson, B.E., B.Sc.
Professor W. H. Bragg, M.A., Local Treasurer
W. Howchin, F.G.S., and J. P. V. Madsen, B.Sc., General Secretaries

Members of Council nominated by Societies:

R. H. Cambage, Chief Mining Surveyor, New South Wales; T. G. Taylor, B.Sc., B.E. (Linnean Society, N.S.W.)

Professor J. A. Pollock, University, Sydney; W. G. Woolnough, D.Sc., University, Sydney; Joseph Brooks, F.R.A.S., Sydney (Royal Society, N.S.W.)

G. Sweet, F.G.S. (Royal Society, Victoria.)

S. Dixon (Royal Society, South Australia).

Fitzgerald-Snowball (Royal Geographical Society of Australasia, Victorian Branch).

Hon. Sir Langdon Bonython (Royal Geographical Society of Australasia, South Australian Branch.)

Officers of Sections.

A.—Astronomy, Mathematics, and Physics.

President: E. F. J. Love, M.A., Lecturer in Natural Philosophy, University, Melbourne.

Vice-Presidents: Professor W. H. Bragg, M.A., University, Adelaide; Professor J. A. Pollock, D.Sc., University, Sydney; R. F. Griffiths, Government Astronomer, Adelaide.

Secretary: J. Dalby, B.A., Lecturer in Physics and Mathematics, School of Mines, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

B.—Chemistry, Metallurgy, and Mineralogy.

President: R. Sticht, B.Sc., E.M., Mount Lyell, Tasmania.

Vice-Presidents: Professor Rennie, D.Sc., University, Adelaide; G. A. Goyder, F.C.S., Adelaide; W. T. Cooke, D.Sc., University, Adelaide, G. C. McMurtry, A.R.S.M., A.R.C.S., Wallaroo; J. H. Young, Adelaide.

Secretary: A. J. Higgin, F.I.C., Lecturer in Assaying, School of Mines, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

Officers of Sections—*continued.*

C.—Geology.

President: A. Gibb Maitland, Government Geologist, Perth.

Vice-Presidents: Professor E. W. Skeats, D.Sc., University, Melbourne.; Professor T. W. E. David, B.A., F.R.S., University, Sydney; W. Howchin, F.G.S., University of Adelaide; W. G. Woolnough, D.Sc., University, Sydney; W. H. Twelvetrees, F.G.S., Government Geologist, Launceston.

Secretary: D. Mawson, B.E., B.Sc., Lecturer on Mineralogy and Petrology, University, Adelaide

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

D.—Biology.

President: J. H. Maiden, F.L.S., Government Botanist, Sydney.

Vice-Presidents: Professor J. A. Ewart, D.Sc., Ph.D., University, Melbourne; Professor R. J. A. Berry, M.D., Ch.M., F.R.C.S., University, Melbourne; C. Hedley, F.L.S., Australian Museum, Sydney; Rev. T. Blackburn, B.A., Adelaide; J. C. Verco, M.D., Adelaide; W. B. Poole, Savings Bank, Adelaide.

Secretary: W. Fuller, Demonstrator in Biology, University, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

E.—Geography.

President: T. W. Fowler, M.C.E., Melbourne.

Vice-Presidents: The Hon. Sir Langdon Bonython, Adelaide; T. Gill, I.S.O., the Treasury, Adelaide; W. Strawbridge, Surveyor-General, Adelaide; T. Parkhouse, Adelaide.

Secretaries: H. P. Moore, South Australian Company, North Terrace, Adelaide; W. H. Selway, Treasury, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

F.—Anthropology and Philology.

President: R. Parkinson, Ralum, Bismarck Archipelago.

Vice-Presidents: Professor E. C. Stirling, C.M.G., M.A., M.D., University, Adelaide; F. J. Gillen, F.A.S.

Secretary: T. Gill, I.S.O., Treasury, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

G. (1)—Social and Statistical Science.

President: Professor F. Anderson, M.A., University, Sydney.

Vice-Presidents: Professor Jethro Brown, LL.D., University, Adelaide; G. H. Knibbs, F.R.A.S., Federal Statistician, Melbourne; T. A. Coghlan, F.S.S., Agent-General for New South Wales.

Secretary: R. J. M. Clucas, Librarian, University, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

Officers of Sections—*continued.*

G. (2)—Agriculture.

President: T. Cherry, M.D., Director of Agriculture, Melbourne.

Vice-President: Professor Perkins, Principal of Roseworthy College.

Secretary: Professor W. Angus, B.Sc., Department of Agriculture, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

H.—Engineering and Architecture.

President: W. Thwaites, M.A., Engineer-in-Chief, Metropolitan Board of Works, Melbourne.

Vice-Presidents: Professor W. H. Warren, M.I.C.E., University, Sydney; A. B. Moncrieff, M.I.C.E., Engineer-in-Chief, Adelaide; J. Vicars, M.E., City Surveyor, Adelaide.

Secretary: R. W. Chapman, M.A., B.C.E., Lecturer in Engineering, University, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

I.—Sanitary Science.

President: R. Greig-Smith, D.Sc., Sydney.

Vice-Presidents: J. B. Cleland, M.B., Perth; E. Black, M.B., Perth; J. R. Baker, Chairman of Health Committee, Adelaide; T. G. Ellery, Town Clerk, Adelaide.

Secretaries: T. Borthwick, M.D., Ch.M., Health Officer, Adelaide; J. E. Mitton, Sanitary Inspector, City of Adelaide, and Local Secretary of the Royal Sanitary Institution, London.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

J.—Mental Science and Education.

President: F. Tate, M.A., Director of Education, Melbourne.

Vice-Presidents: Professor F. Anderson, M.A., University, Sydney; Rev. H. Girdlestone, M.A., Principal St. Peter's College, Adelaide; A. Williams, Director of Education, Adelaide; W. L. Cleland, M.B., Parkside, Adelaide.

Secretary: A. Scott, B.A., Superintendent University Training College, University, Adelaide.

Committee: Consists of Past Presidents and Present Officers of the Section, with power to add to their number.

Objects and Rules of the Association.

Objects of the Association.

The objects of the Association are to give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate science in different parts of the Australasian Colonies and in other countries; to obtain more general attention to the objects of science, and a removal of any disadvantages of a public kind which may impede its progress.

Rules of the Association.

Members.

1. Members shall be elected by the Council.
2. The subscription shall be £1 for each session, to be paid in advance.
3. A member may at any time become a life member by one payment of £10, in lieu of future subscriptions.
4. Ladies and matriculated students of the local University may be admitted as associates at a subscription of 10s. Associates are admitted to the general and sectional meetings, and to the evening entertainments. They shall not be entitled to free copies of the Reports of the Association. Ladies may become members on the same terms as gentlemen.

Sessions.

5. The Association shall meet in session periodically for one week or longer. The place of meeting shall be appointed by the Council two years in advance, and the arrangements for it shall be entrusted to the local Committee.

Council.

6. There shall be a Council consisting of the following: (1) Present and former Presidents, Vice-Presidents, Treasurers, and Secretaries of the Association, and present and former Presidents, Vice-Presidents, and Secretaries of the Sections; (2) members of the Association delegated to the Council by scientific societies; (3) Secretaries of Research Committees appointed by the Council.
7. The Council shall meet only during the session of the Association, and during that period shall be called together at least twice.

Local Committees.

8. In the intervals between the sessions of the Association its affairs shall be managed in the various States by Local Committees. The Local Committee of each State shall consist of the members of Council resident in that State.

Officers.

9. The President, five Vice-Presidents (elected from amongst former Presidents), a General Treasurer, one or more General Secretaries, and Local Secretaries shall be appointed by the Council.

Reception Committee.

10. The Local Committee of the State in which the session is to be held shall appoint a Reception Committee to assist in making arrangements for the reception and entertainment of the visitors. This Committee shall have power to add to its number.

Office.

11. The permanent office of the Association shall be in Sydney.

Money Affairs of the Association.

12. The financial year shall end on the 30th June.

13. All sums received for life subscriptions, and from the sale of back volumes of Reports, shall be invested in the names of three trustees appointed by the Council, and the interest arising from such investment shall be reserved for grants in aid of scientific research.

14. The subscriptions shall be collected by the Local Secretary in each colony, and be forwarded by him to the General Treasurer.

15. The Local Committees shall not have power to expend money without the authority of the Council, with the exception of the Local Committee of the State in which the next ensuing session is to be held, which shall have power to expend money collected or otherwise obtained in that colony. Such disbursements shall be audited, and the balance-sheet and the surplus funds be forwarded to the General Treasurer.

16. All cheques shall be signed either by the General Treasurer and the General Secretary, or by the Local Treasurer and the Secretary of the colony in which the ensuing session is to be held.

17. Whenever the balance in the hands of the banker shall exceed the sum requisite for the probable or current expenses of the Association, the Council shall invest the excess in the names of the Trustees.

18. The whole of the accounts of the Association—*i.e.*, the local as well as the general accounts—shall be audited annually by two Auditors appointed by the Council; and the balance-sheet shall be submitted to the Council at its first meeting thereafter.

Money Grants.

19. Committees and individuals to whom grants of money have been intrusted are required to present to the following meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer.

20. In each Committee the Secretary is the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required.

21. In grants of money to Committees or to individuals, the Association does not contemplate the payment of personal expenses to the members or to the individual.

Sections of the Association.

22. The following Sections shall be constituted:—

A.—Astronomy, Mathematics, and Physics.
B.—Chemistry and Mineralogy.
D.—Biology.
C.—Geology.
E.—Geography.
F.—Ethnology and Anthropology.
G (1).—Social and Statistical Science.
G (2).—Agriculture.
H.—Engineering and Architecture.
I.—Sanitary Science and Hygiene.
J.—Mental Science and Education.

Sectional Committees.

23. The President of each Section shall take the chair and proceed with the business of the Section not later than 11 a.m. In the middle of the day an adjournment for luncheon shall be made; and at 4 p.m. the Sections shall close.

24. On the second and following days the Sectional Committees shall meet at 10 a.m.

25. The Presidents, Vice-Presidents, and Secretaries of the several Sections shall be nominated by the Local Committee of the colony in which the next ensuing session of the Association is to be held, and shall have power to act until their election is confirmed by the Council. From the time of their nomination, which

shall take place as soon as possible after the session of the Association, they shall be regarded as an Organising Committee, for the purpose of obtaining information upon papers likely to be submitted to the Sections, and for the general furtherance of the work of the Sectional Committees. The Sectional Presidents of former years shall be *ex officio* members of the Organising Committees.

26. The Sectional Committees shall have power to add to their number.

27. The Committees for the several Sections shall determine the acceptance of papers before the beginning of the session. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an abstract of his paper, of a length suitable for insertion in the published Transactions, Reports, or Proceedings of the Association, and that he should send it, together with the original paper, to the Secretary of the Section before which it is to be read, so that it may reach him at least a fortnight before the session.

28. Members may communicate to the Sections the papers of non-members.

29. The author of any paper is at liberty to reserve his right of property therein.

30. No report, paper, or abstract shall be inserted in the volume of Transactions, Reports, or Proceedings unless it be handed to the Secretary before the conclusion of the session.

31. The Sectional Committees shall report to the Publication Committee what papers it is thought advisable to print.

32. They shall also take into consideration any suggestions which may be offered for the advancement of science.

33. In recommending the appointment of Research Committees all members of such Committees shall be named, and one of them who has notified his willingness to accept the office shall be appointed to act as Secretary. The number of members appointed to serve on a Research Committee should be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

34. All recommendations adopted by Sectional Committees shall be forwarded without delay to the Recommendation Committee; unless this is done the recommendation cannot be considered by the Council.

Official Journal.

35. At the close of each meeting of the Sections, the Sectional Secretaries shall correct, on a copy of the official journal, the list of papers which have been read, and add to them those appointed to be read on the next day, and send the same to the General Secretaries for printing.

Recommendation Committee.

36. The Council at its first meeting in each session shall appoint a Committee of Recommendation, to receive and consider the reports of the Research Committees appointed at the last session, and the recommendations from Sectional Committees. The Recommendation Committee shall also report to the Council, at a subsequent meeting, the measures which they would advise to be adopted for the advancement of science.

37. All proposals for the appointment of Research Committees and for grants of money (see Rules 19–21) must be sent in through the Recommendation Committee.

Publication Committee.

38. The Council shall each session elect a Publication Committee, which shall receive the recommendations of the Sectional Committees with regard to publication of papers, and decide finally upon the matter to be printed in the volume of Transactions, Reports, or Proceedings.

Alteration of Rules.

39. No alteration of the rules shall be made unless due notice of all such additions or alterations shall have been given at one meeting, and carried at another meeting of the Council held during a subsequent session of the Association.

BALANCE-SHEETS, ADELAIDE SESSION, 1907.

Australasian Association for the Advancement of Science.

Victoria.—Statement of Receipts and Payments for Period, July 1st, 1904, to May 31st, 1907.

Dr.	£ s. d.	£ s. d.	Cr.	£ s. d.
To Balance in Bank, June 30th, 1904	5 0 9		By Remittance to Hon. Treasurer, Sydney office	30 0 0
Cash in hand	0 13 7		Postages and exchange	0 14 7
		5 14 4	Bank charges	1 10 0
Subscriptions for Adelaide meeting—Members	33 0 0		Balance in Bank, May 31st, 1907	6 19 9
Subscriptions for Adelaide meeting—Associates	0 10 0			
		33 10 0		
		£39 4 4		£39 4 4

T. S. Hall, Local Secretary.

Dunedin.—Balance-sheet for 1906-1907.

Dr.	£ s. d.	Cr.	£ s. d.
1904. Feb. 13th—Cash in hand	1 2 1	1906. Sundry accounts from last meeting.. ..	4 18 6
April 8th—Balance from Local Treasurer ..	3 18 10	Professor Chilton a/c Research Committee..	50 0 0
Received from Hon. Treasurer, Sydney	80 0 0	Portobello marine hatchery " ..	40 0 0
" 21st—A. Morton, a/c Research	20 0 0	A. Hamilton (£10 returned)	—
1906. Dec. 8th—Sixteen Subscriptions (to 13/2/07)	16 0 0	Postages (letters, books, and parcels), 1904-7	1 16 4
		Exchange	0 8 0
		Stationery	0 13 6
		Drafts on Sydney (£17 and £6)	23 0 0
		Balance in hand	0 4 7
	£121 0 11		£121 0 11

Walter Hislop, Auditor.

BALANCE-SHEETS, ADELAIDE SESSION, 1907—*continued.*

ADELAIDE.—CASH STATEMENT TO SEPTEMBER 21ST, 1908.

DR.	£	s.	d.
To Balance in Savings Bank from Dunedin session, 1904	5	0	0
Cash in hand from Dunedin session, 1904	0	4	11½
Subscriptions—			
187 members Adelaide meeting	187	2	0
104 associates " "	52	0	0
1 member, Brisbane, 1909	1	0	0
Donation by the Mayor of Adelaide towards Entertainment	10	10	0
Sale of excursion, lunch, and tea tickets	59	17	0
Sale of back volume of Report	0	5	0
Contribution of J. Vicars, Esq., towards correcting proofs	0	10	0
	£316	8	11½

CR.	£	s.	d.	£	s.	d.
By Postage and telegrams				26	16	5
Printing and stationery				72	7	4
Clerical assistance				53	3	0
Advertising				43	10	8
Catering				34	9	5
Drags				38	15	0
Reporting proceedings				8	4	0
Hire of halls, &c.				9	19	0
Petty expenses				6	7	8½
Bank charges and cheque-book				1	2	6
				£294	15	0½
Balances—						
Bank of Australasia	31	16	7			
Less cheques outstanding	12	11	1			
	£19	5	6			
Savings Bank	2	6	1			
Cash in hand	0	2	4			
				21	13	11
				£316	8	11½

W. H. BRAGG, Hon. Local Treasurer.

TASMANIA.

DR.	£	s.	d.
To Subscriptions	10	0	0
Interest	0	2	11
	£10	2	11

CR.	£	s.	d.
By Advertising, &c.	2	10	0
Stationery, postage, and petty cash	2	1	11
Remittance to Sydney	5	11	0
	£10	2	11

July 5th, 1907.

C. E. MORTON.

GENERAL BALANCE-SHEET.—SYDNEY OFFICE.

General Account, July 1st, 1904, to June 30th, 1906.

Dr.	£	s.	d.	Cr.	£	s.	d.
To Balance in Bank, June 30th, 1904	18	10	5	By Clerical assistance	46	2	6
Subscriptions	11	1	0	150 extra copies Vol. IX. Report	15	1	0
Balance	69	2	5	Freight and cartage	1	16	11
				Printing and stationery	11	18	3
				Petty expenses	6	16	0
				Postage	5	7	8
				Bank charges and exchanges	1	1	6
				Furniture	10	10	0
	£98	13	10		£98	13	10

Research Fund.

Dr.	£	s.	d.	£	s.	d.	Cr.	£	s.	d.	£	s.	d.
To Balance in Bank, June 30th, 1904	—			9	8	11	By Investments on June 30, 1906	1,400	0	0			
Mortgage at July 1st, 1904 ..	1,400	0	0				Fixed Deposit due November 19th, 1906	756	0	0			
Received Principal of Fixed Deposits	1,050	0	0				Fixed Deposit due June 4th, 1907	378	0	0			
				2,450	0	0					2,534	0	0
" Interest on Mortgage	112	0	0				Balance in Bank, June 30th, 1906	—			121	8	11
" Interest of Fixed Deposits	84	0	0										
				196	0	0							
				£2,655	8	11					£2,655	8	11

General Balance-sheet.—Sydney Office—*continued.*

Mueller Memorial Fund.

Dr.	£ s. d.	£ s. d.	Cr.	£ s. d.	£ s. d.
Received from Subscribers to Fund	400 0 0		By Fixed Deposits due July 12th, 1906	400 0 0	
" " " ..	26 16 1		Balance in Bank, June 30th, 1906	26 16 1	
		426 16 1			
		£426 16 1			£426 16 1

Audited and found correct.

Robert A. Dallen.

D. Carment, Hon. Treasurer.

MEETINGS OF THE GENERAL COUNCIL.

EXTRACTS FROM MINUTES.

ADELAIDE, JANUARY 7TH, 1907.

THE President, Professor T. W. Edgeworth David, B.A., F.R.S., took the chair at 10·30 a.m.

The minutes of the Dunedin meeting were taken as read, and confirmed.

Mr. W. Howchin (General Secretary) announced that an apology for non-attendance had been received from Mr. A. Morton, F.L.S. (Local Secretary of Tasmania), and from Mr. Gillen and Mr. G. M. Thomson. Mr. Howchin reported that there had been a somewhat important change in the officers during the year: Professor Spencer, the President elect, was compelled through private reasons to send in his resignation. A certain course was prescribed by regulations, and the General Secretary took the course. As a result Dr. A. W. Howitt had been nominated, and the nomination was to be confirmed at this meeting.

The following officers were elected unanimously:—Patron, His Excellency Sir George Le Hunte, K.C.M.G.; Vice-Patron, The Right Hon. Sir Samuel J. Way, Bart., LL.D., Chief Justice; President, A. W. Howitt, C.M.G., D.Sc., F.G.S.; General Treasurer, David Carment, F.I.A., F.A.A., Sydney; Permanent Hon. Secretary, Professor A. Liversidge, M.A., LL.D., F.R.S.; Local Treasurer, Professor W. H. Bragg, M.A.; General Auditors, R. Teece, F.I.A., and R. A. Dallen; General Secretaries, W. Howchin, F.G.S., and J. P. V. Madsen, B.E. Local Secretaries—New South Wales, Professor Liversidge; Queensland, J. Shirley, B.Sc., F.L.S.; New Zealand, G. M. Thomson, F.L.S., F.C.S.; Victoria, T. S. Hall, M.A.; Tasmania, A. Morton; South Australia, W. Howchin F.G.S., and J. P. V. Madsen, B.E., B.Sc.

The arrangements of the Adelaide meeting were approved, and the thanks of the Council accorded to the local committee, and especially to the secretaries, Mr. Howchin and Mr. Madsen.

The members whose names were given in the official journal were elected.

The General Treasurer, Mr. Carment, presented the balance-sheet to June 30th, 1906. He said the figures were satisfactory, and there was a balance to the credit of the funds, which had been invested. In answer to a question, he said the balance to the credit of the Research Fund was £2,655 8s. 11d.

Professor Liversidge explained that any balance left over from the meetings was deposited to the credit of the Research Fund, and it was the interest on that fund which was available for grants for research approved by the General Council. The fund was earning 4 per cent.

The balance-sheet was adopted.

Nomination of Officers for Brisbane Meeting.

Professor Liversidge said that the next meeting of the Association was appointed to be held at Brisbane in September, 1908, but a good many members of the Council thought it was rather bad policy to hold three meetings consecutively in such widely separated towns as Dunedin, Adelaide, and Brisbane. It was thought that it might be better to arrange the next meeting at Hobart in January, 1909, and to postpone the Brisbane meeting to 1911. After consideration, the matter was postponed to an adjourned meeting to be held on Thursday.

In reply to a question by Dr. Black (Perth), Professor Liversidge said he had been informed by Mr. Gibb-Maitland that it was not possible at present to hold a meeting of the Association in Western Australia.

Local Secretaries.

The appointment of Mr. T. S. Hall, M.A., as local secretary for Victoria, in succession to Mr. E. F. J. Love, M.A., was confirmed. Mr. A. Gibb-Maitland was appointed local secretary for Western Australia.

Research and Other Committees.

Mr. Howchin stated that reports had been received from the following committees:—Seismological, Glacial, Structural Features of Australia, New Zealand Food Fishes, Biological and Hydrographical Study of the New Zealand Coast, the Teaching of Science, and Terrestrial Magnetism; but no reports from the committees on Sea-surface Temperatures, Spelling of Native Names, or the Nomenclature of Australasian Igneous Rocks had come to hand. The reports were referred to the Sections concerned.

The Recommendation Committee was appointed as follows:—Dr. Howitt, Professors David, Liversidge, Bragg, Rennie, and Francis Anderson, Dr. Greig-Smith, and Messrs. Howchin, Madsen, Love, Gibb-Maitland, and Maiden.

The Publication Committee was appointed as follows:—Dr. Howitt, Professors Liversidge, Rennie, Bragg, Stirling, Jethro Brown, and Angas, Dr. Borthwick, and Messrs. Chapman, Howchin, and Madsen.

Notices of Motion.

Mr. J. H. Maiden, F.L.S., gave notice of motion that he would move at the next meeting (two years hence)—"That a separate section be formed for Botany."

Professor Rennie gave notice of motion that he would move at the same meeting—"That the two divisions of Section G be made separate Sections."

Publishing Bibliographies.

Mr. J. H. Maiden moved—"That the question of publishing bibliographies in the various branches of science be considered." He submitted that many of the papers published in the volumes of the Association might fittingly find their way into the publications of the local societies, and the bibliography of Australia could be printed in the Association's volume. If they did that, and emphasized the Australasian character of the book, it would be more appreciated.

He also moved—"That subjects be selected for discussion two years in advance." His idea was that the Association might select at one meeting subjects for special treatment at the next meeting.

After discussion, in which Mr. Gibb-Maitland, Mr. W. S. Dunn, Dr. Greig-Smith, Professor Liversidge and Professor Rennie took part, it was decided, on the motion of Professor Liversidge, to refer the matter to the Sectional Committees at the present session, in order that a report might be made to the Council, so that the Recommendation Committee might take it up.

Criminology.

Professor Liversidge reported that he had received a letter from Mr. Arthur McDonald, a member of the United States Senate, stating that he was bringing forward a Bill upon the cause of Crime, and giving other information concerning criminology. Letter received, and referred to the Mental Science Section.

The Council adjourned until Thursday, January 10th, at 2 p.m.

Adjourned Council Meeting, January 10th, 1907.

The President (Dr. A. W. Howitt) occupied the chair.

Inviting the British Association to Australia.

Professor Liversidge said that for purposes of having it placed on record in the minutes, he wanted to refer to a proposal that had been made more than once in favor of inviting the British Association to meet in Australia.

Twenty years ago the Premier of New South Wales invited the British Association to visit Australia, but when 400 members signified their willingness, the cost was considered too great, and the invitation was withdrawn.

A year or two ago an invitation went from Melbourne, which was not accepted, probably because it did not emanate from any scientific body.

If the British Association were to be invited to Australia again, it should be done through some recognised body, such as the Australasian Association for the Advancement of Science. He did not think there was any possibility of anything being done before 1913, so that there was plenty of time to make proper arrangements. No invitation should be issued unless £10,000 to £20,000 was in hand to partly defray the travelling expenses of the visitors. Larger sums were collected for the Canadian and South African meetings.

Future Meetings.

After some discussion it was decided—"That the next meeting should be held in Brisbane, in January, 1909, subject to the approval of the local committee."

Professor Liversidge moved—"That the next meeting after the Brisbane Congress be held in Sydney in 1911." He said at the Sydney meeting, which would start the round afresh, it would be more convenient to alter the order of rotation in order to avoid the difficulty of the Association assembling in such widely separated cities in successive meetings as Adelaide and Brisbane. Carried.

Trusteeship.

Professor Liversidge announced the resignation of Mr. H. C. Russell as a trustee. He moved—"That the resignation be accepted with regret, and that a vote of sympathy be passed to Mr. Russell in his illness." Mr. E. F. J. Love seconded the motion. Carried.

Mr. E. F. J. Love moved and Mr. J. J. Stuckey seconded—"That Professor David be appointed a trustee in the place of Mr. Russell." Carried.

Life Membership.

Professor Liversidge stated that the next business on the agenda paper was Mr. A. Morton's motion, as follows:—"That in future the appointment of life members of the Association be made by the General Committee, on the advice of an absolute majority of the Recommendation Committee; and that not more than one life member be appointed at any meeting of the Association." He drew attention to the absence of Mr. Morton.

Professor Anderson moved and Professor Rennie seconded—"That we proceed to the next business." Carried.

Mr. E. F. J. Love urged the retention of Honorary Life Membership, not so much for honoring Australians, but as a suitable means for recognising scientists of the very first rank who might visit them in the future.

Sectional Presidents.

Professor Liversidge moved—"That the Committee of the Sections nominate Presidents of Sections for next session." If five or six possible Presidents were selected for each Section this system would assist the Local Committees, and ensure a proper or an equal distribution of Presidents amongst the various States. Mr. E. F. J. Love seconded the motion. The matter was postponed to the next Council meeting.

Grants of Money.

Professor Liversidge moved—" That it is desirable that all persons and bodies who receive grants of money shall forward vouchers and a statement of expenditure to the local Hon. Treasurer, for transmission to the General Secretaries, at least one month before the meeting of the next ensuing session, in order that they may be audited according to Rule 18." Mr. E. F. J. Love seconded the motion. Carried.

Surplus Copies of Reports.

Professor Liversidge said that he had arranged a sample set of surplus copies of the Association's Reports for disposal at a reduced price; but, apparently, there was very little demand for them. Some of the surplus Reports ran into 500 and 600 copies, while some were out of print. He suggested that they should be offered to suitable institutions throughout the world at a much reduced rate, or distributed amongst them gratuitously.

The proposal was approved of, and Mr. J. J. Stuckey said that the Association should retain at least 100 copies of each Report.

Associates.

Professor Liversidge moved, and Mr. E. F. J. Love seconded—" That in future ladies and local matriculated University students be admitted as associates at a subscription of 10s." If the motion was passed it would be necessary to form a new rule to that effect.

Mr. C. C. Farr, Professor Rennie, Mr. J. J. Stuckey, Mr. S. Dixon, and Mr. G. H. Knibbs took part in the discussion, in which Professor Liversidge, replying to questions, said that neither steamship nor railway managers objected to associates sharing in the concessions granted to members attending the Congress. He was powerless to stop the practice that had sometimes prevailed in the past of issuing ladies' tickets for a subscription of 5s. Carried.

Australasian Journal of Science.

Professor Liversidge said he had been asked to bring this matter forward. Some time ago he brought out a prospectus for a *Journal of Science*, of which 7,000 copies were distributed all over Australasia and New Zealand. The support received, however, had been very small, and so the matter had been dropped. Perhaps the Association might take the matter up.

Recommendation Committee.

The resolutions of the Recommendation Committee were received and adopted, as follows:—

[Mr. Maiden's proposals for (*a*) Bibliographies of Australasia, and (*b*) selection of subjects two years in advance, were reported on by the Sections as follows:— As to (*a*), Sections B, C, and D approve; Sections A and I express no opinion; Section E does not approve. As to (*b*), Sections A, B, C, D, and I approve; Section E suggests six months' notice.]

Section A.—" That a discussion be held at a joint session of Sections A and B on the 'Theory of the Voltaic Cell,' and that Mr. E. F. J. Love, M.A., and Professor Orme Masson, F.R.S., be invited to open the discussion."

" That the Council notes with satisfaction that the Government of South Australia has decided to install a seismograph at Adelaide, as suggested at the Dunedin meeting."

" That the Australasian Association for the Advancement of Science learns with satisfaction of the completion of the magnetic survey of the main island of New Zealand, and also of the effort which is being made to extend that survey to the outlying island of that colony, and trusts that the Government of New Zealand may see its way to carry the scope of the work still further, so as to include the Macquarie Islands."

" That the Committee on Terrestrial Magnetism be reappointed."

"That the reappointment of the Seismological Committee, with the addition of the names of Mr. R. F. Griffiths and Mr. E. F. J. Love, and the omission of the name of Professor Gregory, and that Messrs. P. Barrachi and Hogben be secretaries."

Section C.—"That a sum of £10 be granted in aid of mapping the old moraines of the Tasman Valley."

"That, as it is desirable and important to ascertain more as to the nature and the age of the glaciation evidenced at Crown Point, Valley of the Finke, Central Australia, a sum of £50 be asked for from the Association's funds, to be placed at the disposal of the committee of Section C for carrying out this important piece of work, the money to be used to defray transport expenses; and that the Government of South Australia be asked to grant such additional transport facilities as it may deem expedient." Professor Liversidge pointed out that there was another application for £50 from Section D, and as it was not desirable to exceed £100 as a total grant during the present year, they might allow each Section £45. It was decided to grant Section C £45, and, with this amendment, the resolution was agreed to.

Section D.—"That the sum of £50 be allowed from the Research Fund for the purpose of deep-sea dredging off Eastern Australia." Dr. Greig-Smith pointed out that the £150 voted by the Royal Society of London had been expended in buying the dredge, and £50 might go a long way in accomplishing valuable work. It was decided to grant £45.

"That the Report on New Zealand Food Fishes be adopted." Referred to the Publication Committee.

"That the Report of the Committee for Biological and Hydrographical Study of the New Zealand Coast be adopted." Referred to the Publication Committee.

"That the request of the Committee for Biological and Hydrographical Study of the New Zealand Coast, 'That the unexpended balance of their grant, £39 10s., be reassigned to them, and that their committee be reappointed, with Mr. E. R. Waite substituted for the late Captain F. W. Hutton, F.R.S.'"

Professor Benham's recommendation in regard to taking steps to urge upon the Government of Tasmania the desirability of putting a stop to the slaughter of penguins on the Macquarie Islands was indorsed.

Section E.—"That subjects for discussion be issued six months beforehand, and that the list of papers should be issued three months before the date of meeting." Referred to the local committee of the next meeting.

Dr. A. Lendon forwarded a letter, bringing before the Section the subject of the work on "Cook and his Comrades," which the late Professor E. Morris was about to publish when he died. The members of Section E are of opinion that the publication of this work is very desirable, as a matter of geographical history, and state that the late Professor Morris labored most zealously on the work, which will be found to be a most scholarly production. Approved, and recommended for publication in the daily newspapers.

Section I.—"That, in the opinion of this Association, in the interest of Australasians, a system for the teaching of hygiene and the medical inspection of school children should be established in connection with the Educational and Public Health Department of each State in Australasia."

"That the attention of the Federal and State Governments and the Government of New Zealand, be directed to the question of preventing tuberculosis amongst cattle and swine, in the following terms:—'That, while recognising the value of the work already accomplished, this association respectfully urges upon the Governments of the Commonwealth and the Australian States and of New Zealand the necessity, while there is still time, for preventing the extension of tuberculosis amongst cattle and swine, and be asked, if necessary, to appoint a commission to consider the best means of so doing, and of ensuring uniform measures throughout Australasia.'"

Baron von Mueller Committee.

Professor Liversidge reported that the Baron von Mueller Medal Committee had met and decided unanimously to recommend that the medal should be awarded to Professor Hill, late of Sydney University, and now of University College, London. Agreed to.

Minutes of Council Meeting held January 12th, at 11 a.m.

The minutes of the previous meetings having been revised by the President before the meeting, were taken as read and confirmed.

Recommendation Committee.

Professor Liversidge said that the Recommendation Committee had recommended that Professor Skeats replace Professor Gregory on the Mueller Memorial Committee. Agreed to.

Section A.—Recommends the adoption of the following resolutions:—"This Association is of opinion that the installation at Perth Observatory of a complete set of magnetographs for the continuous registration of the variation of the magnetic elements is a prime necessity of magnetic research, and respectfully urges upon the Government of Western Australia the desirability of taking action in this direction as soon as possible, inasmuch as Perth is situated at a great distance from any other first-order observatory, and the comparison of records obtained there with those obtained elsewhere would be exceptionally valuable."

The Association is of opinion that the installation at Brisbane, Port Darwin, and Hobart of seismographs of the same general character as those now in use at Sydney, Perth, Melbourne, Wellington, and Christchurch is very desirable, and respectfully urges this step upon the consideration of the Governments concerned. Approved.

Section D.—Recommends the Association to lay down principles to guide the committees in making their recommendations for the publication of papers in the Report of each meeting. Approved.

Recommends the Association to consider the desirability of publishing approved monographs. Approved.

Suggests that the Rev. Thomas Blackburn's paper on "The Principles of Scientific Description in Natural History" be recommended to the council as a subject for discussion two years hence. Approved.

Section J.—Recommended that the committee appointed at Dunedin to inquire into the teaching of science in primary and secondary schools, technical colleges, and universities be reappointed, with the exception of Professor Gregory, who has left Australia, and that the names of the following members be added:—Mr. A. Williams, Director of Education, Adelaide; Rev. H. Girdlestone, M.A., St. Peter's College, Hackney, S.A.; Mr. F. Chapple, B.A., B.Sc., Prince Alfred College, Kent Town, S.A.; Professor Baldwin Spencer; Mr. Blanch, Church of England Grammar School, Melbourne; and Mr. Littlejohn, Scotch College, Melbourne.

That it is a suggestion from this Section that the above local committees from each State meet separately and forward their report to the General Committee in time for the twelfth session of the Association.

That each of the above local committees have power to add to its numbers.

That the reports be sent to the secretary for the next session.

That the secretary of Section J of the present session be empowered to communicate with the conveners of the local committee, and urge the desirability of calling a meeting of science teachers in the various States at an early date.

Professor Liversidge said the Recommendation Committee had not approved of this recommendation.

Professor Laurie said that the committee was appointed by the Dunedin meeting, and it had done only a fractional part of its work. The proposal was simply to carry on the work, and to suggest means of doing it in a more systematic and thorough manner. If, however, the Recommendation Committee wished to go back on the Dunedin meeting, and say that a mistake had been made in appointing a committee, he was not in a position on behalf of Section J to press the motion, and he acquiesced in the decision.

The decision of the Recommendation Committee was confirmed.

A letter from Mr. J. H. Young, of the Pharmaceutical Society Conference, was received, recommending that a subsection of Section B for Pharmaceutical Chemistry be formed. Agreed to.

Section C.—Professor Liversidge said Section C had sent in a recommendation which had been received after the last meeting of the Recommendation Committee, but it was one that ought to be dealt with. The resolution was—"That the following Research Committees be appointed, viz. :—(1) Australasian Glaciation, (2) Committee for Recording Structural Features in Australasia, (3) the Great Barrier Reef, and (4) the Nomenclature of Eruptive Rocks ; and that the members of these Research Committees, appointed at the last meeting, be reappointed. Approved.

Section F.—Committee on Spelling of Native Names.—The Rev. Dr. George Brown asked whether anything had been done with regard to the Research Committee on the uniform spelling of native names. They had taken much trouble over the subject, and had prepared a report in which they gave the mode of spelling adopted by the British Admiralty and the Council of the Royal Geographical Society of Great Britain, as well as examples of the way in which the spelling of some names should be altered. It was strange that their work should be entirely ignored and nothing said about it.

Professor Liversidge said he had no knowledge of the report. It was sent by Dr. Brown to the Dunedin meeting, and therefore would go to the local secretaries of the local committee in New Zealand to deal with.

The Rev. Dr. Brown moved—"That the committee be reappointed, with the addition of the name of Professor Stirling, of South Australia, the omission of the names of Dr. Roth, of Queensland, and the late Captain Hutton, of New Zealand, and that the committee have power to add to their number. Carried.

Section E.—Professor Liversidge said a late recommendation had been received from Section E as follows :—"That the council of this Association be requested to urge upon the Federal Government the desirability of undertaking the scientific examination of the Indian Ocean, between the meridians of 60° and 150° E. longitude, and from the Australian coastline or latitude 20° S. to latitude 50° S., with the object of obtaining reliable data for long period weather forecasting." Agreed to.

Amendment of Rules.

Professor Liversidge said that at the last meeting a resolution was agreed to to amend Rule 4, and he now proposed it with a view to it being passed. The amended rule was—"Ladies and matriculated students of the local University may be admitt·d as associates at a subscription of 10s. Associates are admitted to the general and sectional meetings, and to the evening entertainments. They shall not be entitled to free copies of the Reports of the Association. Ladies may become members on the same terms as gentlemen." Carried.

Presidents of Sections.

Professor Liversidge moved—"That it be a recommendation to the committees of each of the Sections to select five or more gentlemen as possible Presidents for their respective Sections, from which nominations can be made by the respective local committees under Rule 25." Professor Rennie seconded. Mr. G. H. Knibbs moved as an amendment that the word "five" be altered to "three." Mr. J. H. Maiden seconded. The motion as amended was passed.

The President Elect.

On the motion of Professor Bragg, Professor Baldwin-Spencer, M.A., F.R.S., was elected as the next President of the Association.

Votes of Thanks.

The President proposed a vote of thanks to His Excellency the Governor, the Patron of the Association, for the keen interest he had maintained in their proceedings, and for the garden party at Government House.

The Rev. Dr. Brown proposed a vote of thanks to His Honor the Chief Justice (Vice-Patron) and Lady Way for having entertained the members of the Association at a garden party at their residence, Montefiore, North Adelaide.

Mr. J. H. Maiden proposed a vote of thanks to the Premier and the Government for their having placed on the estimates an amount for printing the volume of the Association ; for giving the Outer Harbor excursion ; and for generously granting the s.s. *Governor Musgrave* for the visit to Kangaroo Island and Spencer Gulf.

Professor Kernot proposed a vote of thanks to Sir Langdon Bonython, Professor Stirling, and Sir Edwin Smith for having entertained the members.

Professor Laurie proposed a vote of thanks to the lecturers—Professor David, Mr. Maiden, and Rev. Dr. Brown.

Professor Marshall proposed a vote of thanks to the Marine Board, and the President and staff, for putting the steamer *Governor Musgrave* at the disposal of the Association for a three days' trip in the gulf.

Mr. T. J. Gillen proposed a vote of thanks to Mr. T. H. Jones, Mus. Bac., for his performance on the Town Hall organ ; to Mr. Bevan and the students of the Conservatorium ; to Mr. M. Holtze, for decorations ; to the Railways Commissioner (Mr. A. G. Pendleton, C.M.G.) for concessions on the railways ; to His Worship the Mayor of Adelaide for generous contribution to the general fund ; to the Chancellor and Council of the University of Adelaide ; to the Town Clerk for free distribution of "Official Guide to Adelaide" ; to the River Murray League ; to the Chief Secretary ; to Mr. J. W. Jones, secretary to the Commissioner of Public Works ,for arranging the trip of the *Governor Musgrave ;* to the Board and Governors of the Public Library for invitations to inspect institutions under their care ; to the Council of the School of Mines ; and to the Deputy Postmaster-General (Mr. R. W. M. Waddy) for postal and telegraph facilities.

The Hon. A. Norton proposed a vote of thanks to the Press for the able manner in which the meetings and proceedings of the Association had been reported.

Dr. Woolnough proposed a vote of thanks to Dr. Alfred Howitt, the President, for his opening address.

Mr. Hedley proposed a vote of thanks to Professor Liversidge, the permanent hon. secretary.

Mr. Selway proposed a vote of thanks to the general secretaries, Mr. Howchin and Mr. Madsen.

Professor Pollock proposed a vote of thanks to the officers and members of the local committee.

Each of the motions was carried by acclamation.

COMMITTEES OF INVESTIGATION.

Seismological Committee.

Sir Chas. Todd, K.C.M.G., Angas Street, Adelaide; Professor E. David, B.A., F.R.S., F.G.S., University, Sydney; C. Coleridge Farr, D.Sc., Canterbury, College, Christchurch, New Zealand; W. E. Cook, Loungeville, Queensland; H. Tarlton Phillipps, Illabo, New South Wales; Professor A. Macaulay, M.A., Hobart, Tasmania; R. F. Griffiths, Commonwealth Meteorological Department, Melbourne; E. F. J. Love, M.A., University, Melbourne. Secretaries: P. Barrachi, Observatory, Melbourne; G. Hogben, M.A., Inspector-General, Education Department, Wellington.

Glacial Phenomena Committee.

Professor E. G. Hogg, M.A., Christchurch, New Zealand; A. Gibb-Maitland, Government Geologist, Perth, Western Australia; B. Dunstan; R. McK. Johnston, De Witt Street, Battery Point, Hobart; G. Sweet, F.G.S., Wilson Street, Brunswick, Victoria; W. H. Twelvetrees, F.G.S., Government Geologist, Launceston, Tasmania; W. Howchin, F.G.S., University, Adelaide; G. A. Waller, Zeehan, Tasmania; R. Speight, F.G.S., Canterbury College, Christchurch, New Zealand; A. E. Kitson, Department of Mines, Melbourne; Professor Marshall, M.A., D.Sc., F.G.S., Otago University, Dunedin, New Zealand. Secretary: Professor E. David, B.A., F.R.S., F.G.S., University, Sydney.

Committee for Recording Structural Features in Australasia.

W. H. Twelvetrees, F.G.S., Government Geologist, Launceston, Tasmania; G. A. Waller, Zeehan, Tasmania; T. S. Hall, M.A., University, Melbourne; H. Y. L. Brown, Government Offices, Adelaide; W. Howchin, F.G.S., University, Adelaide; A. Gibb-Maitland, Government Geologist, Perth, Western Australia; E. F. Pittmann, A.R.S.M., Mines Department, Sydney; B. Dunstan, Brisbane; W. J. Clunies-Ross, B.Sc., Technical College, Sydney; R. Speight, F.G.S., Canterbury College, Christchurch, New Zealand; Professor P. Marshall, M.A., D.Sc., F.G.S., Otago University, Dunedin, New Zealand. Secretary: Professor E. David, B.A., F.R.S., F.G.S., University, Sydney.

Committee on Nomenclature of Australasian Igneous Rocks.

Professor E. David, B.A., F.R.S., F.G.S., University, Sydney; A. W Howitt, Clovelly, Metung, Victoria; W. G. Woolnough, D.Sc., University, Sydney; Professor Marshall, M.A., D.Sc., F.G.S., Otago University, Dunedin, New Zealand; W. H. Twelvetrees, F.G.S., Government Geologist, Launceston, Tasmania. Secretary: G. W. Card, Mines Department, Sydney.

Committee for Biological and Hydrographical Study of the New Zealand Coast.

Professor A. W. P. Thomas, M.A., F.L.S., University College, Auckland New Zealand; A. Hamilton, Colonial Museum, Wellington, New Zealand; Dr W. Blaxland Benham, M.A., Otago University, Dunedin, New Zealand; E. R Waite, F.L.S., Canterbury Museum, Christchurch, New Zealand. Secretary: Professor C. Chilton, M.A., D.Sc., Canterbury College, Christchurch, New Zealand.

Committee on New Zealand Food Fishes.

C. W. Chamberlain, D. Barton, and Geo. M. Thomson, F.L.S., F.C.S. (convener).

Committee on Spelling of Native Names.

South Australia—Professor E. C. Stirling, C.M.G., M.A., M.D., F.R.S., University, Adelaide; R. T. Maurice, Adelaide Club, Adelaide; F. J. Gillen, F.A.S., Moonta, South Australia. Victoria—Rev. Lorimer Fison, M.A., 74, Richardson Street, Essendon, Victoria; Professor B. Spencer, University, Melbourne. New South Wales—Rev. G. Brown, D.D., Gordon, New South Wales; Rev. C. J. Prescott, M.A., Newington College, Stanmore Road, Marrickville, New South Wales. Tasmania—Alex. Morton, Museum, Hobart; R. M. Johnston, De Witt Street, Battery Point, Hobart. Queensland—J. F. Bailey, Department of Agriculture, Brisbane. Western Australia—H. C. Prinsep, 160, Hay Street, Perth. New Zealand—S. Percy Smith, Matai Moana, North Plymouth, New Zealand; E. Tregear, Department of Labor, Wellington, New Zealand. Secretary: A. Hamilton, Colonial Museum, Wellington, New Zealand. With power to add to their number.

Committee for Investigation of Terrestrial Magnetism in Australasia.

C. Coleridge Farr, D.Sc., Christchurch, New Zealand; Professor E. G. Hogg, M.A., Christchurch, New Zealand; E. F. J. Love, M.A., University, Melbourne. Secretary: P. Barrachi, Observatory, Melbourne.

MUELLER MEMORIAL MEDAL COMMITTEE.

Professor W. Baldwin Spencer, M.A., F.R.S., University, Melbourne; Professor Skeats, University, Melbourne; E. J. F. Love, M.A., University, Melbourne; J. H. Maiden, F.L.S., Botanic Gardens, Sydney.

For report of this Committee see page xxv.

GENERAL PROGRAMME.

Monday, January 7th—

10 a.m.—Registration of Members at the University.

10.30 a.m.—First meeting of Council.

11.30 a.m.—Sectional Committees meet in their rooms.

4 p.m.—His Excellency Sir George Le Hunte, K.C.M.G., the Governor of South Australia, and Patron of the Association, will receive the members in the grounds of Government House.

8 p.m.—The inaugural meeting will be held in the Town Hall, when Porfessor T. W. Edgeworth David, B.A., F.R.S., will resign the Presidency to Mr. A. W. Howitt, C.M.G., D.Sc., F.G.S., who will deliver the Presidential address ; subject—"Reminiscences of Central Australia and the Burke and Wills Expedition."

Tuesday, January 8th—

10 a.m.—Sectional Committees meet.

10.30 a.m. to 1 p.m., and 2 p.m. to 4 p.m.—Presidential addresses in Sections.

8 p.m.—Lecture at the Elder Hall, University, by Professor T. W. Edgeworth David, B.A., F.R.S. ; subject—"The San Francisco Earthquake and Mexico." Illustrated by a large series of lantern slides taken by the lecturer in his recent visit to the localities named.

Wednesday, January 9th—

10 a.m.—Sectional Committees meet.

10.30 a.m. to 1 p.m.—Sections meet for reading of papers, &c.

1.30 p.m.—Excursion to Mount Lofty in drags ; the outward journey will be *via* the Greenhill Road. After a visit to the summit of the Mount half the party will be entertained by the Hon. Sir J. Langdon Bonython at "Carclew," near the top of the Mount, and the other half by Professor E. C. Stirling, M.D., C.M.G., F.R.S., at "St. Vigeans," near Mount Lofty station, about three miles from the top. The return to town will be made from these two residences *via* Glen Osmond.

8.30 p.m.—A concert of vocal and instrumental music at the Elder Hall, under the direction of Mr. Frederick Bevan.

Thursday, January 10th—

10 a.m.—Sectional Committees meet.

10.30 a.m. to 1 p.m., and 2 p.m. to 4 p.m.—Sections meet for reading of papers, &c.

8 p.m.—Lecture at the Elder Hall by J. H. Maiden, F.L.S., F.C.S., Government Botanist, Sydney ; subject—"Sir Joseph Banks, the Father of Australia."

FRIDAY, JANUARY 11TH—

10 a.m.—Sectional Committees meet.

10.30 a.m. to 1 p.m., and 2 p.m. to 3.30 p.m.—Sections meet for reading of papers, &c.

4 p.m.—Garden party at "Montefiore," by invitation of the Right Honorable Sir Samuel James Way, Bart., P.C., Chief Justice and Lieutenant-Governor of South Australia, and Lady Way.

8 p.m.—Lecture at the Elder Hall by the Rev. George Brown, D.D.; subject—"Some Polynesian and Melanesian Groups and the People who live in them." Illustrated by a large series of lantern slides, many of which are unique.

SATURDAY, JANUARY 12TH—

10.30 a.m.—Second meeting of Council.

2 p.m.—Excursion by drags to National Park. Sir Edwin T. Smith, K.C.M.G., the Chairman of Commissioners of the National Park, will receive the members and provide afternoon tea.

EXCURSIONS.

In addition to the excursions to Mount Lofty and the National Park, already mentioned, the following have been arranged:—

THE OUTER HARBOR.—The Honorable the Premier has kindly invited the members of the Association to pay a visit on the afternoon of Monday, January 14th, to the Outer Harbor, and view the works in course of construction. A special train will be provided to leave Adelaide at 2 p.m. for Port Adelaide, and from thence the s.s. *Governor Musgrave* will convey the party down the river to its mouth. The Government has kindly undertaken to provide afternoon tea on board the steamboat. A return to town will be made, arriving at Adelaide at 6·6 p.m.

KANGAROO ISLAND AND PORT LINCOLN.—The South Australian Government has kindly arranged that the s.s. *Governor Musgrave* shall be at the service of the Association for a three days' trip in the gulfs. It is proposed to visit Hog Bay, Kingscote, Port Lincoln, Sir Joseph Banks Islands, Point Turton, &c., which will afford special facilities for examining the interesting geological, zoological, and botanical features of these localities. As the accommodation is limited, the list must be restricted to scientific specialists. The *Governor Musgrave* will probably leave Port Adelaide on the evening of Monday, January 14th.

INMAN VALLEY, *via* Victor Harbor (87 miles).—Glacial features (Permo-Carb.) and basal beds of the Cambrian series (two days' excursion). January 14th and 15th.

ERRATA ET CORRIGENDA.

Page 523.—Delete footnote reference from third line, and place the same in second line from the top of page, after the word "peak," thus—peak (2).

Page 707.—"Some Aspects of District Nursing." In the authorship of this paper, *instead of* "Lister Foster" *read* "Sister Foster."

INAUGURAL ADDRESS

BY

A. W. HOWITT, C.M.G., D.Sc., F.G.S.,

PRESIDENT.

PERSONAL REMINISCENCES OF CENTRAL AUSTRALIA AND THE BURKE AND WILLS EXPEDITION.

From the times of earliest settlement in New South Wales there was much speculation as to the nature of the interior of this continent, the merest margin of which was known when Lawson, Blaxland, and Wentworth found a practicable track across the Blue Mountains. The vast extent of the "interior," and the many rivers which were found to flow inland, raised geographical questions which were not only investigated by the early explorers, but also led to hypotheses which were still accepted as late as 1858.

In reading the reports of the early explorers of New South Wales it is interesting to study their opinions of the physical geography of the Australian continent.

Before 1831 a convict named Barber—or "the barber"—escaped from custody and lived among the natives, to the northward of Port Macquarie, for some five years. On his voluntary or compulsory return to civilisation he said that a large river, originating in the highlands near Liverpool Plains and the mountains to the northward of them, pursued a north-west course to the sea.

In the years 1831-2 Major Mitchell made an expedition to ascertain the truth of this statement. He reported that the division of the waters falling towards the northern and southern shores of Australia was not, as had been supposed, in the direction of the Liverpool and Warabangle Range, but extended between Cape Byron on the eastern shores towards Dirk Hartog's Island on the west. (*a*)

Another hypothesis was formulated by Mr. Allan Cunningham, who, according to Sturt, entertained Oxley's views of the character

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(*a*) Sturt, "Southern Australia," Vol. I., pp. 160-9.

and nature of the western interior. The quotation by Sturt is, shortly, this—" There is a vast area of depressed country in the interior between the parallels of 34° and 27° which is subject, in periods of prolonged rain, to partial inundation. It would seem, therefore, that either a portion of the distant interior is occupied by a lake of considerable magnitude, or the confluence of rivers—such as the Castlereagh, Gwyder, and Dumeresque—with many more waters form one or more noble rivers, which may flow across the continent to the north and escape to the sea." (*b*)

The belief in an " inland sea " was held fast by Sturt, who says, in the introductory chapter to the work in which he records his expedition into Central Australia—" I am still of opinion that there is more than one sea in the interior of the Australian continent ; but such may not be the case." (*c*)

It seems that in the communication which Sturt sent to Lord Stanley, the Secretary of State, in 1843, he said—" If a line be drawn from lat. 29° 30′ and long. 146° N.W., and another from Mount Arden due north, they will meet a little to the northward of the tropic, and there, I will be bound to say, a fine country will be discovered." He also postulated a range of mountains about the 29th parallel of latitude.

Sir J. Barrow, to whom Sturt's communication was referred, also held the opinion that " about the 28° or 29° the surface rises to a sufficient height to cause a division of the waters, those on the northern side taking a northerly direction and those on the southern side a southerly direction." (*d*)

Even John McDouall Stuart, who was draughtsman in Sturt's party, evidently had this hypothesis in his mind in 1858, on his first expedition to the north-west of South Australia. According to his route-plan he was about at lat. 26° 20′ and long. 134° 15′, and remarks in his journal of July 9th—" We camped on a gum creek, about three miles to the west of the range. My only hope now of cutting Cooper's Creek is on the other side of the range. · · · · If it is not there, it must run to the north-west and form the Glenelg of Captain Grey." (*e*) In his subsequent expeditions he followed up the waters which find their way into Lake Eyre through the Macumba, and it is therefore not surprising that no more is said of Cooper's Creek and the Glenelg.

Such were some of the opinions formed of the physical geography of Central Australia. But there is another opinion which materially

(*b*) Sturt, *op. cit.*, Vol. I., pp. 154-5. (*c*) Sturt, " Central Australia," Vol. 1 , p. 34.
(*d*) Sturt, *op. cit.*, Vol. I., pp. 53-5.
(*e*) " The Journals of John McDouall Stuart " (William Hardman), 1864, p. 18.

affected the exploration of the northern parts of South Australia. This is the hypothesis of a horseshoe Lake Torrens, which persisted to about the year 1858, when a crossing was discovered joining the Far North, as it was then called, to the newly discovered pastoral country in the north-west.

In 1836 Adelaide was founded, and within three years E. J. Eyre made his first attempt to explore the Far-Northern interior. (*f*) His furthest point was a hill which was afterwards named Mount Eyre by Governor Gawler. From the summit of this hill he discovered Lake Torrens. The view northwards was of low, rocky, sandy country, without trees or shrubs or any sort of growth except a few stunted bushes. On the east the view was backed by high, rugged ranges, very barren in appearance, and extending northwards as far as the eye could reach. To the west and north-west appeared a broad, glittering strip of water. This he named Lake Torrens. (*g*)

In 1840 the possibility of an overland communication between South Australia and Western Australia engrossed public opinion in Adelaide. Eyre volunteered to head a party and to pay one-third of its expense. The principal object of the expedition was to open up a practicable stock route. (*h*) Eyre favored a northern route—rather than one to the westward—as being a more promising opening either for the discovery of good country or of an available route across the continent; in fact, this objective of the expedition, if it had been carried out, would have made known the later discoveries of Babbage, Warburton, and Stuart.

The difficulties which Eyre encountered in his repeated endeavors to find a way from the Flinders Range into Central Australia were due in great part to a season of drought. But it was an unfortunate coincidence that in each of his attempts to find a passage he should have struck either Lake Torrens or the lakes which we know now as Lake Eyre, Lake Gregory, and Lake Blanche. Besides these he saw, from the summit of Mount Serle, another, which is Lake Frome.

He considered, and not unnaturally, that they were continuations of one and the same lake, and he thus defines the position in a summary of the facts on which he based that conclusion. He says, referring to the view from Mount Hopeless—" The lake was now visible to the north and to the east, and I had at last ascertained beyond all doubt that its basin, commencing near the head of Spencer's Gulf and following the

(*f*) " Journals of the Expeditions of Discovery into Central Australia in the Years 1840-1: E. J. Eyre, 1845.

(*g*), (*h*) *Op. cit.*, Vol. I., pp. 5-6.

course of Flinders Range (bending round its northern extreme to the southward), constituted those hills—the termination of the island of South Australia, for such I imagine it once to have been." (*i*)

It is therefore to Eyre, whose conclusions were confirmed by the report of Captain Frome in 1842-3, that we must attribute the first development of the idea of the horseshoe Lake Torrens, which would present insurmountable obstacles to any attempt to enter Central Australia from the direction of the Flinders Range.

Eyre, believing it to be impossible to find an overland stock route by way of the north, and after taking into consideration the possibility of reaching Central Australia by following up the Murray and Darling rivers, decided to strike from Mount Arden to Streaky Bay, and then, pushing westward, to see whether some favorable opening of country would enable him to turn northwards. This led him to make one of the most sensational of all the Australian expeditions.

The next expedition which was fitted out to explore Central Australia was that of which Captain Sturt was the originator and leader. Sturt was one of the early explorers who developed the knowledge of the interior of Australia from Sydney. They travelled with bullock teams, horses, convict servants, and, in some cases, with soldiers. Major Mitchell was a typical explorer of this class, and travelled under conditions of climate and surroundings differing altogether from those which the later explorers who attempted to enter Central Australia encountered.

Sturt was the last of the old type, having in his party no less than five bullock-drivers ; but, in fact, he made his remarkable excursions from his depot into Central Australia during a protracted drought with horses only. Considering the new and formidable difficulties which he successfully encountered, Sturt stands pre-eminent among Australian explorers for the care with which he carried out his mission and the general success which attended him under exceptional seasons.

Sturt started from Adelaide on his great expedition to Central Australia on the 12th of August, 1844, and returned to Adelaide on the 19th of January, 1846, after an absence of nearly a year and a half. He decided that as Eyre had proved the existence of a horseshoe Lake Torrens to proceed by following up the Darling River to Williorara (Laidley's Ponds), referred to by Major Mitchell, and thence to gain the chain of hills, by the continuation of which he hoped to be able to reach the good country which he believed to exist near the tropics. He

(*i*) *Op. cit.*, Vol. I., p. 128.

made two excursions westward—the first bringing him to a point from which he could see Mount Serle; the second to Lake Blanche, which he considered to be part of the horseshoe Lake Torrens.

The principal results of his expedition were to make known Cooper's Creek and Eyre's Creek, and to add, as delineated on his map, a Sandy Desert and a Stony Desert to the horseshoe Lake Torrens. His report also strengthened the belief that Central Australia was practically a desert, unfitted for settlement.

For some 10 or 12 years after Sturt's expedition little was done to increase the knowledge of Central Australia, excepting that the country of the Flinders Range had been more or less occupied as runs for cattle or sheep. The desire for new pastoral country, however, led to some small expeditions on the west side of Lake Torrens by Hack, Swindon, and others.

In 1858 Mr. B. H. Babbage was appointed to lead an expedition to explore the country on the western side of Lake Torrens, and also northwards. Previous to this he had been employed in prospecting the settled districts for gold. The results of the explorations of Babbage and his successor (Warburton) were far-reaching, bringing about the ultimate exploration and settlement of Central Australia.

As different opinions have been formed by writers as to their merits and demerits, I shall discuss the questions at issue, and express my own opinions on them. Fuller details will be found in the Appendix. The instructions given to Babbage by the Commissioner of Crown Lands were briefly as follows:—He was to thoroughly explore, as far as practicable, the country lying between the western shore of Lake Torrens and the eastern shore of Lake Gairdner, and thence northwards. He was to survey and map the western shores of Lake Torrens, so as to remove the doubts existing as to the extent, direction, and outline of the lake; in like manner also the shore of Lake Gairdner, and, as correctly as possible, the longitude of all remarkable landmarks, ranges, watercourses, lakes, permanent freshwater springs, and waterholes. This was a large order, since Lake Torrens as then believed to exist would have extended 250 miles from its southern end in a northerly direction. The country between Lake Torrens and Lake Gairdner is some 100 miles in width, and the northern shores of the latter lake run west 100 miles at least. The greater part of this was little better than a desert, and with little or no permanent water. Having performed this service as completely as circumstances would admit of, he was at liberty to push his explorations northerly, to round the northern shores of Lake Torrens easterly, and, as far as possible, to connect the information to be derived from a survey of the northern shores of Lake Torrens with the knowledge of its north-eastern shores as derived from Captain Sturt's explorations. Lake Torrens, as it was then supposed to be, included also Lake Eyre, Lake Gregory, Lake Blanche, Lake Frome, and other lesser intermediary lakes. He examined the country between Lake Torrens and Lake Gairdner, making surveys and carrying out the letter of his instructions, receiving a letter from the Commissioner of Crown Lands, dated the 30th of July, in which there was the following passage:— "Don't let it annoy you if you hear remarks have been made about the slowness of your progress. We fully appreciate your labors and the difficulties you have to contend with."

At this time, however, there seems to have been much dissatisfaction that Babbage had not discovered country suitable for pastoral occupation, not only by the public, to which the press had given voice, but also in Parliament.

Six weeks after that letter, when the Commissioner could not have been in possession of any further information as to Babbage's movements, he wrote to Babbage, strongly censuring him for not carrying out the instructions in the sense in which they were intended. (*k*)

After carefully reading the correspondence printed in the Parliamentary Papers of South Australia and the minutes of the Select Committee (*l*) my opinion is that the strong feeling of dissatisfaction outside, the attacks made upon him by the press, and the adverse feeling in Parliament caused the Government to make a scapegoat of Babbage.

The Government decided to supersede Babbage, and appointed Major Warburton, the then Commissioner of Police, who had done some exploring work, to carry out their intentions.

Babbage, on receiving the letter censuring him, left his camp at the Elizabeth, and proceeded to Stuart's Creek, having received the necessary information from John McDouall Stuart himself. (*m*) From this point he traced down Stuart's Creek to a large lake, which he named Lake Gregory—now known as the Southern Lake Eyre—still thinking that he was on the western side of the great horseshoe, and it was there that Warburton met and superseded him in the command of his party.

(*k*) Parl. Pa., S.A., 1858, No. 25, p. 5, *also* Select Committee Evidence, 877; Parl. Pa., S.A., 1859, No. 21, p. 38.

(*l*) Parl. Pa., S.A., 1859, No. 21, Replies 66-68-72-73.

(*m*) "Journals of John McDouall Stuart," p. 3, June 13th, 1858, footnote.

Having sent Babbage and his party back to Adelaide on the 8th November, Warburton, on the same day, started with two companions and two packhorses to try and cross Lake Torrens to the northern settlements. He did this without difficulty, and on the 15th reached an outstation near Fortress Hill. On the 18th he reported himself to the Government as having arrived at the Mounted Police Station at Angepina, and was in Adelaide on the 10th December, 1858.

We may now ask, was it Babbage who first recognised the independent existence of Lake Gregory, which is now known as the southern part of Lake Eyre, from Lake Torrens, and was it Babbage who first formed the idea of a practicable passage from "Stuart's Country" to the northern settlements, across what was believed to be the horseshoe Lake Torrens?

In 1857 Babbage believed that there was only one passage practicable over Lake Torrens, and to be found near Mount Hopeless, at the north-east side of the horseshoe. (Appendix p. 39.)

In 1858 he wrote—"Either that Lake Torrens does not extend so far northwards as this latitude, viz., 29° 37′, or that, if it does, it must be reduced to a mere inconsiderable channel, and might be readily crossed." In the same letter, however, he says—"My own belief, from what I then and subsequently saw, is that Lake Torrens turns up to Yarrawurta at its northern end, as at its southern it does to the Beda Arm, and that between Yarrawurta and Lake Gregory there are only a few small isolated salt lakes, similar to Lake Phibbs, sufficient, however, to impress Eyre, who, I believe, only saw the country from a distance, with the idea that he saw the loom of a continuous lake." (Appendix p. 39.)

The despatch from which I quote was written from Port Augusta on the 21st of November, when he was on his way to Adelaide, having been superseded in his command on the 5th. On that date he had dissented from Major Warburton as to there being a passage across Lake Torrens, but changed his opinion when the latter told him that Stuart's blackfellow had urged him (Stuart) to return that way. (*n*)

In 1859 Babbage said, in evidence before the Select Committee, in reply to a question by the chairman as to whether the distance of the northern shore of Lake Torrens from Stuart's Creek would be 50 or 60 miles, "No; we here strike Lake Torrens, and I have proved it to be a portion of Lake Gregory." (*o*) The uncertainty of his opinions as to this matter is also shown in what he says as to the view he ob-

(*n*) Appendix, p. 39.

(*o*) Select Committee—Evidence, 456; Appendix, pp. 38-39.

tained from the top of one of the hills of the Hermit Range (?), that to the west and north-west, where he expected to see Lake Torrens, he saw no sign of a lake, nor anything except an extensive plain. As he reached the Hermit Range—by a route on the west side of Lake Torrens—it is manifestly impossible that he could have seen it to the "west and north-west," since, if it existed at all in that latitude, it must have been to the east or north-east of him.

Babbage does not seem to have had a decided opinion on this subject till he gave evidence before the Select Committee, when he said, "Lake Torrens is part of Lake Gregory."

There cannot be any doubt that it was Warburton who first formed an opinion that there was a practicable passage across the supposed horseshoe Lake Torrens, from the newly discovered north-west country. This is shown clearly by the documentary evidence. On the 30th September, when on his way to supersede Babbage, Warburton wrote to Mr. Hamilton in Adelaide, suggesting that Corporal Burrt should be instructed to proceed—about the 20th October—from the Mounted Police Station at Angepina to Mount Nor'-West, and to make a smoke signal, and keep a good lookout himself from the western side of the range. (*p*) This was done, but it was only in the early part of November that Warburton went across—leaving Stuart's Creek on the 8th, arriving at the police station at Angepina on the 17th, and being in Adelaide at the latest on the 10th of December, when he wrote to the Commissioner of Crown Lands. (*q*)

I think that Dr. Gregory has somewhat misunderstood this case, for he says in his late work, "The Dead Heart of Australia," page 259, "As soon as Babbage had gone south, Warburton retreated to the nearest station to wait for the winter, and the expedition did nothing more." No reference is given to the authority for this statement. I have not been able to verify it, but the mistake which Dr. Gregory has made is evidently due to the fact that he has not read the whole of the evidence contained in the Parliamentary Papers, the substance of which I give in the Appendix.

The Commissioner of Crown Lands wrote to Warburton on the 11th December, 1858, as to his criticisms of Babbage. The postscript to the letter asks Warburton as to the reasons which induced him to return from the exploration. Warburton gives his reasons for not "summering out," so that instead of retreating to the nearest station to wait for the winter, he appears to have hurried back to Adelaide.

(*p*) Appendix, p. 37. (*q*) Appendix, p. 39.

I have carefully studied the documentary evidence as to the merits and demerits of both Babbage and Warburton, and have endeavored, to the best of my judgment, to form a true and unbiased opinion, but I must add that it seems very probable that there was a, perhaps, not altogether unreasonable prejudice against Babbage, arising out of the somewhat unpractical manner in which he conducted his expedition when looked at from the point of view of exploration. On the other hand, Warburton, in his report written from the Elizabeth on the 17th of October, criticised Babbage in an uncalled for and objectionable manner, and thus raised a prejudice against himself. (*r*)

The idea of the northern extension of Lake Torrens, including Babbage's Lake Gregory, died hard, for it is evident that Stuart still held it in 1859, for in the journal of his third expedition there is the following passage:—"Friday, 2nd of December, Lake Torrens. Got up at the first peep of day and ascended the sandhill. I fear my conjecture of last night is too true. I can see a small dark line of low land all round the horizon. The line of blue water is very small. So ends Lake Torrens." (*s*) When Stuart wrote this he was where the Neale joins Lake Eyre.

It was in the year 1858 that I first became acquainted with that part of Central Australia of which the expeditions of Eyre, Babbage, Stuart, and Warburton had by degrees made known the difficulties, the dangers, and finally the actual conditions of what, at that time, was known as the "Far North" and the "North-West."

The good season when Warburton explored the North-West country and the extraordinary number of the springs which he discovered, together with other permanent waters, caused him to describe it in most favorable terms. Stuart also reported it as being good, well-watered pastoral country. Thus public opinion became altogether changed. The way into Central Australia was at length opened to the pastoralists, and it was said that—far from being a desert—it was of great promise for pastoral occupation.

I well remember the deep interest which was taken in Victoria in Warburton's discoveries, and it was this which caused my first acquaintance with that part of Central Australia.

One result of this lively interest was that what would now be termed a syndicate was formed in Melbourne, the object of which was to acquire a tract of this "Promised Land" sufficient, as its principal member explained to me, to carry 20,000 head of cattle. A small party, of which I was head, was fitted out for this purpose, and started

(*r*) Appendix, p. 37. (*s*) *Op. cit.*, p. 107.

for Adelaide early in September of 1859, bound for the Far North, as it was then called, our point of departure for the new country in the North-West. The precise time of our departure from Adelaide was fixed indelibly in my memory by the fact that I saw Tolmer's expedition start a few days before, ostensibly to cross the continent. I also remember, in this connection, that we were told of two alternative routes—one being by way of Port Augusta, Beda, and the Pernatty Lagoon, to Stuart's Creek—in fact the way by which Babbage, Stuart, and Warburton all went to the newly discovered country ; the other was by the way of the Flinders Range, and then to strike across from Fortress Hill over the dry land lying between Lake Torrens and the Lake Gregory of Babbage. After carefully considering all the information which we had obtained we decided on the latter route, because in the dry season then prevailing through the North it was quite uncertain whether the former route was practicable. In this, as it turned out, we were well advised, for when we returned to Adelaide from our trip we learned that Tolmer's expedition had proved to be, as indeed his own account of it shows, a complete fiasco. (*t*)

Our route from Adelaide to about Mount Remarkable lay mainly through a beautiful pastoral country, in the flush of spring, after bountiful rains ; but beyond that little (if any) rain appeared to have fallen for many months—if not years ; in fact, we rode into the Flinders Range country during a protracted drought.

To us, coming from Victoria, where the mountains are forest clad, the scenery of the Flinders Range was both novel and unexpected. I well remember how I was struck by the weird appearance of some of these mountains. Brown, rocky masses, devoid of timber, with precipitous cliffs, stratified in places, loomed through the desert haze of a hot north wind. Recollections of such mountain masses were brought vividly to mind when I saw similar bare rugged mountains, through such a desert haze, when passing through the Gulf of Suez. The atmosphere was often so clear that it was difficult to estimate distance ; while at other times mirage produced such fantastic effects that one felt as if in an enchanted land.

What struck me, perhaps, as much as anything were the "gaps," or ravines, often with precipitous rocky sides several hundred feet in height. Such gaps are not only the channels of watercourses, but in places serve as roads, leading from plains on the one side to plains on the other side of a range. It was strange to us to see, where the tilted strata formed the bed of the channel in such a ravine, that water came

(*t*) "Reminiscences, Alexander Tolmer, 1882."

to the surface and then disappeared in the sand and gravel deposits beyond. These pools were very welcome to us in that thirsty land, and where there were sandy places near these pools rushes were growing, forming almost the only green vegetation which we saw. Everywhere else was barren and bare of grass, and in some places of feed bushes also. In places we came to plains lying between hills which were desolate wastes, across which wind-driven columns of dust stalked, reminding one of the Ghin in the Arabian Nights' story of a fisherman who dredged up a casket from the sea.

The country as we saw it might have been described, in the language used by Eyre, as desolate and barren; but when we passed over it we did not find even the plentiful grass which he speaks of here and there, because, the country being stocked, the cattle and sheep had eaten off every blade within reach of the watering-places. One settler, talking about the drought, told me that there had not been any rain to speak of for nearly three years, and that some of his cattle came in from a distance of four or five miles for a drink. All the stock we saw told by their appearance a sorry tale of starvation.

Our horses fared badly in passing through the drought-stricken mountains, but we hoped for better times when we reached the newly discovered Promised Land in the north-west.

Such were the impressions on our minds by seeing this country during a drought, and not in one of the seasons of plenty which also occur at times.

We had a sketch plan of the country which Parry had traversed the year before, and showing the various points we had to make, the first being Hermit Hill and Finnis Springs.

In time we worked our way to Strangways Springs, from which we made further excursions and inspected a good deal of country. All was new to us Victorians: the wide plains, some of soft soil, others so stony that when travelling at night those who were behind could see where the leading man was by the sparks his horse struck out of the stones at each step. It was all novelty to us: the sandhill country, with grass and bushes; the gum creeks, some with fresh, but more with salt, water; the rugged hills, much seamed by sharp-edged slates; then the distant table-topped hills, from which we continually saw rising what we took to be smoke signals. It was an interesting experience in a wonderful country, the mound springs being the greatest wonder of all; but it was not the kind of country that was wanted.

Our return was uneventful. We now knew the country, and made a short cut from Strangways Springs across some very rough and stony country to the Shamrock Pool of Parry, which was about 50 miles from Fortress Hill. In time, and with the exercise of much care, we got our horses through the droughty country of the Flinders Range, and finally finished our ride of some 1,500 miles with the same horses at Mount Sturgeon, in Victoria.

Such was my apprenticeship in Central Australia, which in the near future was to stand me in good stead in a far more important expedition.

The renewal of interest in exploration of the unknown interior of Australia culminated in the fitting out of the Burke and Wills Expedition in 1860. An offer, made by Mr. Ambrose Kyte, of £1,000, on the condition that £2,000 should be given by the public for the purpose of exploring, initiated the scheme. The matter was taken up by the Royal Society. The Government promised assistance, and the Exploration Committee was formed, consisting, I believe, of 21 members, with whom rested the responsibility of organising the expedition and selecting its leader. Their choice fell upon Robert O'Hara Burke, and I assume they also selected the other members of the party. I was not in Melbourne at that time, being engaged in Gippsland as leader of a party in prospecting the mountainous country in which the Mitchell River takes its rise. From time to time, as the Melbourne papers reached our mountain camp, I read of the organisation of the party, of its start from Melbourne, and the difficulties met with in conveying its great outfit to Menindie. Then came the news of dissensions in the party, and of the resignation of Landells.

Naturally I felt a lively interest in this expedition, considering the facts by the light of my experience of the year before. I still clearly remember the day when, having learned from the papers received that Burke had divided his party at Menindie, leaving the greater part of his equipment there and pushing northwards himself with a small party and a slight outfit, I felt a strong foreboding of future misfortune for Burke and his companions. My party were all interested in the news, and I remember talking about it with some of the men by the camp fire in the evening. I said that I felt that Burke had no idea of what was before him in Central Australia, and, half in a joking mood, I said, "Who knows that they may not lose themselves? If so, then I might have to go and look for them." Two of my hearers—Alexander Aitkin and Weston Phillips—then said, "If you go, take us with you." These two did accompany me in my search for Burke and his companions, and proved themselves to be thoroughly trustworthy in every way.

It is easy to be wise after the event; but before I recount my reminiscences of the search for Burke's party and the finding of King it will be well to consider some circumstances connected with the expedition which have always struck me as being of momentous importance, either having led to the series of disasters which attended this party or being of such a nature as to have contributed to the final tragedy.

Reading of the start of the expedition, I was struck by the great amount of the outfit which had to be conveyed with it. Then I read of the dissensions in the party, the consequence of which was the resignations of Landells and of Dr. Beckler, though the latter withdrew his, I think, before Burke left Menindie. No expedition ever set out to explore the interior of Australia with such a lavish supply of outfit, equipment, and stores as this. I wondered by whom it had been selected, and I have since looked into the matter, as far as the written and printed evidence has been available.

It seems that the articles deemed necessary for the expedition were suggested first by Burke, (*u*) being provisions, forage for camels and horses, stores, medicines (including veterinary medicines), services, horses, and pack-saddles. It seems that the term " services " included the wagons. (*v*) The provisions were calculated to last for 18 months, and, to speak precisely, the total cost of all the items enumerated was £4,585 2s. 10d.

The provisions were selected by a sub-committee working with Burke (*v*). The wagons were supplied as being likely to be of great use in carrying stores from Menindie to Cooper's Creek. One very large wagon was fitted up as a boat for crossing rivers. (*w*) The fact that a boat carriage was taken reminds one of the equipment of the old type of exploring expeditions. But the climatic and physical conditions under which the old explorers travelled were quite different to those to be met with in Central Australia. Sturt started with bullock teams and drays; but he did the most important part of his great journey—namely, from Fort Grey to Eyre's Creek—with horses.

The available means of conveyance were insufficient for the amount to be carried. Wagons and teams were therefore hired, and yet there were constant delays, so that, before reaching Menindie, Burke found his progress impeded, and this seems to be one of the causes which gave rise to the friction between himself and Landells.

The difficulties and delays met with in conveying the stores—using that term in its widest sense—may be estimated when one con-

(*u*) Report of the Burke and Wills Commission, 1861-2, question 10.

(*v*) *Op. cit.*, question 44. (*w*) *Op. cit.*, question 81.

siders that the total weight to be carried is said to have been 21 tons. (*x*) This had to be conveyed from Melbourne to Menindie—a distance of some 500 miles—before the real business of exploration commenced. Much of the loading, and also of the equipment, was left on the way up, showing clearly that the means of conveyance were insufficient, even when there was a road of some kind.

This was the first expedition which used camels as one of the principal means of carriage. Once before a camel was used by J. A. Horrocks, one of the earlier explorers of the country on either side of the head of Spencer Gulf. In the year 1846 he set out to explore north-westward from the further side of Lake Torrens, but he was accidentally shot while loading his camel. (*y*)

In Burke's party the camels caused some trouble, for Landells carried rum for them, and it seems that the shearers at McPherson's station got drunk on some of this rum, and Burke insisted on it being left behind, as it endangered the sobriety of his men.

From what I saw of the camels subsequently, and of the "sepoys" (as they were called) who looked after them, I came to the conclusion that any man who was good with horses could manage camels. Therefore, when on my relief expedition, I sent the "sepoys" back to Melbourne, and placed the camels under the charge of Brahé, who did the work to my complete satisfaction. When I received the camels they were suffering from scab, but were soon cured by the use of creosote.

On my way to Menindie, when setting out with the relief expedition, I came across some of the equipment and stores which had been left behind at Balranald and at Tarcoola Station, on the Darling River. Among these things were two of the wagons, one of which carried the boat; six sets of wagon harness; a spare wagon axle; and two spare hind wagon wheels. The other things seemed to be an assortment of the tools, implements, and general equipment of the party. At Menindie I found a still larger assortment, some of which, in my opinion, need never have been taken, while there were other things left behind which would certainly be required and could not be obtained when wanted beyond the settlements.

Burke's instructions were explicit. He was to "form a depot of provisions and stores at Cooper's Creek, and to make arrangements for keeping open a communication to the Darling or by way of the South Australian police at Mount Serle."

(*x*) J. E. T-Woods' "History of Discovery and Exploration of Australia," Vol. II., p. 39.

(*y*) Woods, *op. cit.*, Vol. II., p. 350.

Without doubt he departed from his instructions by his hasty advance to Cooper's Creek without taking the necessary steps to ensure that the stores and equipment, which had been left behind, were brought on to Menindie. Burke's disregard of this part of his instructions seems to show that he was impatient of delay, and thus neglected those precautions which, in compliance with his instructions, would have provided against mishap. More than this: had he waited at Cooper's Creek until his stores had been brought there, and meanwhile opened up a line of communication with the northern settlements of South Australia, he would have obtained a practicable route at all times by which to communicate with the committee and also to procure the supplies necessary for his party. Later on, when speaking of the attempt made by Burke, Wills, and King to reach Mount Hopeless, I shall have occasion to refer again to this.

The haste with which Burke pushed on—first to Menindie and then to Cooper's Creek, leaving the rest of his party and the great bulk of his equipment to follow as best it could—may, however, as I think, be explained, as well as the rush from Cooper's Creek to Carpentaria. The evidence of Sir William Stawell, given before the Royal Commission, (*z*) was that Burke "attended all the meetings, and heard the deliberations. · · · · If Carpentaria could not be reached, it was not considered advisable to attempt exploration in a more north-westerly direction so as to reach the Victoria. This, however, the committee did not deem expedient to press, as it was supposed that Stuart had then, or would shortly have, discovered the route to the Victoria."

Assuming, therefore, as I think we may, that Burke knew what Stuart was likely to carry out, it is then a reasonable conjecture that the haste with which he pushed forward was to enable him to cross the continent first, for it is reported he said that "provided he crossed the continent he did not care if he had only one shirt to his back when his journey ended." (*a*)

This impetuosity has always appeared to me to have been one of the most serious of Burke's errors of judgment, and to have had the most serious results. Amongst other consequences it led to the appointment of Wright—as it seems to me, without sufficient inquiry as to his qualifications—who was to bring the rest of the party and the remainder of the stores and equipment to Cooper's Creek. Wright, as Burke intended and as the former promised, should have left Menindie on his journey as soon as possible after his return there in

(*z*) *Op. cit.*, question 1583. (*a*) Woods, *op. cit.*, Vol. II., p. 354.

order to carry the stores thence to Cooper's Creek. But he remained there from the 5th November until the 27th or 29th of the following January. (*b*) In this he totally disregarded Burke's instructions, as well as his promise to Burke that he would take the remainder of the party out as soon as he returned. (*c*) The reasons for this otherwise unaccountable—one might even say criminal—neglect of duty appear to have been that some cheques of Burke's had been dishonored, and Wright would not move until his appointment had been confirmed and he had someone to fall back upon for his pay. (*d*) Finally, when he reached Bulloo, he remained there; partly because some of his party were ill, but perhaps mainly because, as he said, it would be difficult to find Cooper's Creek, as he had no tracks to guide him and no natives to take him there. (*e*) Wright was evidently incompetent, and Burke made a mistake in appointing him to so important a position.

Another mistake made by Burke was to again divide his party when he started from Cooper's Creek, apparently intending to make a preliminary excursion to Eyre's Creek, which might extend to a three or four months' absence. I draw this inference from the evidence of Brahé, McDonough, Patten, and King, and also from what the latter said when I found him at Cooper's Creek. (*f*) It seems clear that when Burke left the depot he told them he intended to go to Eyre's Creek, and to try to go to Carpentaria if he could do so without incurring any risk; that he was bound to be back in three months, as the provisions he took with him were scarcely sufficient for twelve weeks. That he had determined to try for Carpentaria is shown by what he said, according to King, after they left Cooper's Creek: that he would not turn his face backwards till he had reached the sea. This can be easily understood if one considers that they found practically no difficulties on their march to the Gulf of Carpentaria. The season was favorable, and if the committee's instructions had been followed the journey across the continent and the return to Menindie might have been made without any loss of camels or horses, and also without the lamentable loss of life caused by the "forlorn hope" led by Burke, which resulted, certainly, in success, but also in the death of three of the four who formed this gallant little party.

The first of the small party of four to succumb to the hardships of the return journey was Grey. He was thought to be shamming, but his

(*b*) Wright, in his evidence before the Commission, said the 27th; elsewhere, the date given is the 29th. (*c*) Evidence, 1235.

(*d*) Evidence, 543, 560, 561, 583, 1312. (*e*) Evidence of Dr. Beckler, 1912.

(*f*) Commission's Report—Evidence, 175, 222, 320, 447, 697.

physical breakdown was only too true, for he died at a place called Andaginni, about 40 miles from Brierili, where Wills died. It was the delay of one day spent there for the purpose of burying their deceased comrade that caused them to arrive at the depot in the afternoon of the day on which Brahé started on his return journey.

Andaginni was visited by McKinlay, who misunderstood the native guide, and believed that Burke and his companions had been killed by the blacks, and therefore named this place Lake Massacre.

My experience, subsequently, in going to the Diamantina from my depot showed me how easily the journey across to Carpentaria might be made. McKinlay's most successful journey from the northern settlements of South Australia to the Gulf and thence to Queensland is also proof positive of what Burke and Wills might have done had the instructions of the committee been properly carried out.

When Burke returned to the depot he buried a letter in the cache, from which he had removed the provisions which Brahé left there. (*h*) According to King, the cache was covered up as it was before they opened it, and with horse and camel dung spread over it. The necessity of leaving some mark to show that they had been there was overlooked. According to King, they thought that the word "Dig" would answer their purpose as well as it had Brahé's, who put it there. (*h*) This was a fatal error, and one which bore bitter fruit.

In Burke's opinion the provisions found in the cache would last them 40 days; and here occurs the final mistake, namely, the choice of the route by Mount Hopeless to the northern settlements of South Australia instead of their own track to the Darling, of which they knew all the stages and on which they would meet any party bringing them help. But in considering this matter it must be remembered that they were all in the last stage of exhaustion. Grey had died before reaching Cooper's Creek, and they were reduced to so low a state when they arrived at the depot that, as King said, it was as much as one of them could do to crawl to the side of the creek for a billy of water. (*i*) Had they decided to proceed to Menindie, and allowing 10 days to rest and recuperate at the depot, they would, according to Burke's calculations, (*j*) have had 30 days' provisions. Their journey up from Menindie to the depot took 25 days, counting the camps; but it is more than doubtful whether they, in the state in which they and their two camels were, could have done the back journey in that time.

(*h*) Report Royal Commission—Evidence, 1024, 1025, 1027, 1028, 1031.

(*i*) *Op. cit.*, 1032. (*j*) Evidence, 1042.

The journey from the depot to Petamorra, the cattle station, which is a little beyond Mount Hopeless, took me 14 days, with horses and camels in good working condition; but in the state in which Burke, Wills, and King were it would have required at least twice that time for them to get there, even if they had no hindrance on the way. According to the account given by Wills, they wandered about for 29 days (*k*) endeavoring to find a way out of their difficulties, and at last returned to die of starvation, Burke at Innamincka and Wills at Brierili—two heroes who sacrificed their lives to the ultimate benefit of their country.

I speak with some feelings of certainty as to the difficulties they would probably have had to meet on the route to Mount Hopeless, for the first thing I did after fixing my depot on my second expedition was to open up a line of communication with the northern settlements in South Australia. As there did not seem to have been any rain, I went provided for the worst. I took nine camels, which, in addition to the necessary food and personal requirements of the party of five, had all our water-bags full, the load being as much as they could carry, the smaller camels being obliged, in some places, to ascend the steeper sandridges on their knees. For the first three days from the depot we travelled over earthy plains and sandridges without any signs of grass. In many parts the dead bushes on the tops of the ridges were, so to say, standing on tiptoe, the sand having been blown away from them. Fortunately, however, summer rains had fallen at Strzelecki Creek, and thence onwards to Petamorra I had plenty of water. Before these summer rains the country was probably as bare and waterless as that we crossed during the first three days, and it would, under such conditions, have been impossible for Burke and his companions to have made their way through.

My return journey to the depot was made by following up the course of Cooper's Creek, and thus having permanent waters all the way.

When one considers all the circumstances which contributed to the disastrous ending of the Burke and Wills Expedition, one might well call them a series of misfortunes. But in considering them and the causes which produced them, I am of the same opinion as the Royal Commission, that the party "was most injudiciously divided at Menindie. It was an error of judgment on the part of Mr. Burke to

(*k*) "Andrew Jackson, Robert O'Hara Burke, and the Australian Exploration Expedition of 1860," p. 122, "Journal of the Trip from Cooper's Creek towards Adelaide, April, 1861."

appoint Mr. Wright to an important command · · · · without a previous knowledge of him." (*l*) The greatest regret must be felt that Brahé should have happened to leave on the morning of the day on which Burke returned. But there is some doubt whether Burke expected, when he left the depot, to go further than Eyre's Creek, or to be absent longer than three months. As he did not give any instructions in writing to Brahé when he left, it is quite possible that he did not remember all that passed in conversation with those he left behind. It seems to me that Brahé has been blamed too strongly for what was an unfortunate mischance.

Taking everything into consideration, I think that the unfortunate occurrence of mischances was due, primarily, to errors of judgment on the part of Burke, and that these arose because he did not possess that kind of knowledge which is absolutely necessary to enable even the bravest and most determined man to be the successful leader of such an expedition as was committed to his charge. It is evident to me that at no time was there the necessary means of conveying the 21 tons of equipment and stores from Menindie to Cooper's Creek. This could only have been done if an organised train of packhorses or camels, or both, had been arranged, and the most important parts of the loading conveyed there first, leaving such things as spare supplies, duplicates, &c., to the last. But such an organised service neither Burke nor anyone else in the party was, so far as I know, competent to arrange. Unfortunately, Burke had no experience of the work, and Wills—the best man Burke had, a man of noble character, who seems to have placed duty first—had not had the special bush training which would have enabled him to see what course would be necessary, and also to speak with the authority given by knowledge. Besides this, his duties were sufficient to fill the whole of his time, for he was the only one of the party who could take the necessary observations. It was he who really took Burke across the continent and brought him back to Cooper's Creek. Without Wills, Burke would have been absolutely helpless.

It is nearly half a century since these events took place, and they may now be considered as a matter of history calmly and without any bias one way or the other. I have said that Burke on several occasions showed a fatal error of judgment. If he had followed his instructions, and established a depot of supplies at Cooper's Creek, he might have crossed to Carpentaria and returned without difficulty. But there seems to have been a complete change in his plans after the expedition

(*l*) Royal Commission, Report, par. 1.

left Melbourne. The enormous outfit was practically abandoned, some of it on the road up, the greater part at Menindie; and Burke hastened on with seven of his party, 15 horses, and 16 camels, conveying stores calculated to last six months. There need not have been the fiasco of Wright's attempt to take the remainder of the party and some of the stores to Cooper's Creek, nor the terrible loss of life which followed. There would not have been the necessity for search parties to be sent out to seek for Burke and his companions, nor the very great expenditure which was thereby incurred by the several colonies. I feel with regret that this was brought about by the unwise haste with which Burke pushed on ahead of his party and its supplies, apparently determined to cross the continent before Stuart.

As time went on and no word came from Burke great uneasiness was felt in Victoria, and on the 18th of June, 1861, the Exploration Committee decided to send out a party in search of the expedition. I was chosen for the important position of leader, and, with three companions, started by Cobb's coach for Swan Hill, where I was to purchase the necessary horses and otherwise complete my outfit. But my plans were altered by meeting Brahé at the Loddon, on his way to Melbourne to report the arrival at Menindie of Wright, and also to report that Burke had left Cooper's Creek, with Wills, Grey, and King, on the 16th December.

In view of the serious position indicated by this information, no time was lost in reorganising my party, so that on the 14th of July I again started, with an increased party and outfit. I was to purchase horses at Swan Hill, to procure the necessary supplies at Menindie for a five months' absence, to follow Burke's track, and ascertain, if possible, what had become of him and his three companions.

Menindie, our point of departure from civilisation, was at that time an infant among townships. It consisted mainly of a public-house, a store, and a lockup. It was a place on the frontier of settlement, and, apart from the pastoral interest localised in sheep and cattle runs on the River Darling, essentially belonged to exploration. As I wrote at that time, it was a place where parties were fitted out for trips in search of country for new runs, and the principal conversation was about who was out and who had come in, what country they had seen, what country they had taken up, the new waters discovered, and especially what parties had had "brushes with the niggers." The conduct and the qualifications of explorers were discussed in a critical manner by the bearded conclave which assembled at the public-house. The people about had a thorough veteran bushman look, and beards, pipes, and cabbage-tree hats were the fashionable wear. I remember that a favorite way of passing the time was to criticise the stores and provisions offered at the store for the use of explorers; and on one occasion some dried beef was talked over, smelt, and tasted with the air of connoisseurs.

Although Menindie cannot be included in Central Australia, it was on the verge of it when I started on my search for Burke and Wills and their comrades, because it was then the outside settlement, beyond which was the unknown interior. When I say "unknown" I must qualify that term to some extent by saying that all known of it was from Burke's despatch from Torowotto; from Gregory's account of his expedition down the Barcoo, in search of Leichhardt; and the more distant expedition of Sturt, who discovered Cooper's Creek, the Great Stony Desert, and Eyre's Creek.

My personal reminiscences of Central Australia in connection with the Burke and Wills Expedition practically commence with the start of my party from Menindie. It is not necessary to say more of the country passed over in the first 13 days than that we were following Burke's track, as delineated upon Wills's route plan. The horses were becoming accustomed to the camels, and everything worked satisfactorily. On the fourteenth day we left Burke's track to avoid a long *detour* to the north-east before it turned north-westerly to strike Cooper's Creek. We were, therefore, in new country, much to the eastward of Sturt's route from Fort Grey.

There is a passage in Wills's report of the 15th December, 1860, which is worth noting here. In speaking of the country passed over between Torowotto and Cooper's Creek he mentions that they found the tracks of drays—four distinct tracks, two of which appeared to be those of heavy horse drays, the other two might have been made by light ones or spring carts—and he says they were unable to make out the tracks of the horses and cattle. This was near Burke's Camp 54 (that is, according to the route plan prepared by Wills), on a creek, apparently a tributary of the Bulloo River. Wills attributes these tracks to De Rinsey, and adds, "who, I believe, had some drays with him, and reported that he had been somewhere in this direction." (*m*) I mention this because we also found dray tracks, or what were taken for them. They looked like the tracks of a bullock-dray and a spring cart, which had been travelling when the ground was soft, after rain. We also were unable to make out "the tracks of the horses and cattle," and this caused me to follow them for some distance along the flats

(*m*) Andrew Jackson, *op. cit.*, pp. 44-5.

bordering the creek. The "bullock-dray track" finally ceased at the edge of a steep bank at the creek. The other track, when we traced it further, ended at a log and at two stumps of broken branches. It was thus evident that these seeming tracks were made by logs carried across the flats by flood waters, and the absence of tracks of cattle or horses, which should have been visible if the drays had crossed in wet weather, was accounted for. It possibly also accounts for the fact that Burke's party could not find the cattle or horse tracks. I was pleased to be able to solve this puzzle, because one of my party—Sampson, an "overlander" of great experience—firmly maintained that they were dray tracks until he saw the logs at the end of the "wheel" tracks.

The journey for the next three days was uneventful, excepting that we found a creek in our way running bank and bank. It kept us back for a day, which we spent in getting our equipment and stores across by swinging them with a rope fastened to a tree growing on a small island, and in crossing our horses and camels. The latter positively refused to go into the water, but were circumvented by making them sit down on the bank, and then as they rose up and were off their balance we toppled them into the stream and hauled them across. A more helpless beast under such circumstances I never saw, and as they waded through the deep mud on the other side they drew their feet out of it with a sound like drawing a gigantic cork.

On the fourth morning we ascended stony hills, which Sturt saw from a distance and named the Stokes Range. On the side we ascended the range sloped gently upwards, the ground being covered with sharp fragments of flinty stone. Numerous deep gorges intersected the range lying across our course and making travelling difficult, while the half-dead mulga made it worse by tearing our packs and clothes. We camped at the edge of a deep, scrubby gorge, with plenty of dry grass, but no water.

On the following morning we had difficulty in crossing the gorge, which was overgrown with mulga, interspersed with numerous great blocks of stone. For several hours we forced our way over similar country, including two dry creeks, flanked by precipitous stony ranges. It was a happy chance that none of the horses or camels as they floundered about among the blocks of stone did not disable themselves. I could not believe that camels could have carried their loads up and down such places as we crossed that day. Then we ascended to a stony tableland, almost devoid of vegetation, from which we could see some remarkable flat-topped hills, the characteristic desert sandstone of Central Australia. At noon we suddenly came out at the edge of a bluff overlooking the Cooper's Creek country. It took an hour to descend from it to a wide basin of open country some 700ft. or 800ft. below—a descent that was bad for horses and worse for camels. The flats were literally paved with angular and rounded fragments of loose stone. We slowly picked our way over this kind of ground for several hours, the horses becoming fagged and some very footsore, and the camels tired. It had been a heavy day, with a hot sun and no water. We camped without any, and with very little feed.

From a steep square-topped hill near the camp I had an extensive view to the north-west. The ranges terminated a few miles beyond, succeeded by open plains. Beyond them I could see sandhills extending to the horizon, ridge beyond ridge, scrub-covered, with here and there a tree, until the outlines were lost in the haze of distance. Here was the mysterious vastness of the desert interior, which held, somewhere, the secret which it was our mission to discover.

For some reason, perhaps because of their contrast, this view and another which I had seen nearly twelve months before in the Gippsland Alps have impressed themselves indelibly on my memory. Then, as I ascended a mountain summit on the Dargo River, a wonderful, far-stretching view burst upon me. For many miles the snowy plains stretched northwards to where, on the horizon, the chain of the Bogong Mountains rose, lustrous in their white mantle of snow, resplendently pure, under the cloudless deep blue of the winter sky in the Australian Alps. This came before me mentally as I stood on that hill and beheld its contrast on our first approach to Cooper's Creek.

We made an early start next morning, for the horses were close at hand, not having gone far among the rough rocks and stones, and they looked very much cut up with their hard work and no water.

The plains to which the small valley we had camped in led us were so stony that we had to travel slowly for some hours, traversing the most stony wilderness imaginable. When we reached the sandhills the travelling became good, and we had our first interview with the native inhabitants. We came across a number at a dry watercourse who all ran away excepting an old man and woman and one or two others, who waited till we came up. They were in a very excited state, waving boughs and shouting. My blackboys could not understand them, and it was only by pantomime that I got the old man to understand that we wanted water and could persuade him to guide us. As I walked beside him my horse suddenly neighed in his ear, whereupon he climbed up a tree and remained there, at the top, enshrouded in the leaves until we left him. Proceeding in the direction in which he had pointed for water, we came into the bounds of the rainfall, and one of the packhorses, who kept persistently at the outside of the party, on the lookout for water, found a narrow channel full of it before we came up to it. Here we remained, and, with thought for the future, excavated a small tank, into which we led the water from some claypans. Here our difficulties were over, because it rained heavily in the night, leaving a supply of water ahead of us on the way next day, so that without difficulty we struck Cooper's Creek about half a mile above Camp 60 of Burke, which we had steered for, and which Mr. Welch, our surveyor, had cleverly hit off. (*n*)

From Burke's 60th camp we followed the course of Cooper's Creek, passing his first depot and then coming to his second depot, Fort Wills, which was three miles beyond my Camp 30. The country we crossed consisted in great part of earthy plains, cracked and fissured in all directions, and often without any trace of vegetation; while in other places the dried stalks of plants, higher than a horse, showed what the country would be like after floods. This was varied by occasional sandhills or stony ridges. Where we camped the night before reaching Burke's second depot there was a fine sheet of water between rocky banks.

Among the many questions which I put to Brahé about Cooper's Creek on our way up there was one the reply to which surprised me. I asked him about fish and fishing, and he told me that, although he had seen the blacks with fish, none of the party had caught any, excepting when they bailed out a small hole and caught a few small ones. When we camped at that fine reach of water with rocky banks I felt certain that there must be fish in it, and as soon as I had unsaddled my horse and let him go I got out a fishing line, and, having shot one of the ever-present crows, baited my hook and dropped it into the water. I immediately caught a good-sized fish, and then others of the party became fishermen, with much success. We camped there again on our way back to Menindie, and a large haul of fish was caught. So far as I remember it was over a hundredweight. It must be remembered that this "Fish Pond," as we called the place, was only three miles from Burke's depot. Poor Wills, in one of the last pathetic entries in his journal, speaks of the craving which he felt for fat and sugar. These fish, which occur in all the waters at Cooper's Creek, are extraordinarily

(*n*) Brahé brought down with him the field-books of Wills up to the time when Burke started northward. We therefore knew where to look for the Camp 60 of Burke.

fat, and supplied us with much excellent food, while the fat was used for many purposes. I never could understand how it was that Burke, Wills, and King did not catch fish, for King had hooks when we found him.

The only way in which I can account for the inability of Burke, Wills, and King to do more for their sustenance than collect nardoo is that not one of them had bush experience or knowledge of the food which the natives procured. Among many other sources of supply there were fish, crayfish (yabbies), and mussels in the waterholes, and plenty of pigeons.

While we were at the depot Brahé pointed out the place where he made the cache and the tree on which he cut the words and figures "Dig. 21 April, 1861." I carefully examined the place, and Brahé said, in reply to my questions, that everything was just as he left it, the "plant" untouched, and nothing removed of the useless things left but a piece of leather. I noticed that there were the ashes of three small fires, which appeared to show that the blacks had been there, but the loose, sandy soil was so run over by the tracks of birds and small animals that no traces of footprints could be seen. It seems, however, that the three small fires were made by Burke, Wills, and King individually. I was surprised that the blacks had not found the cache, because of the self-evident fact that something was buried there. As we were supplied with stores for fully five months, there was no need for the things which Brahé had buried there, and we went on, thus leaving, for the time, the answer to the question which we had come so far to solve.

It has been asked why Burke did not add something to the inscription on the tree when he left to try and get to Mount Hopeless. The explanation is to be found in King's evidence before the Royal Commission: (*o*) "We did not expect the party to return; we thought the word 'dig' would answer our purpose as well as it would theirs." This was a mistake, because Brahé was with me; otherwise the word "dig" would have at once suggested my doing so. From this place we had to look out for tracks, and in a few miles we found the track of a single camel going eastward. That evening we camped about a quarter of a mile below the place to which Brahé accompanied Burke and the advance party on their outward trip. During the day we had again seen the track of a camel, and where we were camped we saw camel droppings—where Brahé said he was sure Burke's camels had not been on his outward journey. On Burke's journey outwards the

(*o*) *Op. cit.*, Evidence, 1032.

camels were led, and those at the depot were herded. These tracks were, therefore, puzzling, and I thought it possible that one of Burke's camels had got away and returned.

The next morning I went ahead of the party with one of my two blackboys, to try and pick up Burke's tracks. We were now well beyond the stony hills which had, in a sense, confined the river. The country was opening up evidently towards the north. I thought that Wills might have seen an opportunity for making a departure for Eyre's Creek, for we were, I thought, approaching that part of the creek where Sturt had crossed on his northern journey. While I went on ahead I left Mr. Welch in charge, to follow down the river with the party.

At the lower end of a large reach of water I saw where a horse had been running recently, and for some time. At the same place I found the handle of a claspknife. I then struck out a little south of the creek, being on that side, and again found the same track of a single camel, and camel dung, apparently some months old. The track was, as before, going eastward. I then left the blackboy to follow down the creek, and went myself to the other side of the channel, striking out to the north over some sandy country, where I might have a better chance of finding tracks than along the river or over the flats near it—where they are soon obliterated by birds and animals running about—or on the paths used by the blacks in travelling from one point to another. After about five miles without seeing any tracks, I turned towards the river, and came to it near the lower end of a very large sheet of water, and where I saw, on the opposite side of the dry channel, a number of native huts. I crossed, and at a little distance again found the same track of a single camel going up stream. At the same time I saw a blackfellow and a woman, who had been picking up sticks for firewood. The latter hastened off to the camp, while the former remained, holding the firewood on his head with one hand, and with the other making a number of gestures and signs. He was very excited, shouting out—what I could not understand—holding up one hand with some fingers extended, and then patting the ground, then again holding up his hand, and waving it towards the camp. As I was some little distance from him, I rode nearer, upon which he receded, and as I again came nearer to him he went off in a hurry to his camp. As I could not make out what he wanted, and as I had not seen my party for a considerable time, I rode up the left bank for some distance, following the camel track, and then crossed to the other side, where I cut the track of the party. Following it I then saw that they had halted where I had crossed, and as I came in sight the blackboys left them and rode toward me. As we met the elder one said, "Find em whitefella; two fella dead boy and one fella livo." Hastening on and crossing over to the native camp, I found John King sitting in one of the wurleys. He was a melancholy object, and hardly to be distinguished as a civilised being by the remnants of the clothes on him. He was not only very weak, but much overcome by our arrival, and it was at first difficult to make out what he said. It seemed that we were expected, for two of the young blacks who came to our first camp on Cooper's Creek travelled down to bring the news of white men having come.

It was Mr. Welch who, riding in the lead, first saw a strange figure sitting on the bank and said, "Who are you?" To which the reply was, "John King, the last survivor of Burke's party. Thank God, I am saved!"

I was pleased that this part of the rescue fell to Mr. Welch's share, for he was a pleasant companion, a good comrade, and a man whom I was sincerely sorry to part with when I was starting on my second expedition.

We remained in camp where we found King for ten days, to enable him to recover strength, and even in two days there was a marked change in his appearance for the better. He had plenty to eat, and sugar and fat seemed what he craved for most. I may anticipate by saying that by the time we reached Menindie the clothes which I found for him became too small, and had to be let out. During this time there were several important matters to attend to. While he was too weak to go far from the camp I employed the time in writing down all that he could tell me about their journey to the gulf and the return to the depot. This is what has been printed as "King's Narrative." Then there were two melancholy duties, namely, to go to the places where Burke and Wills died, and to see that their remains were decently interred. I first went to Brierili, where Wills died while King was away with Burke on his last march. I took with me Brahé, Welch, Dr. Wheeler, and King. Brierili is about seven miles lower down than Goyapidri, where we found King and were camped, and in going there we crossed the branch which leads from the main channel, southward, and is probably the feeder of Strzelecki's Creek. Here we found a native path, which led us to where the explorers camped after their unsuccessful attempt to reach Mount Hopeless.

We found the two native wurleys, in which they took shelter, pretty much as King had described them, situated on a sandbank between two waterholes, and about a mile from the flat where they gathered the nardoo on which they tried to exist. We collected the remains of poor Wills, which the drifting sands no longer covered, and placed them in a grave near a tree close by, on which we cut the inscription—

W. J. WILLS
XLV yds
W N W
A H

We also recovered the field-books, a note-book belonging to Burke, various small articles—of no intrinsic value—but now sacred relics of the honored dead.

I found that King, though improving, was not yet strong enough to make a pilgrimage with me to where he left the remains of Burke, and, therefore, on the 21st of September, I went to the place described to me by King, accompanied by Brahé, Welch, Dr. Wheeler, and Aitkin. We searched the banks of the creek upwards for eight miles, and at length, strange to say, found the remains of Burke lying in a small hollow among the dried stems of tall plants, within 200yds. of our last camp and not 30 paces from our track. It was still more extraordinary that I, with three or four of the party and the two black-boys, had been close to the spot without noticing anything. The bones were entire with the exception of one hand and the feet. The body had been moved from the spot where it first lay, and where the natives had placed branches over it, to about five paces away. I found the revolver, which Burke held in his hand when he expired, partly covered with leaves and earth, and corroded with rust. We interred the remains in a grave dug at the foot of a box tree, on which the following inscription was cut:—

R O'H B
21 9 61
A H

Before we left on our return journey I got all the blacks together, who came to the camp in a long straggling procession of men, women, and children. They were made happy by the presents which they received, and I think they understood that these were given to them for their kindness to the white men, and especially to King. It had also the effect of making it easy for me, on my second expedition, to place myself in friendly relations not only with them, but also with the neighboring tribes to the north, and to find guides ready and willing to accompany me in my excursions from the depot. Then, on the 25th of September, we turned our faces homewards to restore King to civilisation, and to the recognition of his faithful services to his less fortunate companions.

At the time when I returned to Menindie with King there were search parties out, and it was deemed necessary to provide a central depot with supplies for any of them who might come in to the Cooper.

I was again selected to be the leader of the party, to form a depot, to open up a line of communication with the northern settlements of South Australia, to carry out such explorations as would not cause an absence from the depot of more than a month, and, finally, to bring down the remains of Burke and Wills in order that they might receive the honor of a public funeral and monument.

This time I slightly varied my route, starting from Mount Murchison, now called Wilcannia.

While we were preparing to leave the Darling it unfortunately happened that Mr. Welch, my second in command and the surveyor to the expedition, became almost blind by an accident when taking an observation of the sun, and had to leave the party and return to Melbourne. Not only was this a great loss to the party, but we regretted losing a good comrade, who had proved his worth on our search expedition. There was no time to replace him by another qualified officer, but, fortunately, I knew enough of navigation to take the necessary sidereal observations to plot my route and delineate the features of the country through which we might be travelling. Taking warning by what had happened, I taught two of my most trusted men—Weston Phillips and Alexander Aitkin—to keep a dead reckoning and to take observations, so that if any accident happened to me the expedition would not be left without someone who could bring it back safely.

In my reminiscences of those times there are two which I may mention as showing the varied kind of interest which was felt in my expedition. One person gravely recommended—as the great difficulty in exploring the interior seemed to be the scarcity of water—that a pumping plant should be erected at Menindie, by which water could be supplied to my party through a hose, which we were to carry with us and uncoil as we progressed, and thus obtain a water supply at any time by merely turning it on! Another suggestion was that we should carry with us some carrier pigeons, and, as the proposer offered to supply the pigeons, we took them. They travelled to Cooper's Creek in a wicker cage, and arrived there safely, excepting that their tail feathers were rubbed down to stumps. However, when King was found, and the fate of his companions ascertained, it seemed worth while to test their homing powers. The first thing to be done was to repair their tails, and to enable me to do this I shot several crested pigeons and spliced the necessary parts of their tail feathers on the stumps of the carrier pigeons' tails, the splices being secured with waxed thread. This proved to be a complete success, as the birds could now fly about the aviary we made with a tent apparently as well as ever. Next morning we started the pigeons on their journey, having previously tied a message on the leg of each bird. On throwing them up in the air they commenced by wheeling round, but separated, one being chased by a large hawk. The others, after flying round in various directions for some time with great speed, drew across the creek southwards and disappeared. The fourth bird, after making a wide circle, pitched into a tree about half a mile off. Afterwards one was found under a bush, where a kite was watching it. One had been killed after we lost sight of the three, for the feathers were seen some distance from the camp. Nothing was ever heard of the others, but in all probability they were killed by some of the birds of prey which are always on the lookout for food.

Another of my reminiscences of Central Australia may find a place here as a comparison to a somewhat similar case which happened when despatches were sent from the Exploration Committee for Burke from Menindie by Mounted Constable Lyons and MacPherson, one of Burke's party. About three weeks after I reached Blanchewater, when I came through to open a route from Cooper's Creek, despatches for me were received at the Angepina Mounted Police Station, with instructions to convey them to me. Supplied with a lithograph of my route plan, they started to run my tracks back, with the help of a Dieri blackboy. He followed them till they were three days' distance from the creek, and then lost them in the drift-sand. Fortunately Corporal Wauchop and Trooper Poynter were both good men in the bush, and took the necessary measures to get through. To secure the blackboy he was handcuffed to one of them at night, and the corporal told him from time to time from my route plan what the country would be ahead of them, so that by-and-by the blackboy would say "What name that paper yabber now ?" They were three days crossing waterless country, having only a little for themselves in their water-bags. At the end of the last day, when they reached the first water at Cooper's Creek, and the blackboy had had a long and welcome drink, he said to the corporal, "No blooming gammon alonga that one blooming paper !" But his expressions were somewhat stronger.

The performance of the duties placed upon me by my instructions on my second expedition caused me to make several journeys to Blanchewater, one to Angepina, and also several trips northward, which were full of interest. Thus a considerable part of my time was spent away from the depot. It was most gratifying to me, and creditable to the members of my party, that during my absence the depot was maintained and all their respective duties carried on in such a manner that no friction was apparent among those who remained there, and that the horses and camels were properly looked after and kept in good health and condition. I attributed the very satisfactory relations between the members of the party when I was absent in great measure to the tact and discretion of Alexander Aitkin, whom I selected to hold authority during my absence. This was against the wish of Dr. J. P. Murray, who had volunteered to accompany the expedition in his professional capacity. My experience of him on my way up caused me to select Aitkin in preference, and his subsequent action in the McIntyre-Leichhardt Search Expedition, and after that in the notorious Carl "blackbirding" case, fully confirmed my opinion.

Owing to the dryness of the season there was a scarcity of feed for our 34 horses, which, in consequence, were scattered in small lots over a frontage of 20 miles above and below the depot. This required two of the men to be constantly on the move looking after them. In doing this they found a horse running wild, where we had seen the tracks on our first journey. He was of a remarkable roan skewbald color, and was so wild that it was with great difficulty he was captured. This was not surprising, for he had a broken rib—probably by a club or a boomerang having been thrown at him. It was a great regret to us all that he was injured in being caught and died of inflammation. So far as I can form an opinion, he was a horse left by Sturt on his last trip to Cooper's Creek.

At the times when I was at the depot I fostered the good feeling between the native tribe there and ourselves. By the kindness of Mr. Frank James, the manager of the Blanchewater Station, I obtained a blackboy belonging to the Narrinyeri tribe who spoke the Dieri language, and thus was able to communicate not only with the Dieri, but also with the Yantruwunta blacks at Cooper's Creek, where we were, who understood that language. In this way I was, before long, able to make myself understood sufficiently for ordinary purposes. Thus I was able to obtain a guide to any place within their ken, which extended for a radius of over a hunderd miles. But there was another advantage which I had, for the old men of the tribal group which were located where we were used to come and bring news to me which messengers had brought them from the Yaurorka, who lived at the southern edge of Sturt's Stony Desert, who had received it from the tribe on the Diamantina River on the other side of it. This news related to John McKinlay, the explorer, who was known to the blacks by the name of "Wheelpra Pinnaru"—that is the head man or elder with the "cart." The word *wheelpra* seems to me to be the native form of our word "wheelbarrow," which has become part of the "pigeon-English" used by the tame blacks, and which is transmitted from tribe to tribe as settlement progresses. The reason why this word was applied to McKinlay was because he had a cart or dray with him. I was told at one time by my native informants that "Wheelpra Pinnaru" was surrounded by a great *arimata*, or flood, and could not get out; then, after a time, it was that the *arimata* had gone away, and that "Wheelpra Pinnaru" had gone away they did not know where to, and that he had thrown his *wheelpra* away—that is, left it behind.

Having made myself acquainted with that part of the Barcoo delta which lay to the north, and as far as the southern edge of the Stony Desert (which the blacks call *Murda pinna*, or Great Stones, or Stony Place), I determined to go further afield to where it was said the great *arimata* had surrounded McKinlay.

This trip was interesting in many respects. Sturt, for instance, when he penetrated into Central Australia as far as Eyre's Creek, did so during a protracted drought. He discovered and graphically described the Great Stony Desert as the dried bed of a former sea. He also described the condition of the country beyond it as a waterless desert—that is, the country which we now know as the Everard or Lower Diamantina.

The route which I followed on my trip was nearly that taken by Sturt; but the conditions of climate were very different to those he experienced. Although the season had been persistently dry at Cooper's Creek, I saw, on several occasions, that heavy rains must be falling far to the north. When I went out that way this proved to have been the case. The country north of that part of Cooper's Creek was a land of lakes, fed by the divergent channels of a great delta, by which the flood waters found their way to the very edge of the desert.

It was in July that I made this journey, and on the 8th of that month we camped at a place called Appenparra by the blacks, and near to the southern edge of the desert. We were five in all, being Dr. Murray, Weston Phillips, Williams, McWilliams, the blackboy Charley, and also one of the Yaurorka tribe.

The conditions of the Stony Desert as I saw them were different from the idea which I had formed from Sturt's account, and I think it will be best to quote my notes made at the time.

"*Wednesday, July 9th.*—Edge of the Stony Desert. This morning, on leaving the camp, we travelled for three miles across sandhills in a north-west direction to one of the chain of large, shallow lakes through which the flood waters find their way to Lake Lipson. These I believe to be the Hope Plains of Sturt. The banks are grassy, and the whole appearance of the country is exactly like that of the neighborhood of Lake Hope. This lake appears to have contained water when McKinlay passed it, judging from the camel footprints on its banks. The rain waters ceased here, and for about 10 miles we travelled across high ridges of loose sand with an occasional large gravelly flat, all vegetation being perished with drought, and the scene was a picture of desolation. The landscape could have been painted in sepia and Indian ink. At noon we came to a dry salt lake, rather boggy towards the centre, and with a fall, as had the whole country here, towards the north. At 2.30, after crossing ridges of red sand covered with porcupine grass, and where there were no living bushes but a few acacias, we came on to the edge of the desert—the sandhills running out in various lengths into it. It was very much as I expected it would be, namely, extensive stony plains, like some I had seen on the south-west side of Lake Eyre. We crossed about five miles of these stones, the travelling not being bad, and camped on a sandridge, beyond which the stony plains extended northwards to the horizon. There was scarcely any feed for the horses; nothing but the dried remains of grass, which looked as if it owed its origin to the deluge. The only green plants to be seen were a few plants of *Portulaca*, which some shower had freshened up. We seem to be getting into rainfall again, as there are some small puddles now only just dry. Distance, 25 miles.

"*Thursday, July 10th.*—Sturt's Desert. Started early—having watched the horses all night to make sure of an early start—there being neither feed nor water for them. In less than three miles, on a north-west course, we came across numerous pools of rain water, a godsend for our horses. The plains are covered with stones, in some places closely packed together like a pavement, in others larger in size and loosely strewn about over a spongy soil. Passed a dry lake about three miles wide, the stony ground sloping to it from three sides, with a sandridge on the other. About 11 o'clock we came in sight of a good deal of stunted timber, principally a kind of prickly acacia, and this our guide announced to be the creek he had spoken to me about.

On reaching it, however, it turned out to be a small oasis in the desert of stones : a tract of sandy and clayey ground well clothed with acacias, saltbush, and grass, and with plenty of surface water lying about. Black Tommy now changed his course more north, and said the creek was over the next rise—a proceeding which led me to surmise that he knew very little about the creek at all. Keeping on the new course we travelled over a large earthy plain, then over a stony tract, then a second patch of sandy country with grass and saltbush, then stones again, till, finding that we might go on to the night for all our stupid guide knew, I halted in some very good grass, with several good claypans of water close at hand. We have had a high ridge of sand on either hand all day, at about five miles distance from each other, and almost on the same course that we have come. Taking all in all, the travelling is not at all bad, and, thus far, the celebrated Great Stony Desert is very little different from large tracts of the stony country which I have seen in what is called in South Australia the Far North and the North-West, excepting that there is comparatively little saltbush here.

"As soon as we had camped Tommy set to work catching rats, and soon had 11 singeing whole on the coals ; they were then covered up with ashes and baked. On taking them out he first pulled off all the tails, made a bunch of the lot, and ate them like radishes ; then he disposed of the bodies *seriatim*, eating each by biting off pieces as he might have done to a sausage.

"After sundown, ducks, swans, and native companions passed over us, going northwards."

When we started on the following morning I steered for a high, white sandhill, to enable me to decide on the direction in which it would be best to direct our course, but on ascending one of the stony undulations which varied the scene, there opened before us an unexpected view—a wide expanse of saltbush flat, covered with a thick coating of native clover and other herbage of luxuriant growth. In descending from the ridge I noticed on a steep descent the sharply defined line of drift marking the level of the flood waters, so marked, indeed, that I halted my horse on it, with his hind feet in the desert and his front on the growing plants. We were in the wide valley of the Diamantina, and I may anticipate what I ascertained later on by saying that the flood waters, as we crossed to the other edge, had extended to a width of not less than 20 miles.

For 17 days we traversed this flooded country, finding everywhere lakes, water channels, lagoons—with wide extents of earthy plains—

now covered with a growth of the tall plants, looking like great white hollyhocks in flower. Everywhere there was an extraordinary growth of fine herbage, in which our horses revelled. We spoke with some of the blacks, but learned nothing of the movements of McKinlay, whose camps we sought in vain. But we found what were evidently his tracks, when on his way northwards, and also two working bullocks, which we assumed must have been his. But what was more interesting to us was finding the tracks of a number of camels and of one horse, much older than his could have been, and probably made by Burke and his companions on their outward journey.

We turned homewards with great reluctance, when our time and our provisions were becoming short, and it was somewhere about where Sturt also turned back on his desperate journey to Fort Grey. He relates how, before leaving, he ascended a hill about 150ft. above the level of the plain, and says—" From it the eye wandered hopelessly for some bright object on which to rest. Behind us to the south-east lay the sandhills we had crossed, with the stony plain sweeping right round them, but in every direction the dark-brown desert extended. The line of the horizon was broken to the north-west and north by hills similar to the one we had ascended; but in those directions not a blade of grass, not a glittering spot, was to be seen." (*p*)

He was then 50 miles from water, and he sat there undecided for more than half an hour before he retraced his steps to his camp and commenced his retreat, the necessity of which was proved by one of his horses falling dead of thirst before noon.

I remember well how I ascended just such a hill as Sturt speaks of, and thought of his remarks as I looked round over the country in the full luxuriance of vegetation after the occurrence of a great inundation. I could see the stony hills and the distant sandhills, but the " brown desert " was covered with the rich vegetation which covers it in times of plenty. For miles I could trace the rank growth of the tall mallow-like plants, higher than a man on horseback, looking like vast beds of tall hollyhock plants in full bloom. I thought how great the consequences might have been had Sturt been so fortunate as to have had such a season as that when I followed his footsteps to this classic spot. Even the Stony Desert would have been deprived of its terrors in such a season, and have been no more exceptional than any other of the bigger plains which are now merely the commonplace occurrences of a great part of Central Australia.

Among the many reminiscences of Central Australia there is one which I may select to round off my tale of the past. When the time

(*p*) *Op. cit.*, Vol. 2, p. 49.

came for me to bring back my party, and having left a cache of things for any of the parties still out who might come that way, I made a short cut to Lake Hope across 90 miles of waterless sandhills. When I got there I was interviewed, as it would now be said, by a deputation of the old men of that part of the Dieri tribe, who made two requests. This was done by the head man, no less than the well-known Jalina Piramurana, whose acquaintance I had made on one of my trips to and from Blanchewater. The first request was that I should go with them and kill the Koonabura men, who were very bad people, and that then he and the other men of the Bando-pinna (Lake Hope) would bury them and take the women. The second request was that I would tell the whitefellow, who they heard was coming up to " sit down " at Lake Hope, that he should remain on the one side of the lake and they would remain on the other. The first request I put off as a kind of joke, and the second I promised to attend to if I saw the whitefellow on my way down to Adelaide. A strong commentary on the Koonabura request was made when we camped on the other side of the lake the next afternoon, for we saw a large number of armed blacks trooping over the sandhills towards our camp. My friend Jalina said, " Koonabura kana"—that is, the Koonabura men. I thought that we should now see a fight, but behold! when they reached the camp, they and the Lake Hope men all fraternised. I had heard before, from the Yantruwunta blacks of the Cooper, about the " tiira-pinnana " of the Dieri—that is, their quarrelsome character —and could now well believe it.

The return of all the search parties terminated the episode of the Burke and Wills Expedition: the eastern half of the continent had been crossed and recrossed. It was no longer considered an unknown and desert tract, but a pastoral region of the greatest possibilities, to be occupied by adventurous pastoral pioneers.

In South Australia the veteran explorer, John McDouall Stuart, by his persistent and determined explorations, had made his way across the continent to the Indian Ocean, thus marking out the track along which the transcontinental telegraph line was successfully laid by South Australia—a work of national importance, with which the name of Sir Charles Todd will always be connected.

Thus closed what I may call the middle chapter of Australian exploration. The next era, thanks to the great public and private generosity of this State, sent forth a new generation of explorers, represented by Giles, Gosse, Tietkins, Lewis, and many others, thoroughly trained and efficient bushmen, who have left little unknown of the former mystery of Central Australia.

APPENDIX.

Parliamentary Paper, 1858, No. 127. In a despatch by Major Warburton, from the Elizabeth, dated the 17th October, there is the following passage :—" I am amazed when I consider Mr. B.'s ignorance, indifference, and rashness. I do not know his plans for the summer; yet I am able most positively to say that, *whatever they may be*, they are *impracticable*; and further, *supposing* his plans were not only practicable, but were already actually carried into effect, even then they would be *useless*. He cannot cart in summer, because the horses can't work without water; he cannot cart in winter, over the country westward or northward of here, because the carts would stick in the first bit of rotten stony country when it was wet. No teams on earth could do the work with such carts; but were all done that Mr. B. so unreasonably expects his *men* to do (he takes no concern about the matter himself), what would it amount to? Simply this—that as an offset to the risk incurred by man and beast, and the expense of wages and rations to all the party during the whole summer, Mr. Babbage's party would have gained from *eight to ten days* out of next winter! I have directed Sergeant-Major Hall to wait upon you, that he may answer any questions. I hope you will be so kind as to give publicity to the simple fact that myself and party are all quite well. I beg to assure you that I will endeavor to do all that reason and prudence permit, but that I dare not throw good lives after bad ones by attempting to follow Mr. B. My breaking up his camp here makes him no worse than he was before, as he could not have got help without *sending* for it, and those who were to send it could not remain here for the purpose after the water had dried up.—I have, &c., P. Egerton Warburton, Commissioner of Police. To the Commissioner of Crown Lands. P.S.—I hope you will excuse this scratch; I could not help it."

Parliamentary Paper, South Australia, 1858, No. 151. In this paper a letter is printed from Major Warburton to Mr. Hamilton dated 30th September, from Port Augusta.—" I am in a hurry at this moment, and cannot write to Mr. Dutton, but will mention what I think might perhaps be done, and leave it in your hands. The line of communication between Port Augusta and Lake Campbell, Stuart's Creek, and all the country there may be to the north and north-west of Lake Campbell, is very bad for stock, and it seems desirable to endeavor to establish a better line through Parry's country. When I get on Stuart's Creek, about lat. 29° 30′, long. 137°, I shall have Mount Nor.'-West nearly due east about 50 miles. Now, I am sure Burrt could find his way to the western side of Mount Nor.'-West Range, and I might meet him from the eastward. Thus there would, if we could join, be an easy and unbroken line through good country. · · · · I cannot say when I shall be in sight of Mount Nor.'-West, but it may be about the 20th October. If Burrt is sent out, he must get well on the western side of the range and make a smoke signal on the most prominent westerly point of the range, keeping a good lookout westward himself. There is water at Mount Nor.'-West, though it may be on the western edge of the range."

Parliamentary Paper, 1858, No. 151. A communication from Mr. Babbage to the Commissioner of Crown Lands, acknowledging his letter of 23rd September, informing him that the Government had decided to instruct Major Warburton to supersede him in the command of the expedition, and instructing him to make arrangements for his return to Adelaide forthwith. Mr. Babbage writes from Port Augusta, on the 21st November, 1858, reporting his proceedings on his journey northward, and at page 9 there is the following passage:—" On proceeding down the Stuart we found near the junction from the south-east, since named the "Margaret" by Major Warburton, a pool of fresh water, and here I halted my party whilst I went out myself to examine the country before us, having, however, previously traced down the Stuart into a large salt lake, which I named Lake Gregory. My first trip was made in company with Jones to the nearest hill of the Hermit Range, situated about 20 miles west of my position. At about 16 miles we found a gum creek, with salt water, but no fresh water, although it might be probably met with higher up the creek. On ascending the hill, which stands up out of a plain, excepting in the western side, where high sandridges butted up against it, I could distinctly trace the shores of Lake Gregory, trending northwards; but to the west and north-west, where I expected to see Lake Torrens, nothing but an extensive plain met my view—not a sign of a lake of any kind being visible. Immediately to the north-north-west was also an extensive plain of a somewhat higher level than the western plain, presenting low bluffs at its sides. To the south-east were the other isolated hills of the Hermit Range, and beyond them a distant blue hill of the Flinders Range, very probably Eyre's Mount Nor.'-West. To the south were several small, isolated salt lakes, and extensive plains covered by low sandridges and scrub. According to the map of the "Recent Explorations," the Hermit Hill should be about 30 miles west of Eyre's tracks; but I found subsequently that a more recent map, supplied to Major Warburton, gave the distance as only 15 miles. The height of Hermit Hill is about 363ft. above the ground at its base, and probably considerably more above the western plain. I feel, therefore, confident, from my view from this elevation, either that Lake Torrens does not extend so far northward as this latitude, viz., 29° 37′, or that, if it does, it must be reduced to a mere inconsiderable channel. and might be readily crossed. I pointed this out to Major Warburton, explaining my reasons for my belief, and offered to accompany him in an examination of it. As this proposal did not appear to suit his plans, I requested him to let one of my late party —Jones—accompany me, that I might examine the country in this direction, and, if I found it practicable, return to Adelaide by Eyre's tracks on the eastern side of the lake; and that, if not, I might at any rate have a companion in the long ride to Port Augusta, *via* the

Elizabeth, Pernatty, and Beda. The Major, however, refused my request, and I had no alternative but to leave to others to reap the fruit of my own labor, and I have no doubt but that the Major, with his accustomed energy, will solve this question, now made easy by the late rains, before his return to town. My own belief, from what I then and subsequently saw, is that Lake Torrens turns up to Yarrawurta at its northern end as at its southern end it does to the Beda arm, and that between Yarrawurta and Lake Gregory there are only a few small isolated salt lakes, similar to Lake Phibbs, sufficient, however, to impress Eyre, who, I believe, only saw this country from a distance, with the idea that he saw the loom of a continuous lake."

Parliamentary Paper, South Australia, 1858, No. 159. Letter with enclosure from Major Warburton relative to exploration in the neighborhood of Lake Torrens — "Police Commissioner's Office, Adelaide, December 10th, 1858. Sir—Since I had the honor of transmitting my report of the 3rd instant I have read Mr. Babbage's official despatch of the 21st November, 1858. The annexed extract from that despatch requires some notice from me, because either I, by the suppression of truth, have assumed to myself a credit which is not due to me, or else Mr. Babbage, by a direct statement of what is not true, has endeavored to conceal his own incapacity by robbing others of such credit as might fairly belong to them. I have underlined the particular portion of Mr. Babbage's dispatch to which I solicit your attention. *Extract*—'I pointed out this place to Major Warburton, explaining my reasons for my belief, and offered to accompany him in an examination of it. As this proposal did not seem to suit his plans, I requested him to let one of my late party—Jones—accompany me, that I might examine the country in this direction, and, if I found it practicable, to return to Adelaide by Eyre's tracks on the eastern side of the lake, and, if not, I might at any rate have a companion in the long ride to Port Augusta, *via* the Elizabeth, Pernatty, and Beda. The Major, however, refused my request, and I *had no alternative but to leave to others to reap the fruit of my own labor*.' It would appear from Mr. Babbage's account that the 'labor' of discovering a passage across Lake Torrens was his, whilst I have reaped the fruit of labor not my own. I am compelled to give an emphatic contradiction to Mr. Babbage's statement, and I leave you to judge on whose side the preponderating evidence shows the truth to rest. In the first place, I make my plea by declaring solemnly and sincerely, on my honor as a gentleman, that in finding the crossing of Lake Torrens I received *assistance* from no one, excepting my immediate companions—Mr. A. J. Baker and Corporal Coward. The views I had *previously formed* received *confirmation* by what Mr. Forster told me on the 2nd October. He stated that when at Stuart's Creek the native had wished Mr. Stuart and himself not to go further, but to return direct to the northern settlements. Before leaving Adelaide I had determined to *try* and find a passage; but whilst on board the *Marion* it struck me that Corporal Burrt, of the mounted police, stationed at Angepina, might, if I succeeded, be useful in conveying the intelligence to Adelaide, and for this purpose I suggested his being sent to the westward of Mount Nor.'-West. · · · · Mr. Babbage did not open the subject of there being a passage to me: I opened it to him on the 5th November. When I opened it he at first dissented from my views, stating that he did not think there was any passage *there*. I then showed him a different map, and repeated to him what Mr. Forster had told me. *After* this, Mr. Babbage changed his opinion, admitting that there might be a passage and adding that he had ascended Hermit's Hill, from which he thought he could see at least fifteen miles—he appealed to his brother-in-law to confirm this extreme range of vision—and no lake was visible. · · · · I think it was on the last morning we were together that Mr. Babbage came to the camp fire, where Mr. Baker, myself, and, I believe, some others were sitting, and said, as nearly as I can remember the exact words—'Major Warburton, do not let us misunderstand each other. You will understand distinctly that I have expressed my desire to go and find a passage across Lake Torrens, and my reason for wishing to do so is that the public will say it is an additional proof of my incapacity that I was in the very spot for finding the passage and yet took no steps to find it.' I replied that 'It was very probable the public would say what Mr. Babbage supposed, but that it was no fault of mine that the time for his exploring was past, that the idea of finding a passage had never entered his head till I put it there, and that he could not expect me both to give him the idea and the means of carrying it into execution to my own prejudice.' This, I believe, ended our conversation on the subject.

Parliamentary Paper, South Australia, 1858, No. 159, p. 3. "Police Commissioner's Office, Adelaide, December 9th, 1858. Sir—I beg to transmit, for your perusal, an extract from an official report of Mr. Babbage's presented to Parliament, and as I think you were present on two occasions when the subject referred to in this extract was under discussion between Mr. Babbage and myself, I should feel obliged if you would favor me with a statement, as nearly as your memory will permit, of what you on those occasions heard.—I have, &c., P. Egerton Warburton, Commissioner of Police. To Mr. Arthur J. Baker, Kent Terrace, Norwood."

"Kent Terrace, Norwood, December 9th, 1858.—Sir—In reply to yours of this date, enclosing an extract from Mr. Babbage's official report to Parliament, which I have read, I beg to state that the conversation which I heard between Mr. Babbage and yourself was quite the reverse of the extract now before me, and herewith annexed. The following is, as near as I can remember, an exact statement, viz., you had been giving Mr. Babbage a description of the springs and country you had discovered, and then went on to describe your plans, and stated you intended to try and find a practicable route from Stuart's Creek into Parry's country, so that the stock might be brought through from the northern runs, and avoid the horrible desert *via* Beda and the Pernatty Plains. At this time Mr. Babbage would not entertain the idea of a practicable crossing over Lake Torrens, nor did he appear to have any faith in your plan until you told him that the blackfellow who accompanied Stuart and Forster had tried to persuade them to return that way. The next day, on our march back to Stuart's Creek, Mr. Babbage said to me that he intended to ask you to allow him to have one man and sufficient provisions to enable him to reach the nearest stocked run east of Lake Torrens. On the Monday morning, before leaving Stuart's Creek, Mr. Babbage came down while we were at breakfast, and before all the men belonging to both parties asked you to allow him to have one man and sufficient provisions that he may try and cross Lake Torrens, and return to Adelaide by that route. Your reply was, 'My instructions were to recall you, Mr. Babbage—not to prolong your exploration duties, as I should be doing were I to allow you to seek for a crossing over Lake Torrens; nor do I think I could, in justice to myself and party, send you to reap the credit of my plans, should there prove to be a practicable crossing; nor do I think you ought to expect me to do so, knowing, as you do, that you had no idea of looking for a crossing until after I had laid my plans before you. By any known route you can return, and I shall be happy to allow you to take any one of your late party with you you choose.' Mr. Babbage then offered to accompany you, which offer you refused, stating that 'I cannot at present say which course I shall take; in fact, I shall most likely go back by the Elizabeth, after satisfying myself as to the practicability of crossing Lake Torrens. I have desired Mr. Charles Gregory to plant stores at the Elizabeth; I therefore think, for the sake of your own property left at the Elizabeth, you had better return there. However, you are welcome to go by any known route you please, and I shall be most happy to render you every assistance in my power to make your journey agreeable.' Mr. Babbage then made this reply aloud, and before the whole of the men, 'But, Major Warburton, only consider what the people of Adelaide will say, when they hear that I have been within a few miles of this crossing for the last three weeks, yet never went to explore it. They will bring this against me as another proof of my incapacity.'—I have, &c., ARTHUR JOHN BAKER. To Major P. E. Warburton, Commissioner of Police, &c., Adelaide."

Parliamentary Paper, 1858, No. 166. In a letter, dated December 11th, 1858, the Commissioner of Crown Lands requested Major Warburton to add to his letter "some remarks more in detail as to the reasons which induced him to return, at the time he did, from the exploration which terminated at the Davenport Ranges." To this Major Warburton replied on the 14th December. The parts of this letter which I quote occur at pages 5 and 6, and are as follows:— "I originally intended to try for a passage *before* proceeding northwards, because I thought that if I found a passage I should then, having a certainty of getting fresh horses at Angepina for my return, be able to take more work northward out of those I then had than I should have dared to take with the prospect of the long and bad journey back *via* the Elizabeth and Port Augusta. . . . . I changed my plan: determining to make a short excursion north-west of Stuart's Creek first; then to return, run the creek down, look for Mr. Babbage's tracks, try to find where the passage across the lake was, and, if Mr. Babbage's tracks were not found, turn back due west, zigzagging the country between Stuart's Creek and the Elizabeth, till I had either reached the latter place or, finding Mr. Babbage's tracks, had run him down. This plan was carried out so far as my arrival on my return from the North-West to within 20 miles of Stuart's Creek, when I cut Mr. Babbage's track on the afternoon of the 4th November; overtook him in 24 hours, and delivered the Government order verbally to him . . . . I cannot see what is the *use* of 'summering out,' unless a man is so far advanced that it would occupy a considerable portion of the *next season* to regain his position. . . . . I could get back easily; and, what is more, I could (accidents excepted) run out again to my furthest permanent water, the Strangways Spring, in 17 days from the time of leaving Port Adelaide; or, as a more fair way of estimating it, 10 days from Mount Serle Police Station would give me exactly the same advantages, in point of position, as I should have possessed had I summered out. . . . . By staying out, therefore, I should have gained nothing but 10 days, whilst I put the colony to expense, idled away my own time, risked the health of my men, and, in all probability, rendered it necessary for them to return to the settlement to recruit when the best season for pushing into the interior had again come round . . . . ."

Parliamentary Paper, 1859, No. 37. "Crown Lands Office, January 4th, 1859. Sir—The duty to which you were specially appointed by the Government in connection with the northern expedition having terminated, I have the honor to inform you that the Government are satisfied with the energy and vigor you have on this, as on former occasions, displayed when in employed in exploring new country. The discovery by you of well-watered pastoral country beyond the limits attained by Mr. Stuart and Mr. Babbage in a northerly direction, but especially your valuable discovery of a practicable route from the northern runs into the new country, over what was hitherto considered to be the bed of Lake Torrens, have, whilst adding to your reputation as a bushman, fully justified the Government in entrusting to you the execution of the service of emergency which had arisen. In appreciation of these services I have the honor to inform you that the Government have authorised the Treasurer to pay you the sum of £100 out of the exploration funds. In conveying to you the approval of the Government for the way in which you have carried out the duty entrusted to you, it is also incumbent upon me to inform you that the Government disapprove of the terms in which you write of your predecessor in the command of the expedition in the despatches which you addressed to me from the Elizabeth. The Government are quite willing to make every allowance for the circumstances under which the despatches were written; but they are, nevertheless, compelled formally to convey to you their disavowal of the sentiments expressed by you.—I have, &c., FRANCIS S. DUTTON, Commissioner. Major Warburton, Commissioner of Police, late commanding Northern Exploring Expedition."

"Police Commissioner's Office, Adelaide, January 13th, 1859. Sir—I have the honor to acknowledge the receipt (this day) of your letter—40-59—dated 4th instant, and beg, in reply, to express my grateful acknowledgments of the remuneration which Government have been pleased to grant me. I trust Government will do me the credit to believe that I am exceedingly sorry for having expressed my real sentiments in the official form which led to their publication and consequent disavowal of Government. No one can be more sensible than myself of the mistake which I made, my regret for which is all the more felt as I fear that the apparent unavoidable publication of those letters may have embarrassed the Government. Had it been possible I would most gladly have withdrawn the letter altogether, but it would have been useless for me on my return, after their publication, to make any such offer, unless I could at the same time have publicly acknowledged the statements I had previously made were founded on incorrect information, and that my opinions were changed. This I could not conscientiously do, whilst nothing less would have satisfied Mr. Babbage.—I have, &c., P. EGERTON WARBURTON, Commissioner of Police. The Hon. Commissioner of Crown Lands."

Section A.

ASTRONOMY, MATHEMATICS, AND PHYSICS.

ADDRESS BY THE PRESIDENT,

E. F. J. LOVE, M.A., F.R.A.S., F.P.S. (LOND.).

THE THEORY OF THE VOLTAIC CELL.

Exactly 107 years ago, Alessandro Volta, Professor of Physics at Pavia, and Copley Medallist of the Royal Society of London, piled up a succession of discs of tinfoil, copper, and moistened cloth—the first voltaic battery—and in so doing set the scientific world a problem which is still unsolved, albeit that its study has thrown a flood of light on every branch of inorganic science and has even furnished the biologist and physiologist with material for profitable meditation. Chemists have seen in it the first faint adumbrations of the explanation of chemical affinity; electricians have fought for a century over the conflicting suggestions which it has afforded respecting the nature and origin of electromotive force; thermodynamicists owe to it the first and completest demonstration of the universal validity of their fundamental principles; of late years, metallurgists have begun to seek in it the explanation of the obscure phenomena disclosed to them by the microscope.(*a*) Even as an adjunct to business affairs, the voltaic cell has played, and still plays, no mean part. So far from being hurried off the stage by the advent of the dynamo, it has maintained its place alongside of that machine as an appliance which no twentieth century electrical engineer can afford to discard; the storage battery for steady current production, the Clark, Hibbert, and Weston cells for electromotive force standards alike have a far wider practical usefulness to-day than the Daniell and Grove batteries of a generation ago—to say nothing of the original Volta pile—ever possessed.

In the history of voltaic theory the names of five workers stand out from the rest as of commanding importance. These are—in order of time rather than of relative significance—Volta himself, Faraday, Lord Kelvin, von Helmholtz, and von Nernst. To these we owe successive generalisations, often supposed to be irreconcilable, yet each ultimately finding its place in a consistent and steadily growing body of scientific doctrine.

It is impossible to overrate the importance of Volta's original contributions to the theory of the cell. The line of demarcation which he drew between the two classes of conductors which we term "metallic"

(*a*) See Ewing and Rosenhain, Phil. Trans. CXCV.

and " electrolytic " ; the definite proof that circuits, consisting entirely of conductors of the first class, are not the seat of a current, while mixed circuits in general carry currents ; above all, the great step taken in theory by locating the seat of what we call " electromotive force " in the common boundary of chemically dissimilar substances—all these stamp Volta as an investigator of the first rank. Not one of them has been upset ; on the contrary, they have been fully confirmed by later study. It is true that the precise locality assigned by him as the *principal* seat of electromotive force in the cell soon became a matter of dispute ; but he had good experimental grounds for placing it, as he did, at the metallic contacts of the circuit, and 80 years of work were required to show that his experiments were open to a different interpretation from the one that he put upon them.

Faraday's entrance into the arena preceded by many years the development of the doctrine of energy, yet the whole tenor of his early work seems to me to show that something of the kind was taking shape in his masterful brain. Considerations not very easy to distinguish from our modern views about energy induced him to depart from Volta's metallic contact hypothesis. The current, he contended, was always the accompaniment of chemical action and exactly measured its amount. It was, therefore, natural and logical to locate the seat of the forces giving rise to the current at the places where chemical action was going on. Thus was initiated the famous conflict between the " contact " and " chemical " theories of the cell : one of the most valuable discussions, from the point of view of incitement to research, that physicists have ever carried on.

While the advocates of these two theories were fighting matters out, without getting much nearer to a solution of their problem, a gigantic revolution was silently going on in scientific thought. The establishment of the non-material character of heat, and of the mutual equivalence of heat and work, soon issued in the wider generalisations which constitute the modern doctrine of energy. Helmholtz and Lord Kelvin were quick to apply the new ideas to electrical theory. Of the two workers, Kelvin (*b*) was earliest in the field as regards the theory of the voltaic cell, and his calculation of the electromotive force of the Daniell element from thermochemical data definitely annexed the voltaic problem to the domain of thermodynamics. Unfortunately his conclusions were misunderstood, his own express limitations to the applicability of his method were disregarded, and, as a consequence, investigators were soon face to face with a difficulty largely of their own making ; the values of many electromotive forces computed from Kelvin's formula-

$$(c) \quad E = \Sigma(J\theta\epsilon)$$

were found to conflict with experiment, consequently the applicability of thermodynamics to the voltaic circuit incurred a degree of suspicion which was quite unmerited.

(*b*) *Phil. Mag.*, 1851. Two papers.

(*c*) The thermodynamic notation is that of my report—" On the Thermodynamics of the Voltaic Cell," A.A.A.S. Rep., 1898.

Von Helmholtz's enunciation of the doctrine of "free energy"(*d*) —a mathematical deduction from the laws of thermodynamics—and his application of it to the circuit, at length brought order out of chaos. It fixed, definitely and for all time, the true relation between electromotive force and thermochemical data, by proving that the transformations of free energy, not those of the total intrinsic energy, are the real measure of electromotive force. It furnished a definition of the latter quantity, in terms of energy and entropy, expressed by the equation—

$$E = -\frac{\partial}{\partial q}(U - T\phi)$$

—an equation independently arrived at by Willard Gibbs—and thus led to a general theory of voltaic action, free from every trace of disputable hypothesis. An almost equal service was rendered to the theory by the demonstration that the free energy, so far from being a mathematical abstraction, is in reality a definite physical property, capable of expression in terms of measurable quantities; Helmholtz's application of his results to the determination of the electromotive forces of the migrationless concentration cell (*e*)—the "simple liquid cell" as he called it—and of the gas battery, made this quite clear; at the same time the striking agreement between the observed electromotive forces and the computed changes of free energy practically settled the nature of electromotive force. In another direction, his establishment of the equation—now well known as "Helmholtz's Law"—

$$E - T\frac{\partial E}{\partial T} = -\frac{\partial U}{\partial q} = H$$

attracted even a larger share of attention, as it expressed the difference between the electromotive force and the algebraic sum of the heats of formation of the cell products—the "bound energy"—in terms of the easily measurable temperature co-efficient of the electromotive force: thus rendering the experimental verification of the thermodynamic theory an easy matter, even in cases where the calculation of the free energy change was impossible. Since the year 1887 we have been assured that the change in the free energies of the constituents of a cell, produced by the passage through it of unit quantity of electricity, is the numerical measure of its electromotive force; in fact, they are but two different names for the same physical quantity. But a new difficulty, of a purely practical character, arose at once: the deduction of the changes of free energy from other quantities more amenable to measurement proved to be an exceedingly difficult task in all cases, and, at first sight, an impossibility in most.

(*d*) Sitzungsb. d. Akad. Wiss., Berlin, 1882. A better name for this function would be—"potential energy of isothermal transformation," had not "free energy" established itself in scientific nomenclature. It must not be forgotten that the free energy of a working substance may be greater or less than its intrinsic energy, according as it absorbs heat from or gives heat to its surroundings when undergoing a "free" transformation, *i.e.*, one which, like the free expansion of a gas, will always take place in the absence of certain definite constraints.

(*e*) Sitzungsb. d. Akad. Wiss., Berlin, 1882, 1887. Monatsb. d. Akad. Wiss., Berlin, 1883.

Then von Nernst (*f*) came to the rescue. He propounded a theory, based on the results of osmotic-pressure experiments and Arrhenius' theory of ionic dissociation, which, at first sight, looked brand new; certainly it was a daring, original, and highly successful attempt to express the electromotive force of all known types of cell by means of a single formula. The connection between Nernst's ideas and Helmholtz's calculations is not easily traced off hand, as their authors speak different languages. The latter confines himself rigorously to mathematical deductions from known facts, the former makes use of the picturesque methods of molecular hypothesis. Nevertheless, it is possible to strip Nernst's theory of its ionic dress—a process which results in a decided increase in its generality—and when this is done its connection with the older theory becomes apparent. What Nernst really effected was, we find, the discovery of a general method of expressing the changes of free energy in terms of quantities ideally or actually measurable. It is true that the method involves an element of hypothesis concerning which the last word has yet to be said, but it is possible to make too much of this; the use of the term "electrolytic solution pressure" need involve only just as much—or should I say as little?—hypothesis as the ascription of specific inductive capacity to a solid dielectric, each being, in the last resort, a matter of definition. I admit that in Nernst's own way of introducing the expression the hypothetical element is much larger, but that is owing to the manner in which the theory originated; it is of its accidents, not of its essence.(*g*) Looking at the matter from the purely practical standpoint, it is clear that Nernst's own statement of his theory, like all working models of natural processes, has a great advantage over abstract reasoning for the average investigator. It has led to an immense amount of valuable work at the hands of men who knew little more of thermodynamic theory than they did of Accadian syntax. Even the man who prefers to do his thinking in generalised co-ordinates frequently finds himself none the worse off for the aid of a comfortable crutch of hypothesis; it is not, therefore, surprising that the results of the bulk of recent work on electromotive forces should be stated in terms of ions and osmotic partial pressures.

During the last 20 years the old dispute between the contact and chemical theories has quietly flickered out, mainly owing to the increased precision which has gradually attached itself to the definition of electromotive force. For this result Helmholtz is primarily responsible, though much is due to the clearness and force with which Lodge (*h*) has followed up the lines of thought suggested by the doctrine of energy: much also to Jahn (*i*) and Gill's (*j*) direct determination of the points at which energy enters and leaves the circuit. Galt's (*k*) determinations of the heat of formation of brass—to which Lord

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(*f*) *Zeitsch. Phys. Chem.*, IV.

(*g*) I am not aware that this underlying relationship between the theories of Helmholtz and Nernst has been indicated elsewhere.

(*h*) B.A. Rep., 1885, 1887; Proc. Phys. Soc., Lond., XVII.; *Phil Mag.* [5], XLIX.

(*i*) *Wied. Ann.*, XXXIV., L. (*j*) *Wied. Ann.*, XL

(*k*) Brit. Ass. Rep., 1898-1899.

Kelvin had appealed as the probable origin of the "volta force" at a zinc-copper junction—helped in the same direction. Though his method of working is open to some degree of criticism, his results suffice to prove that the energy set free in the alloying of zinc and copper is far too small to account for the volta force. If Galt did not obtain quite reliable measures for the heats of formation of the brasses, he at any rate inflicted a severe blow on the contact theory. There seems now to be a tacit agreement to identify the seat, or, rather, seats, of electromotive force with the various sources and sinks of energy in the circuit. The metal-metal, metal-liquid, and liquid-liquid boundaries all have a share; even the body of the liquid plays a part in virtue of ionic migration. The battle has ended in a draw, somewhat in favor of the chemical theory.

It is unnecessary to go into any detail respecting the work of Helmholtz and his contemporaries and immediate successors, as such matters were dealt with in my report (*l*) to this association on the thermodynamics of the voltaic cell, and are now common property. Suffice it to say that the chief results of work on their lines, since the date of that report, have taken the form of utilisation of an established theory, rather than of additions to it. To this statement there is, however, one very important exception.

The distinguished American chemist, Richards, (*m*) has called attention to a remarkable parallelism between the bound energy of a cell and the change in thermal capacity of its contents which takes place during its working. He has shown that the algebraic signs of these two quantities are opposed, and their numerical values of the same order of magnitude, in every one of the numerous cases which he was able to consider; at the same time he calls attention to the differences between the measured values of the two.

In order to see the bearing of Richards' suggestions on voltaic theory, we must revert for a moment to Helmholtz's position. The latter had shown that the bound energy is necessarily represented by the reversible thermal effects within the cell, and his successors—Jahn (*n*) and Gill (*o*)—had proved, by direct experiment, that these thermal effects are identical with the sum of the Peltier effects at the various junctions. In accordance with their work, Helmholtz's equation takes the form

$$\mathrm{E} + \Sigma(\Pi) = -\frac{\partial \mathrm{U}}{\partial q} = \mathrm{H}$$

The comparison of this formula with Richards' figures—though Richards does not make it (*p*)—is, to my mind, of the highest order of significance, inasmuch as it throws a flood of light on the nature of thermo-electricity. There seems to me no room for doubt that part, if not the whole, of the Peltier electromotive force at a metal-liquid or

(*l*) *Loc. cit.* (*m*) *Zeitsch. Phys. Chem.*, XLII. (*n*) *Loc. cit*
(*o*) *Loc. cit.*
(*p*) In fact he does not refer to the formula, and seems to be unaware of its importance.

liquid-liquid junction is due to the change of thermal capacity of the substances there present, in other words, that the Peltier electromotive force itself is, at such junctions, the indirect result of chemical action. Whether this be true of the Peltier effect generally is quite another question. For my part, I have inclined strongly to this view ever since the publication of Roberts-Austen's discovery (*q*) of the inter-diffusibility of solid metals in contact, though I admit that much experimental work remains to be done before a definite pronouncement, one way or the other, can be made. Should the magnitude of the Peltier effect at a metallic junction be found to run a parallel course with the change of thermal capacity during the alloying of the metals, a good *prima facie* case would be made out for this view; but at present, so far as I am aware, the necessary information respecting the thermal capacities of alloys is lacking. All the same, the smallness of the Peltier effect at a zinc-copper junction, coupled with the approximate equality of the specific heats of zinc, copper, and brass, looks rather like a hint in this direction. (*r*)

Richards, as I have said, does not make this comparison, but utilises the new facts for an altogether different purpose. He suggests that the *difference* between the observed values of the bound energy and those of the changes in thermal capacity indicates a real difference between the free energy and the energy of chemical affinity—a difference which he ascribes to energy evolved during change of atomic magnitude. As far as the thermodynamic theory is concerned, this is possible enough; it would simply necessitate the inclusion of an additional parameter in the fundamental equations. But in view of Jahn and Gill's experiments the matter takes on a different complexion, inasmuch as they show that the bound energy is fully accounted for by reversible changes of a purely thermal character. I find it difficult to associate the idea of such a reversible thermal change with that of energy liberated by atomic compression, just as I can attach no intelligible meaning to the temperature of an atom or a molecule. It seems, moreover, fair to remark that the only instances we have of the liberation of intra-atomic energy —if indeed they be such—are those supplied to us by radio-activity, and here we find the energy taking a form which is far removed from that involved in reversible thermal change. It seems to me, therefore, more reasonable to suppose that *intermolecular* changes, other than those involved in the change of thermal capacity, go to make up the balance of the Peltier effects than to cut the knot by ascribing them to *intra-atomic* changes. Nor need we overlook a series of considerations which, if correct, show that the foregoing portion of this paragraph is merely a tilt at a visionary windmill. The outstanding difference between the bound energy and the change of thermal capacity, on which Richards rests his argument, may, after all, not be real, but merely due to the im-

(*q*) Proc. Roy. Soc., 1900.

(*r*) Lodge (Proc. Phys. Soc., Lond., XVII.) says that if you pass a current through a zinc-copper junction you get no brass; but this statement was made before the interdiffusibility of solid metals was discovered. Bar oxidation films I suspect that we *should* find brass at the junction, whether a current pass through it or not.

perfection of the thermal measurements involved, seeing that the changes of thermal capacity affect only the fourth and fifth significant figures of that quantity—never the third by more than a single unit. Considering the state of exact thermometry 35 years or more ago, when Marignac and Thomsen determined these thermal capacities—to say nothing of the other difficulties involved in calorimetry—it is not unreasonable to suppose, with Berthelot, that the fourth figures may be uncertain to the extent of several units, and the fifth of little or no value — an assumption which would deprive the discrepancy, and, with it, Richards' whole discussion, of all significance.

The point at issue is important, inasmuch as it raises once more the question of the measurement of chemical affinity, and even of its nature. To ask whether the free energy represents the energy of chemical affinity, or whether it needs to be supplemented by energy obtained from atomic contraction, is pretty much the same as to ask whether chemical combination is a wholly inter-atomic or a partly intra-atomic process. I need hardly remind you that the first of these alternatives has hitherto been the accepted one, but may content myself with remarking that the data under discussion give us no adequate reason for changing our opinion, though it may be well to keep an open mind on the subject.

By far the most numerous advances in voltaic theory during the last 17 years are due to the work of the advocates and opponents of Nernst's theory. To this theory, therefore, we will now turn our attention, and, as the language of both parties is adopted from that of the ionic hypothesis, we will, to save circumlocution, follow their example.

The success of Nernst's theory, as applied to concentration cells, was immediate and complete. This is not in itself surprising, as his formulæ—stripped, as I said before, of their ionic garb—are, to all intents and purposes, identical with those of Helmholtz's general theory. Nernst, however, was enabled by his mode of presenting the subject to test the theory in a vastly larger number of cases than his predecessor could do, and to prove that his formulæ were generally applicable. The application of the theory to liquid cells—which differ from concentration cells merely in having indifferent electrodes—was not so successful; the observed and calculated values of the electromotive force always differed, the latter being invariably in excess—sometimes by as much as 25 per cent. So far as I can learn, the discrepancy has never been cleared up, though Ostwald called attention to its importance more than 13 years ago.

But the real battleground of the theory has lain in the region of those cells whose electromotive forces depend on the nature of the solid metals present in the voltaic chain. Here, for the first time, it is necessary to introduce hypothesis in order to describe the way in which a metal goes into solution. Nernst effected this by his idea of electrolytic solution pressure, or, what comes to the same thing, by explaining the potential difference at a metal-liquid boundary as depending only on the ionic pressure in the metal and the partial pressure of that metal's own ions in the liquid. Writing as he did in the early days of the ionic hypothesis, it was natural that he should take the same view as others took respecting the functions of the solvent, and ascribe to it a purely passive part, viz., that of furnishing a space in which the ions could play their various parts unhindered. Such a view necessarily involved the assumption that the solution pressure of a metal is independent of the chemical nature of the solvent—in other words, that it is a specific property of the metal. For this reason, Nernst held that the solution pressures may be taken as a numerical measure of the relative chemical affinities of the metals; not, of course, in quite the same sense as the electromotive force; the latter measures the chemical energy, while the former measures the chemical force, so that the two definitions of affinity may be regarded as collateral.

The application of Nernst's complete formula to cells of ordinary type would have led to very complicated expressions for the electromotive force. On the ground of sheer expediency, therefore, Nernst suggested a simplified expression obtained by neglecting, as relatively unimportant, all the potential differences other than those at the metal-liquid surfaces. The electromotive force is then given by

$$(s) \quad \mathrm{E} = \frac{\mathrm{RT}}{\epsilon} \left\{ \frac{1}{n_1} \log. \frac{\mathrm{P}_1}{p_1} - \frac{1}{n_2} \log. \frac{\mathrm{P}_2}{p_2} \right\}$$

The enunciation of this formula lent a new interest to the determination of single potential differences, as, according to it, the difference of two such quantities is, very approximately, the electromotive force of any ordinary cell. Measurements of this kind soon showed that the formula gave consistent results. The solution pressures of any one metal deduced from the potential at its point of contact with aqueous solutions of its sulphate and of its chloride came out identical within the limits of experimental error. Nernst's conclusion, that the part of the electromotive force dependent on the negative ion is negligibly small, was also confirmed in a large number of cases. The formula was, however, found to break down wherever the negative ion was of such a nature as greatly to reduce the solubility of either electrolyte. Great was the joy of the opponents of the theory, while, so far as I know, none of its supporters ever succeeded in eliminating the difficulty. Yet the explanation is not far to seek—at least, I think not. To my mind these are the very cases in which we might expect the electromotive forces, neglected in deducing the approximate formula, to be large enough to upset the basis of the approximation. The reasonableness of such an explanation is best seen by considering an extreme case. If one of the electrolytes is practically insoluble, while the solubility of the other is finite, it is not very difficult to show (from Planck's complete formula (*t*) for the electromotive force of electrolytes in contact) that the potential difference at the boundary of the two electrolytes tends to become indefinitely large. It is not the theory that breaks down in these cases: it is only the approximation. So far, then, Nernst's theory of solution pressures stands on a pretty safe basis, while the enormous utility it has had for investigators is beyond question.

(*s*) The usual notation of the exponents of Nernst's theory is followed.

(*t*) *Wied. Ann.*, XL. I do not give the mathematics of my argument, as they are too straightforward to be worth printing.

It is when we pass on to the consideration of cells of less common type, those, namely, in which the metals are not in contact with solutions of their own salts, that the arguments of Nernst's opponents begin to have something like force. Their objections practically amount to three. I may say at once that I regard one of these as probably unimportant and another as merely demanding a revision of the theory on an unessential point, but the third as proving that the theory lacks generality.

The first objection may be stated thus :—The electromotive force between a metal and a solution of an electrolyte which is not one of its own salts depends on the nature of the anion; the solution pressure of the metal must, therefore, do the same. This has been proved by Paschen (*u*) and, independently of him, by Bancroft, (*v*) to be true in several important cases, though not in all, or even the majority; in most cases it is, as Nernst assumed, untrue. Taylor (*w*) has supplied an explanation of this difficulty, by showing that, when there is any tendency to form double salts at the common boundary of two electrolytes, the potential differences neglected in deducing the formula become very large, (*x*) and suggests that this explanation may be general. I cannot find that he has proved it to be so; but it is at least a suspicious circumstance that the metals which behave abnormally are actually the ones—such as platinum—which do tend to form double salts. Taken by itself, this difficulty does not seem to amount to much.

The second objection to the theory is more serious. It is to the following effect :—The potential difference between a metal and an electrolyte depends on the nature of the cations of the electrolyte—whether they be identical with the metal's own ions or not; further, if we add to a solution of one of the metal's own salts a salt of some other metal with the same anion, we shall at once alter the potential difference between the metal and the solution, and therewith change the computed solution pressure. This statement Kahlenberg (*y*) has unquestionably demonstrated for a large number of solutions, aqueous and otherwise. It is true that Bancroft (*z*) had previously asserted the reverse; but it must be remembered that his calculations are based on electromotive force measurements by different observers, which may not, therefore, be fairly comparable with each other, to say nothing of the fact that some of them hardly seem to be exact enough to settle a question of this kind. Kahlenberg, to whom the very word ion is anathema, sees in his own work the downfall of Nernst's theory, and a strong argument against the hypothesis of ionic dissociation. But I am not prepared to follow him in this contention, as in my judgment the whole difficulty is due to an assumption, which Nernst certainly made, but which can, I think, be shown to be needless, arbitrary, and not prescribed by the ionic hypothesis.

Though there seem to be two cases for consideration, they can be treated together by asking the question—Is the potential difference

(*u*) *Wied. Ann.*, XLIII. (*v*) *Phys. Rev.*, III.

(*w*) *Journ. Phys. Chem.*, I.

(*x*) The explanation is the same as that suggested above for the case of the insoluble electrolyte; but the reason for it is quite different.

(*y*) *Journ. Phys. Chem.*, III., IV. (*z*) *Loc. cit.*

at a liquid-metal boundary affected by the back-pressure of positive ions other than those of the metal itself? Nernst says "No"; but I could never discover his reason. The only surmise I have been able to make on the point is that he must have tacitly assumed Dalton's Law of Partial Pressures to hold in this case. But in view of the mutual solubility of metals, as exemplified by alloys, I doubt the applicability of Dalton's Law. It has always seemed to me to have no more to do with the present case than it has with the mixed vapors of alcohol and water in the presence of one of those liquids. This view is, to my mind, strongly supported by Roberts-Austen's experiments, to which I have already referred. We may fairly suppose that the passage of particles of one metal into the mass of the other takes place ionically—at any rate Nernst would have to suppose so in order to be consistent with himself. But if such ionic transfers between solid metals are possible, similar transfers between a metal and a liquid must be *a fortiori* possible. It follows, then, that Kahlenberg's result is only what might be reasonably expected on the basis of the ionic hypothesis, and that Nernst's theory would be improved—even from his own standpoint—if the restriction which he laid down were withdrawn. An important deduction may be drawn from this argument, viz.:—Calculations of solution pressure are quite unmeaning unless based on measurements of the electromotive force between the metal concerned and a *pure* solution of one of its own salts.

The third objection to Nernst's theory is based on the behaviour of non-aqueous solutions, the allegation being that the solution pressure of a metal depends on the nature of the solvent in which it is immersed, and that quite independently of the ionising of that solvent or the formation of complex ions in the electrolytic solution. The examination of the evidence tendered on both sides of this question has been a thankless task, as so much of it proved to be valueless. To take one reason alone: many workers selected pyridine as the solvent; but their observations must, for the present, be ruled out of court, because the metals and salts used act chemically on the pyridine. One elaborate research of Kahlenberg's (*a*) must, on this ground, be discarded. Measuring the potential differences between some 20 metals and solutions of Li Cl in pyridine, in water, and in mixtures of the two, he found that the voltaic order of the metals changed from solvent to solvent. His argument would be conclusive were it not for the fatal fact, demonstrated seven years earlier by Lasczinski and Gorski, (*b*) that Li Cl combines with pyridine to form the non-electrolyte $Li\,Cl + 2C_5H_5N$; the pyridine solution is, in consequence, nearly free from Li ions, and a very bad conductor: indeed, it is difficult to say precisely what it is composed of. We might fairly expect some abnormalities of a scarcely calculable kind in the electromotive force relations of such a liquid, and when we remark that gold in contact with it is positive to iron, we see that we get them; but these abnormalities neither confirm nor confute Nernst's view—they have simply nothing to do with it.

(*a*) *Loc. cit.* I mention this set of experiments because Kahlenberg attaches special importance to it. See Trans. Int. El. Congr., St. Louis, 1904.

(*b*) *Zeitsch. Electro-Chem.*, IV.

Others of Kahlenberg's experiments are more suggestive, even if they do not prove his point. He finds that solvents of similar chemical constitution give nearly the same electromotive force for a given metal and electrolyte, while solvents of different chemical nature give very different electromotive forces. This would be quite conclusive if the ionisation factors in the different solvents could be assumed as even roughly equal; but we know that, where such factors have been determined, the assumption would, in general, be wildly erroneous. As Kahlenberg did not measure his ionisation factors, and they seem to be undiscoverable elsewhere, he has only made out half a case.

Two sets of experiments are, however, conclusive on the point—conclusive against the generality of Nernst's theory. The first of these is due to H. C. Jones,(*c*) who examined cells of the type

$$\text{Ag.}\left|\frac{\text{N}}{m}\,\text{Ag. NO}_3\text{ in alcohol}\right|\frac{\text{N}}{m}\,\text{Ag. NO}_3\text{ in water}\Big|\,\text{Ag.}$$

(where m had values ranging from 10 to 1,000), in order to measure the difference of potential between silver in alcohol and silver in water, and thus to arrive at the ratio of the solution pressures in the most direct way possible. He used the electromotive forces corresponding to $m = 40$ and $m = 400$, because for these concentrations the ionisation factors of $Ag.NO_3$ in water are known from Kohlrausch's work, and those in alcohol from that of Völlmer, (*d*) while the potential difference at the junction of these aqueous and alcoholic solutions is known to be extremely small. To each of the two specified combinations, therefore, Jones was able to apply Nernst's simplified equation—

$$\text{E} = \cdot 0002\ \text{T}\left\{\log.\frac{\text{P}_1}{\text{P}_2} - \log.\frac{p_1}{p_2}\right\}$$

where everything was known or measured except $\log.\frac{\text{P}_1}{\text{P}_2}$. Thus $\frac{\text{P}_1}{\text{P}_2}$ was determined without leaving much room for cavil, save for an arithmetical slip which I have found in the reductions. Correcting this slip, we obtain for $\frac{\text{P}_1}{\text{P}_2}$ the values $\frac{1}{214}$ and $\frac{1}{240}$ (*e*) for the two experiments, the difference between the two fractions being within the limits of experimental error, but their average value a long way outside those limits. We see, then, that the apparent value of the solution pressure of silver in water is at least 200 times that in alcohol. Jones, however, failed to consider two alleged possible explanations of his results. I venture, therefore, to supply the omission. (*a*) Can the result be due to the presence of unknown complex ions? To answer this we must see what effect such ions could produce. The effects will differ in different cases; but very little reflection is needed to indicate their general nature, which is, luckily, all that we need in this case. If the solution pressure of a metal be large compared with the osmotic pressure of the positive ions supposed to exist in the electrolyte, the presence of unknown complex ions will cause it to be underestimated, since we should

(*c*) *Zeitsch. Phys. Chem.*, XIV. (*d*) Inaug. Diss.

(*e*) Jones gives $\frac{1}{42}$ and $\frac{1}{48}$; but this is due to the slip in arithmetic.

imagine the back pressure of the ions in solution to be greater than it really is. If, on the other hand, the solution pressure be relatively small, we should be led to over-rate it for a similar reason. Now the solution pressure ascribed to silver is one of the smallest we know, being of the order 10^{-37} atmospheres—enormously smaller, that is to say, than the back pressure of the ions in an aqueous or alcoholic solution of silver nitrate even if it be as weak as one four-hundredth of normality Again, $Ag.NO_3$, in aqueous solution, gives rise almost exclusively to simple ions. (*f*) So we are restricted to the possibility of the existence of such ions in the alcoholic solution. But their presence there is very unlikely, as alcohol is a more associative substance than water, and it is now generally recognised that the formation of complex ions becomes increasingly difficult as the degree of association of the solvent increases. Still, they might be there. The important fact is that, if they were there, they would only strengthen the case against Nernst's theory. We should need to increase the ratio of the solution pressures—not to diminish it—in order to include them. (*b*) Can the result be due to ionisation of the alcohol? If so, we must postulate an osmotic pressure of positive ions derived from this source amounting to at least 420 atmospheres. This would involve the ionisation of considerably more than the whole of the alcohol present. It is rather too large a demand on our credulity to ask us to believe that the solution of less than half a gramme of $Ag.NO_3$ in a litre of alcohol could ionise the whole of the solvent, together with some hundred or so more ccm. of alcohol which are not there, and that without perceptibly altering the other physical properties of the liquid—such as density, viscosity, specific heat, and refractive index. After thus considering every known possibility of this particular case, I felt myself compelled to admit that the solution pressure of silver depends on the nature of the solvent in contact with it. I could see no other alternative. It seemed, therefore, reasonable to conclude that the more obvious of the various possible inferences from Kahlenberg's experiments—the inference which he drew himself—is the right one, viz., that what Jones's experiments prove for silver is true for other metals as well.

The case is greatly strengthened by the recent work of Carrara and d'Agostini. (*g*) These investigators performed experiments of the same general character as Jones's, but on a much wider scale. The metals they used were zinc, copper, cadmium, and silver; the solvents, water and methyl alcohol. Several salts of each metal were generally used. All the electromotive forces and all the ionisation factors were carefully determined. The results showed, for silver, a ratio of the solution pressures of about 2,700 to 1; while the three divalent metals agreed in giving a ratio just twice as great. The case here is at least ten times as strong as that derivable from Jones's experiments—and they alone are enough to settle the question.

(*f*) For a proof that a very small proportion of the ions is complex see Guthe, Bull. Bur. Stand., U.S.A., I.; the proportion is far too small to affect the argument in the text.

(*g*) *Gaz. Chem., Ital.* [35], I. See also Sucker's very careful review of this memoir, *Zeitsch. Elektroch.*, XI.

It follows, from the foregoing discussion, that the electrolytic solution pressure must not be identified with the osmotic pressure of the positive ions within the metal. Though the behaviour of aqueous solutions tends to suggest that this osmotic pressure is one of its factors, there is evidently another factor due to the nature of the solvent and, moreover, to the *unionised* part of the solvent, for we have shown that the ionised part cannot account for the experimental facts. But, we may be asked, if the unionised part of the *solvent* has anything to do with the matter, why not the unionised part of the *metal* also? Why, in a word, need we invoke the agency of the ions at all in order to account for the solution of a metal? It is much easier to ask such a question than to answer it. We must, however, remember that ionisation —whatever we may think of ionic dissociation—is an experimental fact. Ions are material bodies which we can weigh and measure: we can even follow their movements in the voltameter. Ionic partial pressure—whatever we think of the expression—is the name assigned to a measurable physical stress. Since the presence of these bodies and the application of this stress at a metal-liquid boundary are simple facts—whether the hypothesis to which they owe their names be true or false —it seems hardly reasonable to deny them a share, at least, in the processes of metallic solution; I am inclined, therefore, to think that translation into a less hypothetical language and an extension of scope, rather than annihilation, is the future which awaits Nernst's theory. For the present we may say that the idea of solution pressure is a very valuable one, provided we do not attempt to define it too strictly—provided, *i.e.*, that we give up Nernst's attempt to unify the theory of electromotive force in terms of the ionic hypothesis alone.

We must, then, abandon the idea of a table of solution pressures and of a voltaic series which is the same under all conditions, and be prepared to recognise that the voltaic series depends on the nature of the solvent used—to admit, in short, a different electrochemistry for every solvent, just as we were driven, 20 years ago, to admit a different voltaic series for every gaseous medium. There is, after all, nothing strange about this. It is no more unreasonable to ascribe to a metal as many solution pressures as there are solvents than to do the same thing for a non-metallic solute, which in fact everyone does. Of course, this amounts to an acceptance of Kahlenberg's position—however he arrived at it—that the relative chemical affinities of the metals are functions of their environment as well as of their own nature. All the same, we have not yet heard the last of Nernst's theory. It is still as capable as ever of acting as a guide to research, for the next great step to be taken must be the study of the electromotive force relations of solvents other than water, in order to see whether Nernst's formulæ are equally applicable to them. It seems not unlikely that a comparison of such results, derived from a large number of solvents, may be the necessary preliminary to the establishment of an adequate general theory alike of electromotive force and of chemical affinity. But we must keep an open mind on the subject, as it may be that the path to such a theory lies in another direction altogether; as old Homer was so fond of remarking, "*ταῦτα θεῶν ἐν γούνασι κεῖται.*"

Section B.

CHEMISTRY, METALLURGY, AND MINERALOGY.

ADDRESS BY THE PRESIDENT,

ROBERT C. STICHT, B.Sc., E.M.

PROGRESS IN RAPID OXIDATION PROCESSES APPLIED TO COPPER-SMELTING.

Introductory.—From a modern point of view the older history of chemistry scarcely affords a subject which is calculated to excite a keener regret in the mind of the man of applied science than the scant, one might say, almost step-motherly, support and encouragement which the industrial arts at one time received at the hands of the purer branches of "the science of the composition of substances." The metallurgist especially has a grievance in this respect. Though his pursuit has admittedly supplied the very working bases on which the speculative romance of pure chemistry has exhausted its powers for centuries, still it has not, until comparatively recent years, received anything like a corresponding benefit in return. Notwithstanding that chemistry from its infancy has occupied itself with the phenomena of combustion, calcination, sublimation, solution, fusion, &c., it has generally disdained to concern itself with the larger problems of practical metallurgy. The metallurgical adepts, for their part, lacking the requisite breadth of view, and adversely influenced by the bias which the man of practice so strongly feels against the theorist, doubtless have been guilty of an equally gross neglect of a more intimate association, and have forfeited the scholastic advantages which a more brotherly attitude would have afforded. Nevertheless, it cannot be denied that the practices of the basic branches of metallurgy reached a creditable state of maturity along purely empirical lines, in utter independence of all theoretical guidance, long before any semblance of chemical lore was rational enough to be worth listening to.

But, though often coming later, theory should properly ultimately overtake and outrun practice, from the very nature of its functions, because, of the two, it alone possesses the faculty of prevision. Thanks to the enlightenment which the disciplinary teachings of an abundance of error have begotten, we feel, at the present time, that this desirable priority of movement has fully established itself, and that theory is leading. Nevertheless, the student interested in the development of the smelting arts cannot but be appalled by the economic wastes which have accompanied the metallurgical work of even the more recent past as a consequence of imperfect chemical knowledge, and nothing will, in this regard, be more incomprehensible to him than that only a poor century and a quarter have elapsed since the most important chemical phenomenon with which metallurgy concerns itself, viz., oxidation, or combustion in air, came to be rationally interpreted and explained. To modern feeling, swayed perhaps by the strenuousness which pervades the moment, it also seems painfully singular that, prior to this event, a full century of phlogistic romance, unintelligibly neglectful of the evidence of the senses, should, moreover, have stifled the all-important earlier recognition, ushered in by Boyle and definitely formulated by Mayow (1669), that the atmosphere is composed of two principal constituents, one of which is the supporter of life and of the combustion of combustible bodies, while the other is not, but extinguishes both. Time has, however, made amends for all this. We may well deplore the phlogistic period, but we are now on the victorious side of the great conflict which terminated it, and there is no ground for the fear that an equally serious lapse on the part of pure chemistry will ever again impede the onward march of its practical applications, by limiting them essentially to the inefficient sphere of mere empiricism.

Pneumatic Processes.—It may truly be said that the natural sciences and the arts only began to draw the true breath of life with the discovery of oxygen, and the new birth of chemistry in the Lavoisierean theory. An honored predecessor in this chair, Professor Mica Smith, of Ballarat, five years ago gave us a fascinating historico-chemical address on "The Study of the Chemistry of the Atmosphere, and whither it has led." The scholarly comprehensiveness of that review has tempted me to lay before you a specialised exemplification of the surpassing importance of that study in its bearing on the technology of a single metal, namely, copper. There is a particular pyrometallurgical branch of applied science into which this research has thrown a wonderful measure of illumination, and to the creation of which, in fact, after centuries of darkness on so simple a subject, the oxidation theory first gave an incentive.

It may safely be said that the work alluded to was impossible before the nature of the atmosphere was correctly understood. I refer to the so-called "pneumatic processes of smelting," meaning methods of metallurgical treatment in which atmospheric air, or the oxygen in it, is made to play a very special *rôle*. In the last instance, nearly all processes of smelting, broadly interpreted, are "pneumatic," since they require the use of air for the production of fusion temperatures by means of proper fuels. But, in the more restricted sense, the term is ordinarily used for such processes in which fusion is accomplished with the aid of fuels other than those commonly comprehended under that name in everyday life. These special combustibles are the metals and the metalloids, and the conventional carbonaceous fuels are generally not even used as accessories. Pneumatic processes may be said to avail themselves of "chemical fuels," a term merely suggested for the sake of a distinction. One absolutely essential feature of the work, which they presuppose, is intensified activity of combination, or accelerated velocity of reaction, without which they are not feasible. Hence they are also referred to as "rapid oxidation processes," and, in a great measure, it is quite correct that the feature of rapidity is the predominating one.

From the nature of the case, rapid oxidation is, however, bound to rapid supply or delivery of the oxidising agent, therefore also to an adequate perfection of the mechanical apparatus serving this purpose; and, as I need not remind you, the oxidation theory and the improvement of motive power by the introduction of the use of steam were practically contemporaneous, so that advancement in the metallurgical application of the former was necessarily conditioned on the advancement of the latter. In other words, the chemical utilisation of pneumatic energy was wholly dependent on its mechanical production, and, in consequence, had to wait on the latter, even after the battle of the new combustion theory had been fully fought out. This required some time, in fact, quite three-quarters of a century. There is no doubt, however, that if the mechanical perfection of blast-producing machinery in the days of Lavoisier had been anything like what it now is, the pneumatic smelting processes would have reached their present status much earlier. The bent to draw the last practical inferences and corollaries from the new chemical theory was strong in those who accepted it, as is evidenced by the literature of the time immediately following, but the machinery at their disposal was weak, and current ideas as to the practicable magnitude of smelting paraphernalia remained cramped, particularly in the metals other than iron.

It is patent also that, as long as the nature of oxidation was not itself understood, the idea of reaping special benefits from it, by expediting it in connection with "chemical fuels," could not occur. But the feeble blast machinery of those days (from the beginning of things up to the end of the eighteenth century and the beginning of the nineteenth) was incidentally responsible for instilling obstructive traditional notions of other kinds also, based on mere hereditary respect for existing practices, and carried to censurable lengths. For instance, we find it was considered a serious error, even in the middle of the last century, to blow air into lead and copper furnaces through more than a single tuyere; and, to further illustrate this spirit, it may be remarked that, if the proper diameter of this solitary tuyere, as determined by custom and established practice, was $1\frac{3}{4}$in., only the most disastrous results were expected to follow, and the smelting to be completely ruined, if it was increased to 2in. It is obvious that under the sway of such ultra-conservative tendencies even the rapid oxidation of carbonaceous fuel would suffer a check, let alone that of combustibles not carbonaceous. Fortunately, our present day reverence for established practice is less, and our progressiveness greater.

Metals and Metalloids as Fuels.—With regard to such non-carbonaceous fuels, and more particularly metallic fuels, it is true that even the ancients possessed a certain fund of knowledge. The easily observable combustibility of lead and copper supplied examples. But the chemical feeling which renders the combustibility of metals a familiar notion is not widespread even to-day, and primitive attitudes of mind in this connection still prevail. Thus the more marked inflammability of sulphur in its elemental state, which held the scientific imagination in bondage for centuries, appears to be responsible for a curious traditional trait which still characterises some of the current metallurgical thinking of the present day. It is much more common than it should be to attribute the generation of heat in the pneumatic processes here dealt with, either solely or chiefly, to the sulphur contained in the mattes and ores treated, and to overlook the iron, zinc, lead, &c. This remark applies even to standard authors, and presents a curious instance of the survival of alchemical notions—holding their own notwithstanding modern training. The intentional combustion of a metal, perhaps, excites a latent feeling of waste, while that of the metalloid appeals as advantageous, or else the burning of the former is valued only as a curious, practically useless, fact, the appreciation of which does not transcend the province of laboratory experiments. When Ingen Housz, about 1780, first showed his philosophical friends the intense brilliancy of the light manifested by the combustion of a steel watch-spring in an atmosphere of oxygen, doubtless no more importance was attached to this striking phenomenon as the forerunner of everyday metallurgical operations, carried out on a huge scale, than is even now applied in the case of phosphorus, the combustion of which he also showed them. It is probably very much older knowledge that a piece of iron, heated to a red heat and very rapidly whirled about in a circle, will heat up higher and throw off sparks. But, until the Bessemer steel process came into vogue, no special industrial importance can have been attached to this fact. Dr. Percy also mentions an old practice of the nailmakers to maintain the heat in the nails during forging by projecting a *cold* blast upon them ; the gulf between this contradictory expedient and its correct chemical appreciation can, however, only be bridged over by a quite modern scientific interest in such phenomena.

First Appreciation of Fuel Value of Sulphides and Growth of the Idea.—Before any truly scientific application or even interpretation of the fuel values of metals could find its way into metallurgical circles, it was necessary that the combustion theory of Lavoisier should be firmly established in the field of theoretical metallurgy, and this was a matter of slow growth. It is only of recent years that metallurgical chemistry can be said to be walking side by side with general chemistry. In the past it has always lagged behind, and has been slow to accept new doctrines, as is customary with practitioners who are engrossed in the purely operative aspects of their work. Nor could Lavoisier's philosophy alone really confer practically telling benefits on metallurgy before the equally important subject of stoichiometry had found an entrance into those circles. Before Berzelius finally (1818) co-ordinated the reasonings of Richter, Berthollet, Dalton, and, supplementing them by his own researches, offered his simple theory of chemical proportions to the world, even the comparatively primitive reactions of metallurgy could not be reliably followed quantitatively, and, speaking generally, the quantitative aspect of his labors is ever paramount with the metallurgist. The distinction of having placed metallurgy on a firm chemical footing in the light of the teachings of these authorities belongs to a Freiberg professor of chemistry and metallurgy, W. A. Lampadius (1772-1844), who, having in the course of a long and busy academic life, lived through the whole sequence of doubt, half-acceptance, and final unreserved allegiance to Lavoisierean ideas, no doubt much more acutely felt the practical change effected by the new thought than do any of his eclectic compeers of to-day. He wrote voluminously on the subjects of both the theoretical and the practical metallurgy of all the metals, and his writings also include treatises on atmospherology—evidence of the keen originative thought he was disposed to devote to pneumatic phenomena. He gives greater prominence to the combustibility of the metals and their usefulness as sources of heat, even in the blast-furnace, particularly in connection with the ordinary sulphides, than any authority save the more recent writers. He speaks definitely (1817) and clearly of the combustion of the constituents of iron pyrites and galena, &c., in the older pyritic smelting method (Roharbeit), quite distinct from roasting or calcining, and refers to the metals and the metalloid as jointly acting as fuels, though occasionally at the unavoidable risk of the scorification of the metal to be saved. He thus evinces a more thoughtful emancipation from the trammels of alchemistic philosophy, which interpreted all fuels as "sulphurs," than do many moderns, who ignore the dominant thermal effect of the accompanying metal. Judging by the text-books his immediate followers do not appear to have remembered this important point later than the forties; and in the subsequent hand-books, before the early seventies, one also seeks in vain for any reference to the fuel qualities of sulphides under circumstances of more rapid oxidation, such as are exemplified in blast-furnace treatment. The elimination of sulphur in that furnace, though empirically known to the profession, cuts no figure in the standard treatises until the imitative application of the Bessemer idea to sulphides again gives it a certain prominence, which has since become greatly accentuated.

Both natural and artificial sulphides, *i.e.*, mattes, claim the attention of the metallurgist almost to a greater degree than the oxides, and their consideration is an all-important preamble to his schemes of treatment. A large proportion of smelting operations, especially in copper, is devoted to the production of artificial sulphides, simply for reasons of convenience, for the purpose of achieving a clean mechanical separation of the metal-bearing portion of the original ores from the valueless portion, and the utilisation of sulphur as a medium for the collection of the metal in a convenient form is particularly practised in cases where there is a superabundant formation of slag. This sulphurisation of the metal is then followed up by oxidation, mainly for the purpose of assisting the elimination of the worthless elements which accompany the metal to be recovered into its combination with sulphur, and which lower the tenor of the matte thus formed. Chief among these elements is iron, ordinarily speaking, the third constituent of mattes, in addition to sulphur and copper.

Now, the behaviour of the metals towards oxygen is controlled by their degree of affinity for that element, and this degree is definitely expressed by the heats of formation of the respective oxides. If the heat evolved is insufficient for the purpose of maintaining the resulting solid products of the operation in a molten condition, then no fusion will result, and the segregation of these solid products from each other, which can only be achieved by ordinary physical means, *i.e.*, gravity, cannot be effected. Fortunately, the heats of formation of the oxides of both iron and sulphur, though not great, are fully sufficient for bringing about this physical desideratum, especially when advantage is taken of the circumstances that temperature of combustion increases with pressure, and that temperature and the degree of concentration of the reacting bodies directly accelerate the velocity of chemical reaction itself. Conversely, therefore, the time element is a vital factor in oxidation processes if a separation of the products by purely physical means is desired, such as by differences of specific gravity, which constitute so important a feature of smelting processes in general. The necessity of concentrating the reactions involved into a minimum of time, and, it may also be added, as far as the gaseous oxidising agent is concerned, into a minimum of space, is thus obvious. Under all circumstances, whether oxidation proceeds slowly or rapidly, only the same amount of heat is generated. But its dilution, so to say, by spreading it over long periods of time, is inimical to the attainment of a pyrometric intensity reaching and surpassing the fusion points of the solid (not gaseous) products involved.

However, these observations are premature as far as the history of our subject is concerned. The facts embodied in them were not inferred for a long while, even from the data which the early thermo-chemical researches of the second and third decades of the last century afforded. Thus the thermal value of iron, among other elements, was determined by Despretz in 1827. The posthumous writings of Dulong, in 1838, gave exacter results for iron, sulphur, copper, zinc, tin, &c., and were followed by Hess (1840), and the still more refined researches of Andrews (*ca* 1848) on these and other elements of direct bearing on our subject, out of the number of those investigated. Subsequently Favre and Silbermann (1852–3) added their comprehensive and still largely authoritative figures for a much more extensive list, though in the meantime many of their results have also been corrected, Thomsen (1853–1886), Berthelot, and others of the more recent thermo-chemists adding enhanced reliability by the employment of more perfect calorimetric methods and apparatus. All this information, however, remained for the curious and the theoretically inclined. The metallurgical practitioners, with typical supineness, allowed it to go unheeded until the early seventies, when the first calculations of the thermal energy inherent in sulphide ores and furnace products make their appearance in literature (Bode). Even the first practical large scale attempts towards the rapid oxidation of copper iron sulphides (1867–8) —of which the general idea was suggested by the sustained success of the Bessemer steel-conversion process, the source of heat in which was by that time universally understood—were not followed through by means of thermal calculations until at least a decade later (Hollway for ores, 1878, Balling for mattes, 1885).

As intimated, it was only the intellectual fillip given to pneumatic smelting in general by that purely practical invention, the Bessemerising of pig iron, in 1855, which stirred the ranks of the other metals into imitative activity. In the case of iron the combustion of that metal itself naturally did not form the object. However, the elimination of certain impurities (sulphur, phosphorus) had engaged the attention of the ironmasters ever since the invention of the puddling process, and much was hoped for in this connection from the Bessemer process. Still, the absence of anything positively analogous in copper or lead smelting divested these particular efforts of pertinent or immediate interest in the latter fields, and further time was lost.

With the rise of chemistry, *i.e.*, with the fixation of the oxidation theory as a foundation truth, coupled with the concurrent better comprehension of the fundamental chemical differences between pig iron, steel, and wrought iron in terms of carbon, the pneumatic processes first found a nutritive soil, out of which they could grow. Unfortunately, the early attempts at applying any sort of rapid oxidation to the refining of pig iron suffered from a partly chemical, partly mechanical hindrance which arose from the erroneous appreciation of the oxidising qualities, or rather, fuel-value of steam—a mistake that was subsequently carried into copper-smelting, and is not extinct even to-day. No doubt the greater ease and economy with which steam of high pressure could be produced, as compared with compressed air, suggested these attempts on the mechanical side. On the chemical the motive was the expectation that the tremendous heat-value of hydrogen would guarantee temperature, while the oxygen would serve to remove the impurities. An associated chemical consideration was that, since the waste of iron by the formation of cinder is very considerable in puddling, an excess of air, or of oxygen, could only be regarded as an evil. Consequently air was avoided, and everything hoped from steam. This prejudice against superfluous air—an evil of which the copper and lead smelters themselves had abundant practical evidence in their own work—doubtless further retarded the appreciation of the pneumatic principle in the case of the metals other than iron.

Review of Early Suggestions and Attempts in Iron before Bessemer.—The history of the rapid oxidation idea as applied to iron-smelting, though foreign to our subject, is still sufficiently closely related to it in these its pristine days to warrant a brief digression for the purpose of marking the course of development.

The earliest positive conception on this subject, and thus virtually the prime movement in this entire metallurgical department, seems to have originated with Professor A. Guenyveau, of the Paris School of Mines, who, in 1835, (*a*) advocated the employment of a mixture

(*a*) Wedding, translation of Percy's "Iron and Steel," 1874.

of air and steam as a powerful means of more rapid oxidation than by air alone, the mixture to be projected upon the surface of the bath of molten iron in the puddling furnace. A little later, in the forties, Reuben Plant is said to have used compressed air alone in this manner, and a similar method was tried at Dowlais and Crom Avon in South Wales for a time, but crowded out by the Bessemer process. A variation held its own for a period, which was the method of Richardson, Plant's former partner, who at first introduced compressed air into the bath by means of a curved hollow rabble through the working doors, and later on by means of a specially built pipe inserted vertically through the roof of the furnace. He also proposed to use steam and air alternately, his object, in all endeavors, being the purification of the iron by the removal of sulphur and phosphorus. This, however, did not result to any satisfactory degree, for reasons which are patent to the iron industry now, but were long misunderstood then. Plant (1849) similarly proposed to use steam alone. In 1854 Jas. Nasmyth, of steam-hammer fame, also patented the use of a current of steam introduced below the surface of the metal by means of a curved pipe held in the hand and reaching down to the lowest portion of the bath. He included the employment of air, but appears to have preferred steam. It was claimed that the introduction of steam for from two to five minutes, shortly after the iron was melted, was attended by very beneficial results as far as purification was concerned. But the method was not a success. A far greater oxidation of iron took place than was expected, or could be controlled, and the decomposition of the steam caused a serious lowering of the temperature, which had to be made up by extra firing. The point involved is that sulphur can only very slightly be removed by dissociated steam, and phosphorus not at all, under the conditions of the work. The very important absorption of heat in the decomposition of the steam might have been foreseen, but was long in being appreciated. Moreover, Deville had previously shown that iron decomposes steam all the less the higher its temperature is. Even within the puddling furnace there are temperatures at which no decomposition takes place, a fact which makes these attempts towards the removal of sulphur and phosphorus futile. These particular efforts at purifying pig iron with steam, or with a mixture of air and steam, as remarked, are of some interest. They are the precursors of numerous attempts having the same general object in copper-smelting, with identically the same fruitless results.

The notion of employing air alone under considerable pressure, in a manner quite distinct from its application as a mere adjunct to the puddling or the refining of iron, does not appear to have arisen in Europe prior to Bessemer's day; but there is no doubt that, from the purely chronological point of view, the scheme was first conceived in America. I refer only to the general pneumatic principle of treating the substance in a molten condition with a blast of compressed air, and thereby further raising its temperature. It in no degree diminishes Sir Henry Bessemer's deserts, as the first practical working exponent of this principle, that another merits the acknowledgment of having conceived the idea earlier than he did. The priority of the thought, as well as its practical execution in a primitive way, is even attributed to the ancient Chinese, for it is said that Wm. Kelly, of Kentucky, the chronological forerunner of Bessemer, was indebted to members of that race, whom he employed, for the knowledge. However this may be, Kelly made his first unpractical attempts at blowing compressed air through a body of molten pig iron, in a manner related to our present practice, in 1847 (*b*). The mechanical problems involved were, however, too much for him, and even in 1857 he was scarcely a step further with the translation of his pneumatic concept into the language of practical mechanics. It is here that the genius of Henry Bessemer shone: and who knows but that, were it not for him, a succession of Wm. Kellys might still be tinkering away at the proper solution of the scheme to this day! Neither Kelly, nor subsequently Parry, had the special subtlety of feeling for mechanical execution which distinguished Sir Henry, and the latter's priority of real invention remains unaffected by the abortive efforts of a few others to utilise the same principle. As Wedding (*c*) remarks, apropos of this point—"It can hardly be called an invention for someone to have an idea respecting the application of an otherwise well-known natural law without at the same time being able to indicate adequate ways and means for its execution." Incidentally, it will be recalled that to these early men, including Bessemer himself, the feasibility of the scheme was considered to lie in the sufficiency of the calorific value of a modicum of carbon in pig iron to maintain a mass of the latter at a high temperature, while it was itself being consumed.

Leaving this digression we may resume the historical thread. Passing over Martien's proposal to drive out the impurities from pig iron by blowing a blast of air through it while on its way, in a liquid state in a runway or gutter, from the blast furnace to the puddling furnace, but in which proposal no appreciation of the essential fact was expressed that enough heat would thereby be evolved to keep the metal in that state, and, in fact, to overheat it instead of cooling it, we come to Parry's attempt at steam-refining in 1856. This consisted of blowing a current of superheated steam, accompanied by a large quantity of air, through a small number of tuyeres into a small reverberatory furnace erected immediately in front of a blast furnace, and holding a small charge of pig, direct tapped into it (35cwts.). The arrangement saved the fuel for the remelting, and also removed some sulphur, but the method was finally abandoned. The decomposition of the steam undoubtedly caused an absorption of heat, and the claim advanced, that an important saving of fuel was effected, may be boiled down to the fact first stated, *i.e.*, the abolition of the remelting.

A much more important and promising idea, constituting, in fact, a quite serious rival claimant for priority, which, but for a managerial veto placed on further experimenting after the failure of the first attempt, might have deprived Bessemer of his laurels as far as they

(*b*) Jos. D. Weeks, *Trans. Am. Inst. Min. Engrs*, 1896, vol. XXVI.

(*c*) Percy-Wedding, "Iron and Steel," 1874.

rested on the discovery of a chemical fact, was Parry's trial with an airblast, made only a couple of months before the publication of Bessemer's first patent of 1855. A horizontal system, or grid, of wrought-iron pipes, connected with the blast, was placed in the bottom of a reverberatory furnace, with a large number of wires stuck vertically into the upper portion of the pipes. Then fireclay was tightly rammed around the structure, so that, upon the withdrawal of the wires, the clay bottom was left perforated by about 100 small holes, all accessible to the blast. In this feature of bottom tuyeres even Bessemer was thus anticipated here. After careful drying the furnace was heated up and about one and a half tons of pig iron were run in, the blast having been previously let into the tuyere system. An exceedingly vigorous action shortly ensued, the bath greatly heating up, but, unfortunately, the metal broke through the side of the furnace, stopping the experiment, and a repetition was not permitted. The merit lies in the fact that the execution of the idea was predetermined and premeditated, and the discovery of the increased, almost volcanic, action of the metal was not the result of an accidental observation only, made in some casual way. Together with the rise in temperature this action was consequently discovered, by both Kelly and Parry, before Bessemer. But their manner of materialising it in a proper mechanical form was impracticable and crude.

Bessemer's Invention.—The next events in order now are Bessemer's own inventions. These are so well known that I may avail myself of the circumstance that the application of the pneumatic principle to the manufacture of steel and wrought iron is really foreign to my subject, and confine myself to a brief résumé, virtually only the statement of a few facts and dates, to note the march of time. The first Bessemer patent was granted on October 17th, 1855, and stood for a method of forcing currents of air or steam, or of air and steam, into and among the particles of molten pig, &c., the metal so treated retaining the fluid state and being readily poured and run into moulds. This patent applies to Bessemer's very earliest experiment, in which the pig was melted down in a crucible, contained in a pot furnace, the gases being introduced by means of a pipe inserted into the metal from the outside. The description states that steam cools the metal, but air causes a rapid increase of temperature, so that the metal passes from a red to an intense white heat. This increase in temperature typifies the main essence of the Bessemerising process. Subsequently it remained the inventor's chief labor to perfect the mechanical side of his invention to the fullest and most enduring extent. The second patent, two months later (dated December 7th, 1855), already embraces all the essential detail features of the Bessemer process and its practical execution in the form in which these have maintained their vogue to the present day. Currents of air, or steam, are forced up through the molten metal, contained in a suitable vessel, spherical or egg-shaped, built of iron and lined with refractory matter (firebrick), and which may be suspended on trunnions to allow of tilting, the vessel being closed at the top, with the exception of an opening for the introduction of the molten metal and for the escape of the gases, sparks, etc. The chemical action going on within is attributed to the decarburisation of the pig iron, the temperature evolved being due to the combustion of a part of the carbon. Subsequent patents, extending through 1856, recognise further features of the process, which we do not need to go into. Suffice it to say that the fertile facility of the inventor in a few years wholly exhausted the budget of possible mechanical variations of apparatus which could be made use of, and was not long in finding the type which has since permanently established itself in iron practice. This is the laterally suspended, tiltable, pear-shaped converter, with vertical bottom tuyeres, which dates from 1858. There is no doubt that this tilting movement has very largely contributed to the utility, as well as renown, of both the apparatus and the process. It is, however, not original, nor is this the first time that Bessemer availed himself of it—*vide* his prior use of it—for heating and melting apparatus in the manufacture of bronze powder and of optical glass (*d*). The mechanical movement is doubtless of an ancient date, applied to household utensils among other things. A pertinent metallurgical precedent may be seen in the tilting cupola furnaces, hung on trunnions and moved by a lever, which, at Bessemer's time, were still in use in Sweden for the melting down of cast iron for foundry purposes; size 8ft. high, with two tuyeres and a taphole in the same level, a little below the line of suspension (*e*). Bessemer adapted the general mechanical idea to his specific wants, adding the hollow trunnion and the wind box for the supply of the blast, and the geared movement, which he first actuated by a hand crank, later by means of the well-known hydraulic apparatus.

Of special interest is the form of 1862, which is the prototype of our customary upright copper-converting vessel, with raised side tuyeres entering the body horizontally a certain distance above the bottom, and which will be referred to again later on.

Chemically, progress was much less rapid, and, from an ultimate point of view, we are far behindhand in this respect even to-day. In the absence of a proper understanding of the chemical features, pressure and temperature seemed to the inventor the principal essentials, and he hoped, with adequate pressure and a suitably constructed vessel, having an almost closed opening, to attain temperatures of up to 50,000° F. This aspect of the process owes much to Swedish engineers, who, while neglectful of the mechanical side (as is evidenced by their retention of the old fixed vessel of 1855–6), were a mainstay of the chemical principles of the method during its years of depression, when it failed on the impure English ores. Bessemer owes immensely to Goranson and others, who perfected the pneumatic side by properly appreciating its superior importance (*f*). They increased the tuyere area, thus obtaining a more abundant air supply, with a corresponding

(*d*) Sir Henry Bessemer, F.R.S., "An Autobiography," 1905, pp. 71, 105.

(*e*) See, for instance, Wehrle, "Probier-u. Hüttenkunde," 2nd ed., 1844, plate 6, figg. 165-6.

(*f*) Harbord, *Steel*, 1904.

shortening of the duration of blowing. This greatly increased the temperature and overcame the difficulty of cold pouring, which was common before.

In August, 1856, Bessemer communicated the salient features of his discovery and invention to the British Association, in a short paper read before the Mechanical Section at its Cheltenham meeting, and entitled "On the Manufacture of Iron without Fuel." The curiosity which this characteristic title aroused gave way to extreme enthusiasm in circles then capable of appraising the facts presented, and the rapid oxidation idea generally received a tremendous uplift from this—in fact, one may say, its first valid start. Men in other branches of work began more seriously to appreciate its nature and importance, and efforts to widen its application, by extending it to the other metals, eventually followed. The most nearly related one of these, owing to its comparative non-volatility, is copper. As far as that metal is concerned it is an interesting fact, by the way, that Bessemer himself does not appear to have thought it worth while to investigate the applicability of his process, although, as a manufacturer of gold bronze in a very large way, he was a fair consumer of the red metal. One would like to know his special reasons for dismissing the subject. His universality justifies the assumption that the idea occurred to him, just as it did to others immediately after the announcement of his patents. Possibly his unfavorable experiences with the impurity of most English coppers may have dissuaded him. This decisive step, which was to work as significant a revolution in the world of copper as the mother invention did in iron, was left to others. However, the stamp of genius can hardly be said to be impressed on the respective earlier efforts, for they were generally only shy and halting innovations within, not radical departures from, the current Welsh inheritance of our time-honored reverberatory furnace practice.

Early Adaptations of Bessemer Idea to Copper.—The first adaptation of the Bessemer idea to other metals reveals itself in a patent to Gossage, dated August 20th, 1856, which was for the treatment of ore by means of compressed air; but is not explicit on the subject of the exact scope of the invention, and does not mention copper. The second adaptation more nearly follows the original in principle, but is, in point of execution, only a harking back to the pre-Bessemer pneumatic refining days of the iron puddlers. It is the patent of Wm. Keates, dated September 4th, 1856, and refers directly to copper ores, for the first time. It is evidently inspired by the Bessemer patents for the claim of introducing atmospheric air at a pressure "into and through or over the surface of the mass of melted regulus or matt containing copper," The invention is further described as introducing the "aforesaid currents for the purpose of desulphurising regulus or matt of copper." A professional associate of the patentee subsequently (1878) characterised it as not having "contained the idea of oxidising iron and melting the charge by the heat generated by the oxidation of its constituents. It was the application of a hot or other blast to a roaster furnace, for the purpose of getting rid of the sulphur in the roasting process." This is imperfect chemistry, for a desulphurisation could not, under the circumstances, be effected without a simultaneous oxidation of the iron. But the remark goes to demonstrate that this fact was not taken into account, and that the Keats patent is not a valid precursor of either the Hollway process for treating pyritic ores, nor of the so-called Manhès process for treating mattes.

A few days later, on October 18th, 1856, Isham Baggs patented a method in which he proposed to smelt the ore raw, or after calcination, draw off the slag, and then inject a current of air, oxygen, or other gas into the metal bath. Next in order are patents by Glass, in 1862, pertaining to the similar pneumatic treatment of antimony ores. In France Leclerc, about the same time, patented the treatment of arsenical and antimonial copper ores by the injection of air, and then of steam, to refine the metal, and remove arsenic and antimony.

The above appear to be the earliest attempts to apply the Bessemer method to copper materials. To follow this particular line of mere ideas further would serve no purpose. But little success can have attended these patents in practice, as none of the proposals have survived. There was no prominent practical suggestion, embodying the true pneumatic principle, submitted to the copper industry for some time after 1856, a state of suspense which the prejudice created by Bessemer's own tribulations with his steel process no doubt was largely responsible for.

A decade after Bessemer's original patent, however, we finally find the pneumatic principle begin to take root in a manner which led to more permanent things, of which the first expression is contained in an American patent taken out in 1865, by A. Raht, in Tennessee, for the treatment of copper mattes in a Bessemer converter. Unfortunately this idea was not put into effect on an efficient scale, for want of capital, and it remains merely a nominal precursor of the present practice. The year after, in 1866, the celebrated Austrian Rittinger experimented on a working scale with the enrichment of mattes by rapid oxidation. He again only used a curved hollow rabble, sunk into molten matte in a reverberatory furnace, but—a new point—with the simultaneous addition of quartz sand for the scorification of the iron. This is the first positive appearance of the important feature of an intentional slagging of the ferruginous base. After this preliminary enrichment was completed the regulus was to be roasted to blister in the usual way, and the refining finished in the same furnace. The experiments, then interrupted by war, were repeated by Rittinger at Schmöllnitz, Hungary, in 1871, but remained inconclusive, because of the insufficiency of the blast at his disposal, which did not create a proper energy and intensity of reaction. However, several calcinations and fusions of the matte were avoided and saved, and the black copper stage was sooner reached. (*g*)

An interesting patent of about this time is that of Dixon, January, 1869. It refers to the employment of a blast furnace, similar to a pig-

(*g*) *Oesterr. Zeitschr. f. B.-u. H.*, 1872.

iron cupola, built in two parts—a fixed upper one, supported on columns, and a lower one, detachable therefrom for repairs. Copper matte was to be reduced in this apparatus by the pneumatic method, by passing a blast through an accumulation of molten matte in the lower portion, the upper level of which mass was to stand a little higher than the tuyeres. The operation was as follows:—After heating the furnace up with coke, a quantity of sand or other silicious material, corresponding to the iron contained in the matte, and made into balls with an admixture of tar, was first thrown on top of the coke bed. The matte, broken into small pieces, was then fed in layers, alternating with coke and quartz. The blast was gradually increased, and, as soon as the matte-level rose above the tuyeres, a violent action took place, accompanied by the copious emission of fumes of sulphurous acid. The method was claimed as adaptable to the treatment of pyritous ores, and, though evidently nothing has come of the whole proposal, it is an interesting anticipation of Hollway's ideas on the blast-furnacing of pyrites, *i.e.*, of modern pyritic smelting.

Chemical Oxidation Processes, &c.—Following the above order of development, we would now enter upon the true and actual initiation of genuine pneumatic methods, in the sense of the rapid oxidation of mattes, but, as a matter of convenience, let us speak of a few proposals of a by-the-way character which sprang up about this time. The most important of these was a scheme of accentuated oxidation with the aid of other oxidising agents than the atmosphere, namely, solid chemicals, which followed in the footsteps of similar proposals in the iron industry, notably the processes of Hargreaves and of Heaton. For a short time these chemical processes were, by some, accepted as serious rivals of the Bessemer method itself, and though they certainly would have been more justified in the treatment of copper than of iron, they have not made more than a passing impression in either metal. The earliest of these treatments for copper seems to be that of Low,(*h*) who, in 1859, proposed to subject coarse metal (low-grade matte) to the oxidising influence of currents of air in a reverberatory furnace, adding to the molten bath predetermined quantities of a mixture of peroxide of manganese, litharge, and saltpetre, the composition of this mixture to vary with the ores. The object was to scorify and oxidise iron, sulphur, arsenic, &c., and to work up to metallic copper. The process was said to decrease the duration of treatment from 10 days to 36 hours, and to save correspondingly in fuel and labor. Nothing further was done along this line, however, until 1870, when, following one of Bessemer's patents, involving the addition of saltpetre, and, under the stimulation of the flurry caused by the chemical-puddling schemes mentioned above, Wagner (*i*) proposed to adapt the notion to copper mattes. This idea (which in its original conception really dates back to Patera, in 1855) was to fuse them with 15 per cent. of equal parts of nitre and soda, oxidising the protosulphide of iron into oxide, and, by cautious application of the chemical

(*h*) *Journal des Mines*, 1859, No. 28.
(*i*) *Berg-u. Hüttenmänn. Zeitg*, 1870, vol. XXIX., p. 133 *et seq.*

flux, reducing metallic copper out of its sulphide, while a sodium sulphate slag would result capable of carrying in solution the non-cuprous oxides. The method, it appears, was not fully worked out, and the idea has found no further entrance into copper, and is not likely to do so, though an analogue is in use for nickel.

Another out-of-the-way process of rapid oxidation of mattes, but exhibiting more novel mechanical features than chemical ones, which belongs to this period (the late fifties), is that of von Rostaing.(*j*) Molten matte is poured on a disc of refractory material, which is caused to revolve at a high rate of speed, say 2,000 revolutions a minute. The stream is thus divided into so fine a spray that each rebounding particle, in its passage through the atmosphere, becomes thoroughly oxidised. In this way low-grade matte may be deprived of 37 per cent. of its sulphur contents, and the copper tenor correspondingly increased. There is, of course, no simultaneous increase of temperature, for the particles congeal. But the interesting reversal of the usual procedure in the mechanical execution of the pneumatic method, consisting in projecting the substance to be oxidised through the gaseous oxidising agent, instead of the latter through the former, together with the enrichment which the matte receives (and which is a chief feature of pneumatic smelting), may justify the reference. There have been some modern replicas of this general conception, but it is, on the whole, foreign to current tendencies.

Causes Contributing to Delay in Application of Bessemer Idea to Copper.—We now return to the time when the first valid attempts were made to transfer the distinctive features of Bessemer's great invention to the work of copper-smelting in all earnestness, and in a competent, thorough, and dynamically adequate manner. The realisation of this transfer had, so far, transcended the operative ways and means of earlier experimenters and patentees—a scantiness of equipment which lead to half measures, falling far short of the actual capabilities of the principle, even in the comparatively narrow sphere of the red metal. Kupelwieser, writing in 1869, (*k*) briefly explains the absence of headway in the application of the Bessemer process to the production of metals other than iron by saying that it was owing to a variety of causes. In part the delay was due to the expense of the special and costly apparatus required for experimenting. More prominent still, however, was a serious fear of heavy metal losses. An erroneous sentiment no doubt prevailed at the time in this respect, nurtured by the knowledge that even the slow-going Welsh roasting process yielded excessively rich slags, so that, in all chemical probability, the accelerated pneumatic method would very injuriously aggravate this evil. Lastly, he attributes the manifest hesitation displayed to an apprehension that success would only be achievable along lines of very considerable operative magnitude. This belief sprang from certain experiences with the Bessemer method for iron, in which a contracted scale of working had so far proved quite dis-

(*j*) *Bull. Soc. d'Encourag.*, 1859.
(*k*) *Oesterr. Zeitschr. f. B.-u. H.*, 1868, vol. XVI., No. 50.

astrous. This experience induced a strong disinclination to test the applicability to copper with the use of small quantities only; while the courage, both financial and metallurgical, to face the possible loss of large quantities of metal through miscarriage of experiment, was not fostered by the cramped manipulative conditions under which all copper-smelting was then carried out. It required an exceptional working environment to provoke the necessary boldness.

Unfortunately for their renown, the first successful investigators of the true Bessemer principle applied to copper were themselves not as much impressed with the results of their labors as the modern reviewer of their endeavors is persuaded to be. Still, notwithstanding this diffidence on their own part, there can be little doubt that a veracious historian is compelled to bestow upon them, without reserve, the honor of having first demonstrated the feasibility of the Bessemerising of copper mattes to metallic copper in an absolutely convincing manner. The time of which we are speaking were the years 1867-8, the place was Bogoslowsk, in the Ural Mountains, and the agents were three Russian engineers in the Government service. The facts which these men established were of far-reaching import, but they undervalued them. No present-day experimenter, however modestly constituted, would read into the same results an equally restricted scope of usefulness. On the contrary, with his wits sharpened by the testimony of numerous similar instances, in which unforeseen industrial mountains have grown out of chemical molehills, he would rather be inclined to magnify the value of every at all practically useful or significant feature into one of permanent and consequential importance, especially when on the scent of a patent. Not so the Russian engineers referred to. After conclusive empirical evidence, on a fair working scale, that the Bessemerising of copper mattes was within the region of achievable things, they withdrew from the field, reported semi-adversely, and left the practical rediscovery of the facts they were the first to note—together with the settlement of a few bothersome, but actually quite trifling, practical difficulties—to other hands. The latter are now currently credited with the entire invention; but, though they are unreservedly entitled to the distinction of having made copper-converting a complete practical success, it will be noted that this success was won on purely eclectic lines, *i.e.*, that every element which led to it had some forerunner, to which the priority properly belongs.

First Practical Investigation of Subject by Semennikow, von Jossa, and Laletin.—It is only natural that the absence of powerful pneumatic appliances at copper-smelting plants suitable for the purpose, and the fear of metal losses, should have restrained the copper men of most localities from branching out into the unknown. A happy conjunction, however, brought the requisite apparatus and materials into close juxtaposition with each other in the isolated locality named above, on the western boundary of Russia—perhaps the only such combination extant anywhere at that time—so that it was only natural again that the first really adequate investigation should be conducted there. The Bogoslowsk mining field contains both iron and copper ores, and both are treated on the spot into their respective marketable products. In 1867 it occurred to M. Semennikow, then the governmental head of the mining industry of the district, to have the question of the suitability of copper mattes for the Bessemerising process looked into, and accordingly a few preliminary trials, with small quantities, were made at the Bogoslowsk copper plant, which were promising enough to have him order their repetition with the paraphernalia of the steel works at Wotkinsk near by. These tests were placed in the hands of two officials, A. von Jossa and N. Laletin, who subsequently published their results in the Russian *Mining Gazette* of May, 1870.(*l*) Honors are thus divided, M. Semennikow, as directive head, carrying the distinction of originator, the two subordinate engineers that of executants of as interesting and important a set of technical investigations as—next to Bessemer's own first trials—the world has ever seen in this particular line of work. The investigations were most carefully conducted, for that time, and the report is as creditable, painstaking, and thoroughly scientific an one as the subject has yet been honored with by any qualified metallurgist. It would take too long in this place to go into all the details, but the following data are worth presenting, to show how conscientiously and ably the work was done.

The principal tests at the Wotkinsk steel works were made on rather small quantities, though no doubt these were considered very liberal at the time, viz., a total of 500 pud (18,000lbs.) of matte, of a grade of about 31.5 per cent. copper. Certain liberties of an experimental character were taken with the converter blows, such as continuing the blowing beyond the critical points, the object being to gain the information. The consequences, however, doubtless affected the final verdict. The vessel used was of a somewhat antiquated type, ovoid in shape, flat-bottomed internally, with a height of 1.5 metres and a greatest diameter of 1.25 metres, and with a long, retort-like neck. It had seven tuyere bricks in the bottom, each with five openings, about ⅜in. in size; and in some of the tests, with air only, two additional lateral tuyeres of 1½in. diameter, lying tangentially in the plane of the bottom, were brought into play, while, simultaneously, all the bottom tuyeres were closed, except 6 to 10 of the holes. A number of tests was made with steam and air, the former being introduced through the centre bottom tuyeres. The matte was remelted in a gas-fired reverberatory furnace, and run into the vessel in charges of 45 to 55 pud (1,620lbs. to 1,980lbs.). The blast pressure ranged from 8lbs. to 12lbs. per square inch, but was manipulated to suit the phenomena, the ejection of molten material from the nose giving rise to serious apprehensions of loss, so that the experimenters strove to keep this down by using only 4lbs. to 5lbs. pressure. The frequent choking of the tuyeres also seemed ominous. It became necessary to clean them as often as 10 times during a blow, and this appears to have been done by interrupting the latter. The general run of the operation is, however,

(*l*) *Berg-u. Hüttenmänn. Zeitg*, 1871. The older files of this publication have supplied a large proportion of the historical matter given in the paper.

described exactly as we now know it. The flame indications which, as given, point to a great purity of the matte used, are quite correct, and the completion of the slag-forming period, as revealed by a change in the color of the flame, is explicitly referred to, and is interpreted as standing in some relation to the chemical reactions taking place. It is stated that one may absolutely rely on the fact that, if the process is terminated three to five minutes after this particular alteration in the flame takes place, a product of from 72 per cent. to 80 per cent. copper is obtained, but that further blowing leads to a scorification of copper. The process, it is remarked, could be positively and reliably divided into two periods. The first was distinguished by a yellow flame with violet streaks, a violent ebullition, and vigorous projections from the vessel, with a high temperature, maintained by the combustion of the iron, so that during this period the matte and slag were in an exceedingly fluid state. The second period differed from the first by a much shorter flame of a "green" color, by an even or uniform noise within the retort, and by a sinking of the temperature. With the second period the slags grew thick and cold, and enclosed particles of enriched matte. Continuation of this period caused a decided falling off of the temperature, a great entanglement of matte, attended by a considerable copper loss, also the formation of accretions of black copper, inconveniently adhering to the cooling walls of the retort. It was, therefore, held advisable to interrupt the process soon after the appearance of the "green" flame, and to diminish the body of slag. This was done by bringing the vessel into the horizontal position and skimming off the slag in layers, after allowing it to cool into such, the skimming being repeated three to five times in each blow. Evidently it was done too timorously. On the completion of the entire blow the vessel contents were poured into a cast-iron mould, in which they separated into rich matte and slag. The quantity of the first mentioned varied greatly, from 2 pud to 18 pud (72lbs. to 648lbs.).

With the 18,000lbs. of matte 15 tests were made in all, which were divided into four groups, viz., enrichment to a product of 72 per cent. to 80 per cent. copper; retreatment of this product into one of 80 per cent. to 95 per cent. copper; enrichment of the matte with the injection of steam with the air; finally, the treatment of the enriched matte to black copper in the roaster furnace (Spleissofen). Complete analytical data support the conclusions drawn, but the gases were not analysed.

It was unfortunate that the blowing of the white metal in the second group gave disastrous results, for to these is to be attributed the non-appreciation of this portion of the process. Only 20 puds (720lbs.) of the rich matte were used. The blowing was done with the two side tuyeres and only three bottom openings. On pouring, 2 pud to 3 pud (72lbs. to 108lbs.) of 80 per cent. matte were obtained, but the retort was found lined with a coating of scrap copper of 95 per cent. tenor, from ½in. to 1½in. thick, which had remained behind. A repetition of the test, with the addition of charcoal, gave no better results; neither did the partial tilting of the vessel, so that the blast struck over the surface of the bath, improve matters. The conviction therefore forced itself on the minds of the experimenters that the second stage was impracticable. In reality the reason was the employment of too small a quantity of matte, had they but known it; for a heavier yield of metallic copper would have permitted of pouring some of this metal, instead of its sticking to the lining *in toto*.

The chemical reactions von Jossa and Laletin explain elaborately, but on assumptions that violate the chemical feeling of to-day, by introducing the formation of sulphates. They recognised that there was no special (*i.e.*, no chemical) copper loss during the slagging period, their analyses not showing more than 1 per cent. copper in the oxidised form. The slag, however, became injuriously rich during the second period, or the after-blow. Had they continued their experiments there can be no doubt that this point, as well as others which seemed to argue against the process, but which were mainly the results of mechanical difficulties, would have been fully overcome, for these two engineers had the great advantage over the ordinary copper metallurgist of the day, of manipulative familiarity with steel-converting. The general course of the chemical reactions they identified as similar to those of the Welsh process, except for the very decided gain in time and intensity.

The tests made with the combined injection of steam and air yielded no conclusive results, whether the former was admitted continuously or intermittently. The general phenomena were the same as in air-blowing, except that the projection of molten material was greater, which may have been due to the greater pressure employed (10lbs. to 12lbs.), and the slags cooled more quickly. The operation was stopped after 10 to 15 minutes of blowing, on the appearance of the color change in the flame; but the matte only assayed 63 per cent. to 66 per cent. of copper, while the slags contained 6.5 per cent. to 9 per cent. of copper, principally mechanically included. The sulphur in this matte was found very low, viz., 18 per cent. to 19 per cent., and its composition indicated the presence of considerable metallic iron, which the experimenters regarded as alloyed with the metallic copper. The reason of the failure of steam-blowing was given as lying in the lowness of the temperature of the oxidising reactions involved, and which did not permit of an energetic reaction between the steam and the sulphides. According to Regnault, a white heat is necessary for the formation of metallic copper out of cuprous sulphide in a current of steam—at lower temperatures there is scarcely a reaction. The temperature in the retort, they stated, even with air alone, did not reach this point, and the combustion of the iron was hampered in the creation of a high pyrometric intensity for an analogous reason. The conclusion they came to was that the application of steam, with or without air, has no chemical or economical advantages.

Reviewing their results as a whole, von Jossa and Laletin drew the following conclusions:—

1. The Bessemerising of copper mattes by means of superheated steam alone, or together with an air-blast, for the production of black copper, is scarcely practicable.

2. The production of black copper (of 95 per cent. copper) with the application of highly compressed air, though perfectly feasible, is likely to be unprofitable, partly on account of a marked copper wastage and partly on account of the formation of mere accretions of metallic copper on the sides of the vessel (*i.e.*, the copper thus forming scrap, instead of collecting in a body).

3. Notwithstanding the above, the suggestion of M. Semennikow is deserving of the greatest attention, and may be of great utility in practice if applied to the working up of a copper matte under the following conditions :—

a. Copper matte from the blast-furnace should be run into the Bessemer retort immediately after tapping, to save remelting ;

b. The Bessemer operation should only be carried to the stage at which a product of from 73 per cent. to 80 per cent. of copper is produced, approximately expressed by the formula $Cu_2S + 0.12\,FeS$, up to pure Cu_2S. Owing to the circumstance that the formation of this product is accompanied by special external phenomena of a reliable and distinctive nature, there is no difficulty in conducting this particular method in a Bessemer vessel of any dimensions whatsoever.

On the subject of the losses, the authors state that the copper waste, on the whole, is negligible, if the process is thus terminated at the white metal stage, and it is likely to be below 10 per cent., the slags themselves carrying but 0.5 to 2 per cent. copper, the balance being in suspended matte. And, provided the blowing is stopped soon after the appearance of the "green" flame, even the mechanical loss is not serious. They were aware that this entrainment was not a true loss, inasmuch as the converter slags are always available for return to the smelting operations which precede the pneumatic treatment.

c. The white metal, or regulus, above referred to, the writers recommend bringing up to black copper in the ordinary way in a roaster furnace provided with a number of tuyeres for the use of an air blast.

The ordinary Bogoslowsk scheme of matte treatment was very simple, and consisted only of three steps, *i.e.*, calcination of the coarse metal, roasting of same to 95 per cent. black copper, and refining of this to 98 per cent. blister. The new scheme, however, would have curtailed this still further, thus : enrichment of the matte in the converter by means of an air blast, and bringing the product, white metal, up to blister, &c., in one continuous operation in the reverberatory furnace.

On the economical side the advantages of the Bessemerising, including the subsequent proposal for fining, which took one day, are stated as follows :—

1. A gain in time : at Bogoslowsk the concentration of 450 pud (16,200lbs.) of matte (31.5 per cent. copper) into 95 per cent. black copper required four and a half days ; the new method would bring the same quantity of matte up to white metal in three blows of one

and a half to two hours, which could be brought to blister in the air-blown Spleissofen in the same time as the black copper in the common furnace. Incidentally, the tedious work of calcination, the circumstantial transportation of the matte to and from the roast piles, &c., would be wholly avoided.

2. A saving in fuel: this would reach 40 per cent. of the firewood used in the various operations involved before.

3. A saving in labor and wages, which would amount to about 50 per cent. with the new method.

The question of the converter linings is fully gone into, and their composition taken as five parts of fine crushed quartz and one part of refractory clay.

In fact, except the investigation of the gases and the thermal processes implicated, the two engineers left very little unattended to. Their final verdict, while unfavorable to the current production of blister by the pneumatic method of Bessemerising, still must be admitted to be scientifically fair, and candidly favorable to the general notion. To the initiated it will be apparent that there is nothing in their observations which clashes with the knowledge of to-day, the chemical explanations alone excepted. On the contrary, there is scarcely a point of our modern practice which they have not anticipated, the gravest error being their condemnatory conclusion that metallic copper cannot be conveniently produced. As intimated, this is solely attributable to the small quantity of matte experimented upon. In this connection it is interesting that precisely the same lack of appreciation of so simple a fact also embarrassed the more successful experimenters of a later day—not for the duration of single blows or days only, but for years. These Russian pioneers, therefore, are far from deserving of any imputation of superficiality in comparison. It is to be regretted that the expedient of "double-banking," that is, the blowing up of successive charges of matte for the afterblow, did not occur to them, for this would have led to final success, *i.e.*, the pouring of an ample liquid bulk of black copper, instead of its adhering to the sides of the vessels in a chilled condition. For this operative expedient they had, of course, no precedent in steel-blowing. Their manner of skimming, or, rather, of lifting the slag in chilled layers, also discloses that they thought too conservatively in lines of the current practice in matte-smelting.

Aside from this point, viz., the prejudice against blowing white metal for copper, which the limited scale of experimentation is accountable for, and which is, unfortunately, serious enough to deprive Semennikow and his assistants, von Jossa and Laletin, of the priority of true invention, there is, as remarked, little that present-day knowledge can cavil at in their delineation of the fundamental features of the process. On the contrary, certain facts are already recognised which even the modern professional man is frequently none too familiar with. Thus, judging from recent writers, it would almost seem as if the circumstance that, during the slag-forming period, the heat is kept up to a large extent by only the oxidation of the iron had been established but a few years ago. It is, however, the direct elementary outcome of the thermo-chemical relationships of the molten solids and the gases implicated, and the Russian investigators no doubt valued it as the A B C of the chemical phenomena taking place. As producers of steel out of cast iron, the undesirable facility with which iron is oxidised, and the difficulty with which sulphur is eliminated, doubtless spared them any effort in the transference of this knowledge to copper mattes. At all events, speaking lightly, it is very much to the credit of these Columbuses of matte-conversion, if one may so call them, that they did not follow a popular modern error, and ascribe the whole generation of heat to the sulphur alone. The more notable combustion of this element, on the contrary, they quite correctly attributed to the after-blow, or the copper-forming period.

With these Russian experiments it may be said the pneumatic process, as applied to copper mattes, now was fairly launched on the sea of possibilities, though, for a protracted period yet, there were but few metallurgical mariners who possessed sufficient valor to take the ship by the helm and further test its sailing capacity. Theoretically no further refinement was necessary for practical success, and even in point of apparatus and manipulation (though this side formed the chief stumbling block to more rapid advancement), there was really but little left to add, and particularly nothing radically novel which had not been done before in the Bessemerising of iron, and might not, as usual, have been duplicated. At all events the suitability of sulphide substances as sources of great heat, under conditions which accelerate the chemical phenomena of the ordinary copper-smelting processes, was completely established, and sufficiently understood to afford hopes of the early and extensive introduction of the general idea for the improvement of those processes.

Interlude of Steam-refining of Black Copper, &c.—Unfortunately, however, interest in the pneumatic treatment of mattes (or ores), as far, at least, as it is distinguishable in contemporary literature, remained of a passive sort for a considerable time to come—probably in consequence of the very judgment passed by the pioneers themselves. But transiently another project, which may be conveniently dealt with at this place, engaged the attention of copper men, viz., the steam-refining of the metal. This old idea revived, while the other youthful one grew moribund. On the face of the proposition it would seem to have been obvious that the dissociation of steam, as a chemical combination, would demand heat for the liberation of oxygen. But, as against this, compensating advantages continued to be hoped for from the removal of sulphur and arsenic, &c., by means of the hydrogen. Air being merely a mechanical mixture, is ready to hand for refining purposes without a previous sundering of its constituents, but its oxygen content is low compared with that of steam, and it held out no prospects of the formation of convenient, highly volatile compounds, such as hydrogen sulphide, and phosphide, &c. Hence steam remained in greater favor. One curious proposal falling into this category was that of LeClerc, in the later sixties. Impure black copper was to be heated to softening in a reverberatory furnace, and a fine spray of water then thrown on the surface, in the expectation that it would be at once dissociated, and that sulphur, arsenic, and antimony would enter into combination with the hydrogen, while the oxygen would combine with the non-volatile elements, iron, lead, tin, and a portion of the copper, and these oxides would be scorified by the furnace lining. A second operation was to follow, consisting of the injection of an airblast, ostensibly to oxidise the balance of the foreign elements ; the copper then to be brought to pitch in the usual way. Another proposal of the time, pursuing the same general scheme. was that of Guillemin. It advocated the introduction of a current of steam to the bottom of the metallic bath, in a reverberatory furnace, through channels of fire-resisting material, or metal pipes protected by refractory substances. Similar attempts by others also led to no result, and the reasons were clearly set forth by Wedding (*m*) in 1869. Molten copper does not decompose steam, whereas the impurities do, at least partially, and are oxidised with the evolution of hydrogen. But, considering the relative quantities of these impurities and the copper, it was hopeless to expect that antimony and arsenic, or lead and bismuth, would be sensibly removed by steam. Still, the method would probably contribute to their easier elimination, merely in consequence of an increased exposure to the atmosphere, as an incidental consequence of the ebullition of the bath caused by the steam. As regards the sulphur in the copper, both this quasi-mechanical and the direct chemical effect might, with some confidence, be looked forward to. Wedding's experiments corroborated this, but the manipulative difficulties attending the work were too great. The admission of dried superheated steam of 22lbs. to 24lbs. pressure fully achieved the mechanical effect referred to, though it was true that ordinary poling had the same result. Still, this cannot, of course, be carried out at the same stage of the refining process, because the reducing action of the hydrocarbons present prevents the oxidation of the impurities. Nevertheless, it was inferred that even the subsequent toughening process could probably be more rationally carried out by means of a judicious application of steam than it is currently performed with the aid of the wholly irregular and uncertain moisture contents of a pole of green wood.

A further proposal of the same general class was that of Tessié du Motay, in 1869, who endeavored to use oxyhydrogen gas for the production of steam in copper-refining ; and still another scheme was that of MM. Laveissiere, expressed in a patent of 1874, for improvements in the refining of metals other than copper, which consisted in the employment of a Bessemer apparatus, utilising preheated gases, such as oxygen, air, steam, &c. This reference may close the list of processes having for their object the purification of metallic copper by any sort of rapid oxidation process. It may be taken for granted that steam-refining efforts have practically come to an end. In view of the ease and certainty with which the Bessemer process casts out the deleterious elements during the conversion of mattes into blister,

(*m*) *Preuss. Zeitschr. f. Berg-u. Hüttenwesen*, 1870, vol. XVIII., p. 211.

these older efforts have lost their interest. Its intense oxidising and volatilising action guarantees the purity of the metallic product without, at the same time, being violent enough to entail either an excessive waste of copper or of the precious metals, when present.

To return to the pneumatic process applied to mattes, it may be remarked that the only other investigations of a kind similar to those suggested by Semennikow, and carried out by von Jossa and Laletin, which are recorded, were those of Stridsberg and Kollberg, in 1868, at Westanfors, in Sweden. They were, however, only conducted on a small scale, and not pursued far enough to yield any notable results.

Chronologically the next significant event in the historical development of our subject ushers in the extremely important subject of the utilisation of sulphide ores as metallurgical fuels for their own igneous concentration. The remarkable demonstration of the value of such ores in this connection, which John Hollway's Penistone experiments gave to an incredulous, at best only half-convinced, technical world, took place in 1878-9.(*n*) Owing to the fact, however, that this transitional movement of the pneumatic principle from mattes to ores has only recently fully established itself in actual practice—in the methods of pyritic and pyrite smelting—and that the perfection of the process of matte-conversion was approximated much sooner, we will not venture on the discussion of the ore process, but further pursue the matte aspect of our theme instead. The results of Hollway's researches were nugatory, as far as their immediate translation into current practice was concerned, and they had no influence on progress in the pneumatic treatment of mattes, beyond, in a general way, again emphasizing the feasibility of the rapid combustion of sulphide substances, while complying with the usual metallurgical requirements of complete fusion of the solid products, accompanied by increase of tenor and ready mechanical separation of the waste from the valuable.

Restitution of Pneumatic Process by Manhès and David.—In the more restricted and considerably more facile department of matte-conversion the credit of having first surmounted the practical difficulties standing in the way of the production of black or blister copper belongs to the French industrialist, M. Pierre Manhès, of Lyons, and his engineer, M. Paul David. Their first attempts were made early in 1880, with a small bottom-blown converter vessel capable of treating 200 kilos, on matte previously melted down in a crucible. The usual phenomena of flame, volcanic ebullition, &c., accompanied the trials. The slag thickened from overblowing, became impervious to the blast, and was ejected in quantity. Metallic copper formed, but was chilled by the blast, and the numerous vertical tuyeres were choked by it. The mechanical difficulties thus encountered seemed insuperable with the bottom-blown vessel. The first step towards a partial cure, and an extremely simple one, but on which really hinged the entire subsequent good fortune, was the elevation of the tuyeres from bottom to side, and their insertion horizontally through the walls of

(*n*) "A New Application of Bessemer's Process of Rapid Oxidation, in which Sulphides are Utilised for Fuel," *Journ. of Soc. Arts*, Feb., 1879.

the vessel, a short distance above the bottom of the inner cavity. In this manner a space was formed below the tuyeres, in which the metallic copper had an opportunity of settling. Remaining quiescent, and out of reach of the blast, it was not thrown against the lining, and did not chill, but collected, and could be poured out in a body with the scoria at the end of the blow. In addition to this very important mechanical success, an equal feeling of triumph followed on the observation that the metal thus produced was of a purity considerably exceeding that of the ordinary black copper locally obtained by the usual roasting and fining process, for it only contained 1.5 per cent. of other elements. The excessive quantity of slags formed during the blowing, however, continued to constitute a scarcely less formidable difficulty than the correct position of the tuyeres, and so remained, in fact, for a very much longer time. Simple as the manipulation for the removal of the slags really is, no matter what the original grade of the matte treated, the solution was not actually found until some six years later—after the process had been introduced in America. It happened that in these early endeavors in France the method was assessed too exclusively along the lines of the features of the iron-converting process: such as a single blowing period and but a moderate production of slag, and had not yet found an individuality of its own in the minds of the experimenters. The abundant slag formation, the wear of the lining, and other points nowadays accepted as matters of course, were greatly lamented, and effort was wasted in their attempted suppression, instead of working out the best mechanical procedure for their amelioration. Mattes of 50 per cent. to 60 per cent. copper, it was found, offered little difficulty, and could be finished to copper in one blow. A small addition of quartz prevented the thickening of the modicum of slag such mattes made, but spiegeleisen was found to be more serviceable by yielding a fluid silicate of manganese, and keeping up the heat. The treatment of 20 per cent. to 30 per cent. mattes up to the same end, however, gave much trouble. This difficulty is now generally circumvented, simply by not blowing such low-grade mattes. The early men, innocently, expected the converters to serve all grades equally well, and the method was, as a whole, so economical, compared with the ordinary treatment, that fine shades of saving in handling and treatment were not valued. Instead of bringing these low-grade mattes up to a proper tenor in the preceding smelting, they were blown to about 60 per cent. in the vessel, poured out with the slag, allowed to cool, separated, remelted, recharged into a fresh vessel, and blown again, and this unnecessary complication, as remarked, remained the practice for a number of years.

The original trials were made at the works of M. Manhès, at Védenes, and occupied a year. Then the process was currently introduced on a working scale at Eguilles, in the vicinity of Sorgues (Dep. Vaucluse), at an old plant provided with water power—an accidental mechanical feature which, for a considerable period, was publicly held to be the particular factor which rendered the new process more economical than the roundabout methods whose place it was usurping. The

Eguilles converters had originally been built for steel-converting, were of the customary upright, cylindrical type, with a hemispherical bowl at the bottom and an equivalent dome at the top, surmounted by a short neck or nose. They were 2m. high by 1.4m. diameter, and had a capacity of 3,000 kilos of pig iron when new, but which was equal to only 1,500 to 2,000 kilos of matte. The bottom wind box was replaced by an air belt encircling the body, and for the numerous bottom tuyeres there were substituted 18 to 20 small horizontal tuyeres, placed about 0.3m. above the bottom of the cavity. The openings were about 1c.m. in diameter, and at first were contained in special bricks 20c.m. long, corresponding to the thickness of the lining. The latter was the same everywhere, except at the nose. The lining was made up of clay and sand, and lasted at first 10 to 12 operations—frequently only seven or eight—while later on as many as 18 blows are said to have been made blast pressure, 25c.m. to 35c.m. of mercury; and the air supply, 100 cub. with one lining. The size of the charges was usually 1,000 kilos; the m. per minute. The ores at Eguilles were, and still are, very impure, and contain much arsenic, antimony, lead, and zinc, &c., all of which elements, as already stated, it was at once observed, by the evidence of the rolling mill, were as completely removed, either by scorification or volatilization, as if the mattes had been derived from clean ores. The cost of the operation stood at from 160 to 170 francs per ton of copper—a figure which compared exceedingly favorably with the cost of the analogous operations in the Welsh process. This, notwithstanding that fuel in England was only half as dear as in Southern France, amounted to from 320 to 350 francs. The rather high copper contents of the converter slags (2 per cent. to 3 per cent.) were recognised as an indifferent matter, since the slags could be returned to the matting furnaces. By contrast with the Chili bars which were refined in the same locality, and which contained at least 4 per cent. of impurities, the production of a black copper by the converter, with only 1.5 per cent. foreign elements, caused considerable *éclat*. In addition to the lightening of the refining operation from this source, the simplification of the entire course of treatment by reducing the former six to eight operations, from ore to copper, down to only three—*i.e.*, smelting for matte, converting and refining—together with the concomitant saving in fuel and labor, and the extraordinary gain in expedition, were all points which were enthusiastically appreciated.

These metallurgical achievements formed one of the last subjects which Professor Gruner—who, in the early days of the Bessemer steel process, had been none too favorably impressed with its possibilities—interested himself in. A posthumous essay of his (1883) on the subject (*o*) was completed by his son, and forms the first authoritative statement published after the no less meritorious, but now forgotten, Russian announcement of a dozen years before. The method since this time goes under the name of the "Manhès process." Gruner's appreciation is expressed in his final remarks: "I will not contend that the Bessemerising process will alter the metallurgy of copper as radically

(*o*) *Annales des Mines*, 8 e Serie, Tome III., p. 429.

as it has that of iron, but at all events one may predict a great future for the new method. Wages and fuel are decreased to such an extent that all copper smelters are bound, sooner or later, to avail themselves of it."

There is one practical point—of paramount importance in our modern practice—which these early French references treat with scant appreciation, and that is the possibility of fixing the termination of the slag-forming period by means of a change in the color of the flame. As remarked, the mattes used (which did not assay more than 33 per cent. copper, and occasionally as low as 15 per cent., and even 10 per cent.) were very impure, and doubtless this fact greatly obscured the color change. We have seen what special stress the Russian pioneers of the process laid on this phenomenon, and how they interpreted it as affording a positive means for determining the consummation of the white metal stage of the blowing. The French accounts, on the other hand, show that this most useful indicator was scarcely recognised, and betray some confusion as to the meaning of the flame. This oversight, in fact, caused much unnecessary work, for it doubtless contributed to the conservative belief that there was no other feasible procedure than to divide the operation into two separate and distinct campaigns, with an intermediate remelting of the white metal obtained from the first blow. The advantage of at once pouring this enriched matte into a second vessel for completion, instead of cooling and remelting, was mooted, and this may have been carried out; but the still greater gain by simply smelting the matte beforehand to a somewhat higher tenor (say, 50 per cent.) to begin with, and blowing this to white metal by the flame, which has now become so easy a matter, and then pouring and skimming the slag and finishing the white metal to copper, was not recognised.

By contrast, however, Manhès occupied himself with and patented proposals for carrying the operation even beyond the ordinary finishing point. He attempted (1880) the concentration of the precious metals into a rich regulus, and also (1880-1) the refining of black copper direct in the converter. As regards the former, the argentiferous copper obtained was to be blown still further, until nearly all the copper was oxidised, when the precious metals would be found in a small remaining quantity of regulus. The other suggestion was to blow the matte to black copper, as usual, and then to refine and pole direct in the converter under a charcoal cover. To facilitate these operations the addition of 2 per cent. and more of spiegeleisen was deemed necessary, and this was to be given during the fusion of the matte (or the black copper) in the cupola furnace. These notions, however, led to no permanent results. Generally, in ordinary work, manganese, silicon, or phosphorus were to be used to furbish up the heat in mattes held to be too low in sulphur, particularly towards the end of the converting.

An interesting item, in view of the very recent application of the pneumatic method to the refining of metals other than iron or copper, is that even in these early days all manner of refuse metal, like pewter, copper scrap, brass, old bronze, &c., was treated, either by itself or together with matte. (*p*) Zinc, tin, lead, &c., oxidised easily, a small dose of spiegeleisen, or manganiferous pig iron, being added to liquefy the slag. M. Manhès was partial to this metallurgical laxative. Before turning to the pneumatic methods, he had invented the alloy cupromanganese, which was used at the end of the ordinary refining process, or at the moment of ladling, and was a substitute for the charcoal, lead, or sulphur commonly employed.

In addition to thus setting the copper-converting process thoroughly on its feet, Manhès was also the first to treat nickel mattes in the converter (1883-4), enriching 16 per cent. matte to 70 per cent. nickel by 15 minutes' blowing. Much more than this is not accomplished to this day, owing to the equivocal behaviour of nickel in relation to sulphur and oxygen.

The Manhès practice was covered by a number of patents which mark the progressive steps of the invention in point of time, and, though outside of the proper scope of this paper, may be briefly referred to in consequence of the adverse fate of the most important ones in the United States of America, where the method has found its principal home. The original French patent is dated May 26th, 1880, and claimed the general features of the process and the use of the Bessemer converter for the purpose. A few days later followed the refining scheme above mentioned. A specification of October 23rd, 1880, covers the use of manganese, silicon, and phosphorus. The horizontal tuyeres were patented on February 9th, 1881, and, while it may be freely conceded that they were the first step towards a rational mechanical solution of a very prominent difficulty, the idea, though original with M. Paul David, has a clear precedent in Bessemer's steel converter of 1862. This was a pear-shaped vessel having a re-entrant shoulder at the bottom, the ledge of which is occupied by an encircling wind box, from which, radially placed, horizontal tuyeres issue through the lining into the interior of the apparatus at a fair elevation above the bottom of the cavity. David arranged the construction so that thin rods of iron could be driven into the tuyeres through openings in the cover of the wind box, or "air belt," for the purpose of clearing the tuyeres for the free passage of the blast. (*q*). This "punching" is a most necessary performance, since during a great part of a blow the tuyere orifices are constantly choking up, even with the most skillful manipulation of the vessel. The apparently exceedingly trivial matter of placing the lateral tuyeres and the holes in the "air-belt" in such a position that punching was feasible, as well as this commonplace manœuvre itself, later on assumed a most formidable financial importance in connection with the American patents. Legally boiled down to their concretest individual essence, the patent claims here were estimated

(*p*) Revived by Schwietzke, "Bessemerising of Zinc, Lead, Tin, and Copper Refuse," *Metallurgie*, 1906, vol. III., No. 20.

(*q*) Bessemer naturally also had openings, closed with screw caps, in the face of the air-channel, for access to the tuyere bricks. *Journal of Iron and Steel Inst.*, II., 1886, p. 645.

to enshrine only these two practical points as actual novelties, all the other chemical and metallurgical features of the whole brilliant idea falling like empty pods by the side of these paltry kernels, both in their passage through the patent office and through subsequent long-continued litigation instituted for the reclamation of royalties in America. Developments in this connection were eagerly watched by interested circles, and mechanical evasions and subterfuges resorted to in new installations, both in Europe and America, occasionally incomprehensible to the outsider on account of their circumlocutory inconvenience. Ultimately, in 1902, the whole question terminated adversely to the inventor, the court, while giving full honor to the patentees for the great service rendered to metallurgy by the process as a whole, calling in question the intelligence of the patent office in granting protection to features as hackneyed as the two points referred to.

Features of French Practice: Horizontal Vessel.—As intimated, certain parts of the operation remained a long time less understood, or, at all events, less attended to, in France, so that it became the established custom there to blow the same matte twice, with a melting going before each blow. The vessels remained of small size, and hence all disturbing influences were accentuated by the diminutive quantities of matte treated, increasing, so to say, in the inverse ratio of the superficial size of the converter, or rather of the extent of its receptive capacity. Irregular yields of copper induced by variable grades of matte, which caused the white metal and copper to stand at varying levels with respect to the fixed one of the tuyeres, induced M. David to abandon the conventional upright form of converter in 1883, and to invent the recumbent, horizontal form so much in favor at the present time. It was patented in France in December of that year, but did not come into use outside of that country until 1893. Like its predecessors in the mechanical adaptation of the idea to the requirements of actual work, it is also eclectic. It is about the only construction which Bessemer did not elaborate, probably deterred by its defects; but Nyström, in 1862, had designed a similar converter for steel, and there were also the Danks and other rotary puddling furnaces. Like the latter, the converter—now a simple cylinder with two flat ends, and the usual nose in the centre of the length—was placed horizontally on rollers, and rotated on these by side-gearing, instead of in trunnions, as in the tiltable, upright type. This departure gave an opportunity, not afforded by the older construction, of realising the maintenance of the position of all the tuyere openings in the same horizontal line, no matter at what level this line stood with respect to the contents of the vessel. The alignment of the tuyeres is on an element of the cylinder forming the vessel, so that, with the rotation of the latter about its axis, all the tuyeres enter the bath collectively, at any desired level of same. This is not the case with the upright shape, where the tuyeres all occupy the same level, relatively to the bath, only when the latter is in its normal upright position, and the depth of entrance of the blast varies among the battery of tuyeres when the vessel is tilted. The new construction permits of dipping the tuyeres collectively into the bath to any depth, and of avoiding blowing into finished copper, on the one hand, and not sufficiently deep into the supernatant matte, on the other. The mechanical details, however, still remained somewhat primitive in France, calling in the assistance of hand labor. The vessel rested on a light carriage, by means of which it was trammed in and out of position. The arrangement of the blast connections did not permit of turning it up or down, except at the end of the operation, &c. It was claimed for this form that mattes running as low as 15 per cent. to 20 per cent. of copper could be brought up to blister in a single operation. But this was facilitated by removing the excess of slag through openings placed axially in the vertical ends of the vessel. At the Manhès works, and others working along the same lines in Southern Europe, this type has remained in vogue since 1883, the upright form thus having been employed there for only two years. Outside of this locality, however, and notably in the United States, the upright form has held its own until the present day, its place being only quite recently disputed by the horizontal type. Needless to say, the radically different industrial and economic conditions in the newer countries, coupled with American mechanical genius, have given rise to the perfecting of the constructional details of both forms of vessel, and of all accessory apparatus, out of all comparison with their European prototypes.

Introduction into America.—After two years of successful running in France on rather difficult mattes, the process was punctually scrutinised, and favorably viewed, by an American company operating in the marvellous copper-mining district of Butte, Montana, which is one of the seven wonders of our modern mining and smelting industry. It required considerable industrial enterprise to think of transplanting the method so early to a new field of this prominence, in which operations were carried on on so vastly different a scale from those of its birthplace, for the reason that none of the more important elusive, but economically telling features, such as the question of metal losses, &c., had as yet been at all settled to the satisfaction of the profession at large, and the average copper metallurgist of the day entertained very serious doubts on these subjects. However, the immediate economical side—which has always presented a strong temptation to American practitioners—was too alluring, and, with characteristic dispatch, the process promptly found a lodgment in transatlantic circles. This occurred as early as 1883-4, and took place at the instance of Mr. Franklin Farrell, President of the Parrott Silver and Copper Company, one of the oldest establishments in Butte, and then one of the largest. The installation was carried out under the general direction of Mr. Manhès, under letters patent applied for in 1883-4, and the immediate supervision was placed in the hands of M. Vernis, a pupil of Manhès, assisted by several workmen from Eguilles. Three vessels were erected at the Parrott Works in 1884, for experimental purposes, of the same type as the old vertical converters at Eguilles, and, after a year's trial, were followed by a permanent working plant, increased to six converters by 1885. For some years this remained the only such works in the country, and, though surrounded with the usual nimbus of secrecy, its operations were keenly watched in copper circles—especially by the company's neighbors in the same locality. In the patent office the process appears to have had a difficult pilgrimage to make, for though, as remarked, the application was made in 1883, the first letters patent were not issued until 1892.

Operations during the first couple of years at Butte (*r*) remained under the tutelage of the French home method of procedure, the mattes being kept at about 35 per cent. copper and the blowing divided into two distinct operations, the slag and the white metal being poured together after the first blow, and the latter remelted for the second. It was held that, even under the very much wider manipulative scope which Butte conditions offered, it was impossible to blow to copper without an intermediate discharge of the enriched matte. The keener practical sense of the local metallurgists in charge, however, was not long in emancipating itself. By 1885-6 the greater suitability of a 50 per cent. matte for a single vessel blow to copper, the possibility of pouring or skimming the slag separately when white metal was reached, and the feasibility of at once blowing the latter to a finish without additional heat from remelting, were all points promptly taken note of by them. The introduction of these important improvements is due to A. J. Schumacher, who also greatly perfected many of the detail mechanical features in the construction of the vessels, their movement, handling, lining, &c. By the years mentioned it may be said that the process, on its manipulative side, was matured for a life on a vaster scale, and what further growth it has since sustained is due to the restless activity of many similar minds characteristic of its new home, to which the method of to-day is always merely an omen of something better for to-morrow. Curiously enough, it appears that even the practice of regularly and systematically punching the tuyeres, which is so essential a part of the work, as well as the philosophy of once for all accepting it as inevitable in that light, instead of as an inconvenient spasmodic drawback, were first introduced at the Parrott Works

The Upright Vessel.—As intimated, the Parrott installation became the mechanical prototype of the American converting plant, and has laid the foundation for the wonderful perfection of apparatus which has signalised the last 20 years in that country. When a settled constructional basis for all parts had been arrived at, its vessels measured externally 8½ft. high by 5ft. diameter. They took initial charges of 2,500lbs. of 45 per cent. matte, rising to 9,000lbs. with the corrosion of the lining. The number of tuyeres, which consisted simply of perforations of the lining, was 16. When lined, the vessels weighed 16,000lbs., and they withstood 16 blows. They were filled by means of a swing spout from a remelting furnace standing on an elevated platform behind the row of vessels. Originally tilted by hand, subsequently by means of belting off a line shaft, they finally, in 1890, received hydraulic apparatus for that purpose. They were at first relined in their trunnions, but were later on made removable and run in a half turned-down, *i.e.*, horizontal, position to the relining floor on a special

(*r*) Prof. T. Egleston, *School of Mines Quarterly*, 1885, vol. VI., p. 320.

buggy or carriage, a jib crane serving to lift them off and on the latter. An important departure, the practical value of which can scarcely be overestimated, notwithstanding its near-lying simplicity, was the division of the heretofore undivided metal shell of the vessel, at first into three, subsequently into two parts. These were bolted together, so that top and body could be separated for the relining of each, as required, instead of obliging the liner to crawl into the vessel for the purpose. This departure alone has not only greatly eased this work, but also proportionally improved the lasting qualities of the linings, now put in with greater freedom and care. In fact, American progress is built up of a multitude of similar practical ruses, far too numerous to mention. Last, not least, the more recent application of electricity to cranes for lifting and carrying purposes has again so modified the arrangement of all plant, and so simplified all handling, that very little seems left to improve. The outward configuration of the converter vessels also underwent detail changes, though the general type was not altered before 1893. The original Parrott vessels of 1884 were built entirely of wrought iron. In 1889 cast-iron bodies were tried, but their unwieldly weight and liability to crack soon put them out of commission, and thereafter steel-plate constructions, with cast-iron mountings, came in and have since remained—at least for the vertical type.

On the strength of the undoubted success of the Parrott installation—which was the first in the world to turn out the unprecedented quantity of 14,000,000lbs. of blister copper of extreme purity by the pneumatic method in a single year—the very much larger Anaconda Company, also operating in the Butte district, undertook the experimental investigation of the method, and in 1888 constructed two small stationary vessels, set on trucks, and tilted by hand, of an over-all height of 7ft. and a diameter of 4ft. In 1890 these works introduced the Stalmann type of square vessel, 8ft. high over all by 5ft. square externally, with 10 tuyeres, six of them in straight alignment on the back, the others on the sides. A battery of 12 of these vessels served the Anaconda Works for a period of four years; but, on the removal of the plant to another locality, and its simultaneous enlargement, a return was made to the older cylindrical shape for purely mechanical reasons, largely suggested by considerations connected with the use of large vessels equivalent to those of steel practice. This departure gave rise to aspersions against the square vessel which have since been perpetuated by the traditional tendency of authors to rely on each other in matters of opinion on which they have no positive information, although, to the enlightened and open-minded practitioner the subject may wear an altogether different face. It is so in the present instance. In the early days of copper-converting, notions verging on superstition were entertained by many in regard to small, really unessential, details, the importance of which has now been long forgotten, and, wholly owing to insufficiently practical accessory features restricted to the outer mechanism, the square type was misjudged. Under this influence others more theoretically inclined have tried to reason fundamental theoretical defects into the square cross-section, but of which actual practice has established nothing. Ten years of hard, faithful, and excellent service at Mount Lyell—where the original Stalmann vessels are still in use—have fully shown the fallacy of these misconceptions.

Mechanical Progress with Pneumatic Process.—The history of the pneumatic process, applied to copper mattes, now becomes chiefly that of the mechanical portion of the work. The transfer to America has transformed this so trenchantly that the more recent establishments more than rival the perfection of operative detail typical of steel-converting plants, and do not stand so very far behind them in point of capacity. The daily Bessemerising of some 675 tons of 40 per cent. matte, which is carried out at the Anaconda plant at the present time, shows to what dimensions the work has grown in a single establishment. The newly lined vessels there weigh 42 short tons, and are handled by 60-ton electric cranes, with 15-ton cranes for the ladles, &c.

Chemically, however, the period so far reviewed added nothing essential to what was known before from the earlier experimenters: in fact some things were forgotten, and impossibilities were undertaken. Fruitless attempts were made, for instance, to evade the inflexible chemical laws which govern the slag-formation within the converter. The desire that, instead of requiring regular and frequent renewal, the linings should last a week, or longer, led to irrational trials with basic linings. Special alloys or chemical elements were employed to supply heat not obtained, because suppressed or wasted by ignorance of the inherent means at hand for creating it. But the attention of the practician has turned away from these theoretical desiderata. Phosphorus and silicon he now replaces by a stick of wood, a shovel of coal, or a lump of matte at the proper time. The basic lining he eschews, knowing that he must have silica to slag off his iron. Generally he has come to the conviction that he cannot force or deviate the chemical routine from its predetermined orbit, and he has thrown his whole soul into the question of handling costs. Hence the perfection of apparatus. Of the general progress along this line only indications can be given here.

The most significant step in this direction was taken in 1892, when the magnificent plant of the Boston and Montana Copper Company was started at Great Falls, Montana, laid out altogether on simple but grandiose lines, after the pattern of modern steel plants. Gas-fired regenerative tilting reverberatories supplied the matte, direct poured into ladels and transferred to the vessels by powerful electric cranes, which also handled the vessels and the slag. The vessels were of an unprecedented size, of the upright cylindrical shape, 7ft. diameter by 14½ft. height, of an initial charge of 5 tons of matte, and a final one of 11 tons. However, still larger vessels were introduced at Aguas Calientes, Mexico, from 1894 on, which measured 16ft. in height by 8ft. diameter: the largest upright copper converters ever built. They converted very low-grade mattes, being heavily lined in this instance with siliceous ores. But, irrespective of this special utilisation of large converters, their size apparently has not yet reached its limit, for we read of one now being experimented with at Great Falls, Montana, of an elliptical cross-section, 9ft. by 10ft., which is expected to double the duty of a single lining in terms of metallic copper by raising it from 15 tons to 30 tons, without, at the same time, requiring more than the same duration of blow.

Needless to say, water-jacketing the vessel was experimented with, particularly in the early American days.(*s*) It is difficult to see what the incentive was, in view of the fact that the loss of heat by radiation is small, and a mere bagatelle compared with that suffered through the escaping gases, and the loss by convection in the water would have been greater. Furthermore, the endeavor to prolong the life of the linings by cooling them is an elementary chemical fallacy, in view of the absolutely autonomous conditions as to slag-formation and heat-development which obtain within the converter. As might have been expected, the trials with the water-jacketed shell, as well as of the water-cooled pipe-coil buried in the lining, both only yielded failures.

As regards the tilting mechanism, the earlier experimental forms having outgrown the use of hand-power, or of direct belt-driving by pulley or gearing on the converter axle, adaptations of the hydraulic mechanism current in steel practice universally took the place of these. At first the horizontal rack and pinion arrangement was in favor, latterly the vertical one is more used, being, in fact, necessitated by the special mechanical problem presented by the horizontal converter mounted on rollers. But this portion of the apparatus is far from perfect, involving as it does too many inefficient elements, such as pressure-pumps wastefully worked, and the intervention of accumulators or intensifiers, at best crude combinations for the supply of hydraulic power, not to mention the heavy losses incident to its transmission through the pipe-system, valves, &c. Converters of the present day, now being built under progressive direction, are receiving —and those of the future will, preferably, always be supplied with—individual electric motors direct connected to them.

The troublesome question of the conveyance of the molten products, *i.e.*, matte, slag, and blister, to and from the vessel involved, and still involves, considerable hand-labor. It assumes formidable proportions where the production is large, and is now solved in such establishments by the extensive use of electrically carried ladles. The most modern practice in regard to the slag is again to pour it into casting-machines, built after the style of platform-conveyors, on which it is chilled by water, and which transport it to storage-bins for blast-furnacing. The blister is commonly still poured direct from the converter into moulds mounted on carriages run underneath the vessel: the old large ingot-shape of bars, however, having recently been replaced, for argentiferous blisters, by that of flat cakes, in which the

(*s*) H. W. Hixon, "Notes on Lead and Copper Smelting and Copper-converting," 1897.

distribution of the precious metals is more uniform. The direct casting of the blister from the vessel into thin anode plates, in preparation for subsequent electrolytic refining, is also practised, but offers many difficulties. The best solution appears to be to transfer the copper in crane-carried ladles to a special storage reverberatory furnace, in which it is partially refined and brought to pitch by means of compressed air and poling, and from which it is then poured by suspended ladle into a special endless chain casting-machine.

In point of blast-supply the earlier period simply duplicated the blowing machinery of the steel plants, on a smaller scale, and for a lower pressure. Later on various high-class types of horizontal blowing engines came in, until to-day the practice in respect of this most important, or rather, vital accessory, stands on the high level of mechanical perfection characteristic of the times. A common delivery for the older, smaller, upright vessels is 3,000 cubic feet of free air per minute. Large units recently installed supply 6,500 to 15,000 cubic feet per minute. The quantity of air consumed may be inferred from the fact that in American practice a 7ft. by 14½ft. upright vessel demands 200,000 cubic feet of free air per short ton of copper produced, not excluding leakage in transmission, &c. At Mount Lyell the corresponding figures are 100,000 cubic feet for a 50 per cent., and 165,000 cubic feet for a 40 per cent. matte for the long ton of copper. The very latest blowing apparatus of all, the turbo-blower, of which great things are expected in the future for blast-furnace work, has so far only found one application for copper-converting purposes, and that is at Mount Morgan. It is electric motor-driven there, but in combination with the steam turbine—its naturally cognate driving apparatus—its further development may be watched with interest. On purely mechanical grounds, however, no type of rotary blower can ever surpass the efficiency of the reciprocating piston type of blowing-engine.

The Horizontal Vessel.—In recent years the newer installations have, as already remarked, been giving the preference of type of vessel to the recumbent horizontal form of Manhès and David, of 1883; known also as the "trough," "barrel," or "Leghorn" converter. They have, however, as also stated, departed very essentially both from the dimensions and detail appointments of the small vessels of Eguilles and their local modifications. As mentioned above, this shape has a precursor in a form of steel converter constructed by Nyström, in 1862, the special object of which was to permit the tuyeres to be placed at any desired depth below the surface of the metal, so that the latter could be partially or wholly traversed by the air currents. An advantage, it is stated, did not accrue from this point; on the contrary, the varying contact of the metal surface and the lining greatly increased the wear of the latter. Turning to copper-converting, it may be said that, as far as actual practice is concerned, the same feature, *i.e.*, the ability to regulate the position of the tuyeres to suit the volume of the matte, largely remains a mere mechanical hyperbole. It is contended that a lower pressure of blast, accompanied by a saving in power, &c., is thus rendered sufficient for the oxidation of the matte constituents. Now, the prime object in blowing is to effect a complete absorption of the oxygen blown in, and in good practice this is achieved. A given pressure, therefore, corresponds to a certain depth of matte: so that a low pressure corresponds to a shallow column and a simultaneous retardation of the work, and a higher pressure corresponds to the more appropriate opposites. As a matter of fact, this special purpose of elevating the tuyeres, so that a low pressure shall suffice, is scarcely heeded by the operatives, who much prefer to dig the tuyeres as deeply as they can into the matte, and to penetrate as high a column as possible, so as to ensure intenser action. Structurally, too, the horizontal cylindrical shape is one of the least secure constructions that could be devised, which is particularly true of its top. Experience corroborates this, for in addition to the greater difficulty of putting the lining in firmly, as compared with the upright form, the insecure top lining has more frequently to be changed; and the proximity of the roof to the bath also greatly aggravates its abrasion. The lining is, however, the sorest point about the whole operation, and should not be abused. The main advantage in favor of the roller-born horizontal type is an ordinary manipulative one. Especially where cranes are used, the ease and despatch with which the vessel can be lifted off and on to its bearings, its accessibility, and general handiness (except for lining), have made it popular in its current American designs. Its size has grown to great limits. The later French forms are 1.44m. long by 1.44m. diameter, but even the first trough converter introduced in America (1893) was 5ft. 8in. in diameter by 8ft. long. Those at the recently finished Washoe Works at Anaconda are 8ft. diameter by 12½ft. long, and have an initial capacity of 7 short tons of matte, with a final cavity capable of holding 12 tons. The Rio Tinto vessels are 7ft. diameter by 15ft. length, and have an initial capacity of 3 tons to 4 tons, and a final one of 8 tons. For special purposes the horizontal converter has been made 8ft. diameter by 20ft. long.

The Bottom-Blown Upright Vessel.—Notwithstanding the momentary vogue of the horizontal converter, there are indications that even the old bottom-blown upright converter may, in due course, be reinstated, or rather—since the early trials were only crudely conducted in the light of present skill—may eventually be properly appreciated. The Great Falls 7ft. by 13ft. converter, when provided with 16 ¾in. tuyeres in the bottom, successfully brought matte to blister in a very much shorter time than the side-blown vessels, and with a far more even corrosion of the lining, both of which points are the natural results of the better distribution of the air. A current of blast entering from below is divided into a stream of bubbles in ascending the bath. A side-blown current is more likely to break through in gulps. The latter also corrodes the lining, by preference in the immediate vicinity of the tuyere openings, and naturally, since the tuyere holes are in the back of the vessel only, chiefly on that side. The vertical converter is, in fact, in America looked forward to as the future form, provided the difficulty of making the bottom tuyeres stand is overcome. In large charges the drawback of blowing through the metallic copper is not of any consequence. The critical points, *i.e.*, the flame phenomena for slag and for copper, are said to be less easily observed, but this may, without fear, be put down as an almost trifling drawback, if correct, which experience will very soon remedy.

With regard to the important subject of the correct position of the tuyeres an interesting solution may be added, which was devised by Auerbach, in 1886, for the small Bogoslowsk converters of that time. It consisted in placing the tuyeres, pointed upward at an angle of 45° from a bottom wind-box, in a circular line around the circumference of the dish-like bowl of the converter cavity. By this means the metallic copper collecting in the bowl was not disturbed by the blast. The arrangement, though clever, no doubt suffers from the usual difficulties so far inseparable from the proper maintenance of bottom tuyeres, the wear being made specially objectionable by their position.

Conditions for Successful Converting.—The considerations which govern the efficiency of the converting operation are simple, but must not be neglected if the best achievable results are desired. They are, first, a sufficient bulk or mass of substance to act upon; second, the production of sufficient heat by the chemical reactions to keep all solid products well molten; and third, an energetic and rapid oxidation of the oxidisable constituents by means of an adequate column of air or blast. In small converters the mass treated easily suffers a cooling, particularly with an excess of blast towards the end, and this cooling grows in proportion to the diminution in size of bath, *i.e.*, capacity of vessel. The production of heat by internal reactions, fortunately, is accompanied by the creation of a solid product—slag—which, remaining within the vessel, conserves the greater part of the heat evolved, the escaping gases not carrying off enough to affect the maintenance of the slag and enriched matte in a state of liquidity. This fact is still more marked in the after-blow, or second period, when the sulphur of the cuprous sulphide is the only fuel consumed, the thermal work being materially supported by the superheating which the cuprous sulphide derives from the preceding combustion of the iron sulphide and from the formation of the slag. Finally, the rapidity of combustion is directly determined by the proportions of the column of blast absorbed in the unit of time. Velocity of reaction tends to counteract the robbing influence of radiation, of the convection of heat by the escaping gases, and of the absorption of heat by the metallic product which it does not yield up for any chemical purpose, and these abstractions of heat grow with the temporal extension of their influence. Quickness of reaction is an essential, therefore, and presupposes an adequate blast supply; and, for the best thermodynamic results, magnitude of mass treated is scarcely less important. These principles point the way to future progress in the work.

The Linings.—The question of the linings has been made one of the metallurgical spectres of the method, and much lament has been wasted on it from the inception. Their constant replacement is one of the main elements of cost, it is true; but, however serious this may be, the converter should at least not be held accountable for the expense of any work of smelting which properly should have been done in the blast furnace or reverberatory furnace beforehand. An intermittently working apparatus like the converter—which is furthermore marred by an imperfect contraposition of the substances forming the slag, *i.e.*, the iron in the mass of matte and the silica merely on the superficial surface of the lining enclosing that mass—is not a judicious means for the scorification of large amounts of iron. The early attempts to work up very low grade mattes, which led to the alarmed feeling here referred to, were irrational, and demanded too much. The endeavor should be to work up as high grade mattes as the local economic conditions will at all allow. The copper converter should be regarded from the standpoint of a refining apparatus, and not of a smelting apparatus, and this point of view will not only conduce to a betterment of the preceding smelting, but will also place the consumption of lining on the most rational basis possible under the local conditions. That the consumption of lining will have to be patiently suffered until certain radical improvements in the general practice of the pneumatic method shall have been established, which can at the moment only be imperfectly apprehended, is an unavoidable necessity inherent in the present state of things.

Given a proper, comfortable grade of matte, the operatives—if not the writers—have, however, long ago accustomed themselves to accept the expense of the linings as a matter of course. And when we recollect that the difficulty of providing suitable refractory material in sufficient quantity is said to have led to the early condemnation of the process in England (Vivian's, 1884-5), we are but painfully reminded of the ingrained conservatism of the practising metallurgist, shying at trifles because they are new. With respect to the composition of the linings, experience has very greatly narrowed down the demands once made on the "refractory" qualities of the material used. In fact it is now patent that, as far as the metal bath is concerned, the lining should not be actually chemically refractory at all, but should afford a suitable facility of scorification if the blows are not to be needlessly and uneconomically protracted. The mechanical, rather than the chemical, properties of the lining have required study, for the former decide its lasting qualities quite as much as the latter; and for this reason we occasionally find the most chemically ordinary silicas and clays in use, as the outcome of the empirical search for the cheapest, while, at the same time, most enduring, materials which the respective locality affords. The chemical composition of the lining is necessarily as acid as possible, from the nature of the chemical work expected of it, and should consist of the maximum amount of *free* silica which it is possible to get into the mixture, consistent with the presence of an amount of clayey substance supplying the cohesive qualities which the siliceous material lacks. The presence of a maximum of uncombined, free silica is a *sine qua non* for the development of a proper amount of heat to conduct the operation to a successful finish, and, since the silica acts as the chief determining agent—both in respect of the relative amount of iron scorified and of the temperature and heat units evolved—its affinity for iron should be kept unhampered by the presence of alumina, or other bases, in the lining.

In view of the importance of this question of the lining material, attempts were not long in being made having for their object the introduction of siliceous material from the outside during the blow, so as to conserve the lining. Efforts towards blowing sand through the tuyeres were undertaken very early, but have not been successful. Aside from the nuisance caused by the sand's blowing out of the windbox when the tuyeres were being punched, this fine material did not properly assimilate with the iron in the bath, and the bulk of it sped out through the nose. The feeding in of siliceous material in lump form also had not altogether the looked-for effect. It floated on top of the matte, and the paucity of oxygen there, due to its absorption in lower regions of the bath, impeded the union of iron and silica in the higher portions. Nevertheless, the question is not yet given up as hopeless, and it is still receiving a good deal of attention. Meanwhile siliceous ores are frequently added before or during the blow, or worked into the lining of the converter body as a convenient and advantageous half measure.

Basic Linings.—In connection with this subject, the old question of basic linings is being revived. This, as remarked, was at first taken up in direct disregard of the fundamental chemistry of the process, which is inexorably bound to the formation of a silicate of iron for the removal of the latter element, and, needless to say, the results were absolutely negative. Of late years the use of basic linings has, however, again been brought to the front with the special intention of employing a lining which shall be indifferent to the chemical action going on in the converter, while the latter is simultaneously supported by the systematic introduction of siliceous substances from the outside, principally ores. Special constructions and special manipulations are resorted to for the purpose of overcoming the obstacles experienced in the earlier attempts, and briefly indicated above, and some measure of success has been achieved. It must be clear at the outset, however, that, even at the best, the above strictures on the treatment of low-grade mattes in a Bessemer vessel continue to apply and must be observed, for otherwise the apparatus simply becomes a hybrid pneumatic appliance, halfway between an inadequately devised and conducted pyrite smelting furnace and an overburdened copper-converter. In any case the *basicity* of the lining plays no part whatever in these particular schemes, and the magnesite used might as well be replaced by a proper thickness of any other substance indifferent to oxygen, sulphur, and silica. In this connection the designation of "basic" is misleading. What is striven for is an indifferent, *neutral* behaviour, and, as regards this chemical attitude, Vautin's suggestion to use carbon blocks is worthy of renewed attention, though possibly their wearing qualities would be unsatisfactory.

The latest embodiment (*t*) of the so-called "basic" idea makes use of a horizontal converter 20ft. long inside by 8ft. diameter, with

(*t*) Process of Baggaley *et al.*, 1905.

36 $1\frac{1}{4}$in. tuyeres. It is furnished with the usual nose, but, in addition, has a special trapped feed-opening, for the introduction of the siliceous ore, near one end of the cylinder. It is also provided with an axially situated overflow opening, for the molten products, in the other end, which opening is suitably sealed against the issue of the gases and discharges into a special settler, or forehearth, for the separation of the slag and the dragged-out matte. The apparatus thus is virtually a continuously working cylindrical reverberatory furnace, in which the heat is generated entirely on the pneumatic principle. The siliceous or semisiliceous cupriferous ore fed in flows over a previously introduced bath of low-grade matte, in which the Bessemerising action is effected with its assistance, the lining of magnesite remaining indifferent. The 20ft. traversed are said to be enough to almost complete the assimilation of the silica contained in the ore (only 50 per cent.), so that a liquid slag issues from the overflow end. The sulphides in the siliceous ore are liquated out, and such silica as happens not to unite with iron floats away in the form of honeycombed shells—a point which is interpreted as a particular advantage, since it increases the acidity of the slag beyond that which the internal work automatically creates, and to this extent relieves and lightens the work of assimilation. This point, however, does not quite commend itself to true metallurgical feeling. The original copper tenor of the preliminary matte bath is 15 per cent., and it is proposed to obtain this matte by the prior smelting of heavy pyrite ores with coke. In the course of the converter treatment the matte is enriched until it finally is high enough to justify blowing direct to copper, which can at once be done in the same vessel. It cannot be said that there is anything in this method, taken as a whole, to justify great expectations and which cannot be achieved, with proper skill, in a more rapidly working manner by means of pyrite smelting. This statement holds true for the same aggregate quantities of the various original ores, including that from which the 15 per cent. matte was derived, as well as for a lower blast. The only noteworthy difference lies in the greater acidity of the slag, since the pyrite furnace and the ordinary acid-lined converter only reach about the same degree of acidity. But the increment obtained in the crude, merely mechanical way involved, *i.e.*, as incidental to the liquation of the sulphides out of the siliceous ore-matrix, is hardly distinctive enough to constitute a metallurgical reform. The basic converter lining does not require replacement, it is true, except at long intervals, when mechanically worn out; but, as a smelting apparatus, the vessel itself, doing its chemical work as it does, at the top of the matte bath, in a frothy mixture of matte, ore, and slag, falls far short of the perfection of a blast-furnace in the spatial co-ordination of the reacting bodies. To speak historically, the method is only a modern replica of Hollway's treatment of premolten pyrites in an ordinary Bessemer converter, when, feeding it with charges of pyrites and quartz, he succeeded in blowing for 14 hours without injuring the lining to destruction and enriched a 1.8 per cent. ore into a 50 per cent. matte. Nevertheless, he concluded that the converter apparatus was unsuitable for the work, and the blast-furnace more rational.

A pendant to the above method is a similar recent one, (*u*) which aims at the same general object of circumventing the lining, but which, recognising the true role assigned to the "basic" lining, supplants the latter by water-cooled furnace walls. The process is, however, conducted in a constructionally much inferior apparatus. This virtually consists of an adaptation of the old Swedish fixed converter, water-cooled in the tuyere region and in other places where a chemical attack of the walls might take place, which is built together with an automatically discharging forehearth for the separation of matte and slag, the whole under one reverberating roof. The ores to be Bessemerised with the assistance of the matte bath are fed through a charging-tube situated above the Bessemer dome, in which they are preheated by the escaping gases. Blast is only driven into the converter part. A heavy layer of slag is maintained on the matte, and the blast is forced in, just below the contact of matte and slag, so as to cause an energetic agitation, with the greatest possible utilisation of the oxygen at the most serviceable place, close to the point assumed to be reached by the floating siliceous ingredients in the ore. This process and the one above mentioned, though not of a revolutionary nature, at least are first attempts of note towards an emancipation from the acid lining, and, as pioneers of a difficult subject, may be remembered with some interest.

The "Selecteur."—We have now arrived at the present-day state of the copper-converting apparatus and its application, as far as they can be touched upon here. One characteristic and important innovation, however, remains to be mentioned, though its use is limited to practically only one locality. The pneumatic copper process could not be truly an accelerated Welsh process if it gave no opportunity for the formation of copper "bottoms." This deficiency in the procedure and plant so far described is fully made up by M. David's latest form of converter vessel, which he has called the "selecteur"—in allusion to the working scheme which it supplants. The shape of the vessel employed, also evolved at Eguilles, is spherical, with a spout or nose, thus again bringing down to a recent date one of Bessemer's early forms (that of 1855, never built), the special object of which was to minimise radiation. This prototype, however, was to be blown by means of an inserted tube, while the selecteur is supplied with a number of bottom tuyeres. These are so aligned as to coincide with the elements of an hyperbolic paraboloid, the idea being for the blast to give the bath a gyratory motion. Laterally, halfway up its rounded side, the vessel has a smaller, hemispherical, lined pocket, bolted on externally, and so arranged that, by means of a communicating channel between the two cavities, a portion of the contents of the larger can be let into the smaller by properly rotating the whole. By this means the copper first formed—which, as in the reverberatory process, contains most of the gold and a large portion of the impurities in the matte—can be mechanically separated from the rest at an early stage in the blow, thus rendering the balance of the metal so much the cleaner. The sulphides of arsenic, antimony, bismuth, nickel, cobalt, tin, lead, &c.—

(*u*) A. Torkar's method, Austria, 1904.

as far as they are not either volatilised or oxidised and scorified (which they will all be long before the copper, on account of their appreciably greater heat of combustion), and as far as they have a lesser heat of combination with sulphur than copper—are reduced into their metallic states by the first copper formed. Hence a small amount of the latter will serve to collect a relatively large portion of certain of these associated elements. The metals are concentrated in some ratio to the quantity of bottoms produced, so that the amount of the latter is of great importance. Gold may thus be extracted in its totality in about 14 per cent. of bottoms. But the selecteur allows the correct proportion to be well approximated, dependent on some experience being had with the particular matte treated, for the various impurities quantitatively predispose or indispose one another for reduction. The apparatus is the most ingenious representative of the mechanical aids to pneumatic treatment which has been yet devised, but it has not come into use outside of its French home. Fortunately, impure mattes are not common in districts where the converter process is most extensively employed at the present time.

Elimination of Impurities by the Pneumatic Process.—Of paramount importance is the general ease and thoroughness with which the pneumatic process eliminates current impurities from copper, even without the formation of bottoms. From the practical manipulative point of view alone, this feature constitutes a wonderful improvement over the older treatment methods. Though known in a general way since the time of the first Manhès experiments, the subject has only of recent years been more closely investigated, and is far from being finally dealt with. The amount of chemical analysis involved is extreme, and satisfactory parallel or congruous conditions for analytical research are unattainable. Comparative working tests are mutually exclusive, so to say, since no specific bulk or parcel of matte can be tested by *both* methods. Moreover, the distribution of the impurities is perplexingly irregular in both mattes and copper, so that insurmountable obstacles arise, even from the sheer impossibility of securing truly representative average samples. However, in fairly definite terms, a good deal is reliably known already, and it predicates the superiority of the converting method in respect of a few metals absolutely, and in respect of certain others relatively, owing to their more expeditious elimination. Notwithstanding numerous calcinations and oxidising smeltings, the older, less energetic processes admitted of but a mediocre purification from step to step. Arsenic and antimony were practically dragged through the whole curriculum, up to the last. But in the modern practice, even when previous treatment does not essentially work off the injurious elements, the accentuated thermal and chemical vigor of the pneumatic process accomplish a trenchant disruption of affinities in a single operation lasting merely as many hours as the older work took days, weeks, or months. As in the older treatment, purification is effected only through two channels, *i.e.*, either by volatilisation or by scorification. But, under the new conditions, elements and compounds become volatile which were less so under the old. Elements going into bottoms are brought into direct contact with the blast in the agitated whirl within the vessel, while in the reverberatory furnace they are shielded from the influence of the air by the cover of the matte and slag and by their affinity for the metal. That most injurious of all impurities, bismuth, is removed by volatilisation in both cases; but the reverberatory furnace gets rid of scarcely more than one-half (54 per cent.), while the converter drives out practically all (94 per cent. to 96 per cent.), only little remaining in the copper and less in the slags. Lead is equally removed by both methods, all of it vanishing (99 per cent.), but arsenic is largely volatilised in the vessel (73 per cent. to 91 per cent.), while, in the reverberatory furnace, it goes into the bottoms, unless eliminated in the calcinations (21 per cent. driven off). Antimony goes into bottoms also (total eliminated, 50 per cent.), and in the converter rather more is removed (62 per cent. to 73 per cent.). Selenium and tellurium are very largely eliminated in the reverberatory furnace; in the converter much the same (57 per cent. to 71 per cent.). To repeat, as far as the more common impurities are concerned, the old and the new methods stand on the same level as regards lead; the old is inferior with respect to antimony, very much less capable as regards bismuth, and enormously behind as far as arsenic is concerned.(*v*)

As against the enthusiasm which the converter adept is apt to feel over the superiority of his process in this important connection, the *savants* of the Welsh process have entered certain quiet protests. As expressed by Mr. Allan Gibb,(*w*) the degree of elimination of any impurity in the converter depends upon the proportion originally present and upon the proportion of other impurities present, which behaviour is analogous to that of the impurities in the case of furnace-bottoms. As, in both instances, the commencement is matte and the end blister, and as there is only one chemical element to do the oxidising, and, moreover, since the concentrated energy of the converter only replaces the attenuated energy of the other method, it follows that, whatever the intermediate steps may be, the final results of both methods must, on the whole, be much the same, and this fact is borne out by his observations. Making a comparison of the total roaster operation with the action of the converter, Mr. Gibb shows that there is not much difference in the *degree* of elimination, but a very marked difference in the *manner*. Bismuth, not forming salts with cuprous oxide, is removed almost wholly by volatilisation in both processes; but arsenic and antimony, for their part, while chiefly volatilised in the converter, are both principally slagged in the reverberatory furnace. Mr. Gibb contends that the difference of action is less due to distinctions of a physico-thermal character than to chemical ones, viz., to the composition of the respective slags. The Bessemer slags having only 1 per cent. to 2 per cent. copper, and the roaster slags containing from 6 per cent. up to 40 per cent. of copper, simply in consequence of the longer

(*v*) E. Keller, *Trans. Am. Inst. Min. Eng.*, 1898, vol. XXVIII., p. 127, and later papers.

(*w*) *Trans. Am. Inst. Min. Eng.*, 1903, vol. XXXIII., p. 653, and other papers.

exposure to air, the latter afford an opportunity for arsenic and antimony to form arsenates and antimonates with the cuprous oxide, salts which are not volatile at the roaster temperature. In the converter the elements mentioned are volatilised from the very beginning of the operation, roughly one-half being removed by the time white metal is formed. The pressure of blast in itself has no purifying effect; but, secondarily, by creating a higher temperature and energising the blows, it will tend in that direction.

While thus, as a whole, the rapid pneumatic treatment of mattes may present no paramount chemical advantages over the older work in point of purification — especially when really dirty mattes are Bessemerised (which, so far, appears not to have been done)—its tremendous advantages in point of simplification cannot be gainsaid. And not the least important corollary for the practical metallurgist is the corresponding mental relief which it affords from the otherwise ever-present vexatious question of the impurities, aside altogether from expedition, economy, &c.

Chemical Features of the Process.—As remarked above, the chemical features of the process have as yet scarcely received the attention which they deserve. The complete secret of the slag formation is not yet lifted. It is not understood how the oxidation of the iron is effected; and, though the end result is, of course, the formation of protoxide, which forms a silicate with the quartz of the lining, it is a moot point what becomes of the combination of oxygen and iron, or what is its behaviour between the time of its first formation and its scorification. It has been thought that it remained in solution in the ferrous sulphide of the matte as protoxide. On the other hand, there is a likelihood of the formation of a higher oxide, which is subsequently at once reduced to protoxide in the presence of silica, with which iron can unite in no other permanent form. More positive knowledge is to hand regarding the behaviour of the white metal in the after-blow. The assumption that the cuprous sulphide is oxidised directly to metallic copper and sulphurous anhydride is not tenable. There is, on the contrary, a formation of cuprous and cupric oxide, which play a reducing role with each other, wholly analogous to the roaster process, though, of course, the reactions are run through with greater speed.

The evidence of the gases points to the fact that both during the first blow, or the slag-forming period, and the after-blow, practically the whole of the oxygen in the air blown in is (or can be) utilised. In this respect the converting process and pyrite smelting, in its purest form, act exactly alike. There are moments during the blowing for slag when there are leakages of air through the molten column, easily permitted by the very irregular turmoil going on within the vessel, and free oxygen may also appear towards the end of the after-blow, just before the copper finish. But, on the whole, the theoretically desirable condition of things is actually enacted during such portion of the two periods when the most work is being done.

There appears to be a kind of preferential oxidation of the iron of the matte during the first period. Of course, only that portion of the sulphur is available for oxidation during this period which is not bound as cuprous sulphide. The rest is commonly assumed to be combined with iron as protosulphide, notwithstanding that it has been long known that there is practically always a shortage of sulphur for this purpose, and which gave rise to the supposition that mattes contained lower sulphides of iron—a view no longer held. Generally speaking, the first 10 minutes or so at the beginning of the blow are the most interesting in regard to the iron, the average percentage of sulphurous acid in the gases by volume then running up from only 1 per cent. to 10 per cent. within that time. Thereafter it remains at about the latter figure up to the end of the slagging, while, simultaneously, the free oxygen in the gases ranges from mere traces in the first 10 minutes to only 1 per cent. for the rest of the period, with an occasional 3 per cent. (all by volume). If the iron and sulphur contained in the protosulphide of a 50 per cent. matte were equally oxidised, then about one-third of the oxygen of the blast should go to the iron, and about two-thirds to the sulphur, and the escaping gas should contain 15 per cent. by volume of sulphurous acid. It, however, contains only 10 per cent., and, at the same time, only a trace of oxygen or free air. It is thus obvious that relatively more of the iron is oxidised than of the sulphur in the monosulphide, assuming that all the iron is present in this condition. In any case, sulphur takes second place for a part of the slagging period. It is also likely that portion of the sulphur is driven out in the elemental state, without oxidation within the vessel. The protosulphide acts in this manner in the pyrite furnace, and the conditions in both apparatus are fundamentally identical.

Subsequently, during the afterblow, the sulphurous acid increases up to over 18 per cent. by volume, with a simultaneous 0.5 per cent. of oxygen, and it is only during the last few minutes of the finish that the oxygen may reach 2 per cent. to 3 per cent. or over. It is only here, then, during the whole process, that, in good practice, an excess of air can be said to escape from the converter. Yet the dire effects of such an (assumed) excess were once greatly feared, both in the pneumatic treatment of mattes in the converter and of pyritic ores in the blast furnace!

One important circumstance which assists in explaining the preferential oxidation of the iron, as compared with the sulphur, is that the total iron and its associated sulphur present in mattes stand in the relation to each other of a compound which actually contains *less* sulphur than ferrous sulphide and *more* iron. This phenomenon is the outcome of the decomposition of the true ferrous sulphide, by mere heat, in the smelting operation from which the matte is derived, the particular iron sulphur compound which results depending on the temperature, pressure, &c., of the matting operation. It, however, probably always contains free iron. In fact it may be regarded, for all practical purposes, as consisting of true ferrous sulphide plus metallic iron. Now, undoubtedly the oxidation of this uncombined iron takes place instantly from the commencement of the blow, the combustion of the real protosulphide being relegated to a secondary position during the whole period, though quite concurrent with the other. The oxidation of the protosulphide requires its preliminary decomposition, which, besides demanding heat, also takes time. The oxidation of free iron is not thus hampered, and its preferential combustion must be especially marked when its amount is considerable. As is well known, most mattes contain it to a sufficient extent for it to be shed out of the solution on cooling to a degree more or less manifest to the magnet, and even the naked eye.

But even on general thermo-chemical lines it should be obvious that the iron will be disposed to take the part of the main fuel, even to the extent of the elimination of portion of its concomitant sulphur without oxidation. The position is simply that all pneumatic processes, to be rightly weighed, should be regarded from a point of view accepting the *oxygen* as the active agent in the combustion process, not the fuels themselves. It is the gaseous oxygen, while it traverses the molten mass, which seeks combination, and not really so directly either the iron or the sulphur, since these are combined with each other. And while on this search the oxygen necessarily exercises a discriminating or selective action. It prefers that element of the two present with which it can generate the greater amount of thermal energy. Berthelot's law of maximum heat, though not absolutely correct, covers the case. But when the position is thus viewed from the standpoint of the oxygen, our valuation of the calorific importance of the combustible elements is liable to be subverted from its ordinary plane. What is meant will become clear from the remark, for instance, that although the heat of formation of ferrous oxide in terms of iron is 1,220 calories and that of carbonic acid in terms of carbon 8,080 calories, still one kilogram of oxygen combining with iron to protoxide yields 4,270 calories, and with carbon to carbonic acid only 3,030 calories. In terms of oxygen or air, therefore, the fuel values of iron and carbon are quite inverted from the positions they occupy in the popular judgment. And there is a similar incongruity between iron and sulphur. In terms of the unit weight of these substances, the heats of formation of the protoxide and of sulphurous acid are respectively 1,220 and 2,221 calories. Expressed in terms of oxygen they are respectively 4,270 and 2,221 calories—the same weight of atmospheric oxygen, therefore, giving about twice as much heat when burning the iron in the matte as when burning the corresponding sulphur. This contrast of figures will serve roughly to indicate the position in the converter, without going into further details. The air admitted has full sway to satisfy its selective tendencies in an excess of sulphide, and, for the reasons mentioned, and certain others springing from the properties of iron sulphide in high temperatures, which tend to impede the oxidation of the sulphur, it no doubt does so. Even under less energetic conditions, such as those of ordinary temperature and atmospheric pressure, it is true that ferrous sulphide acts quite the same—the iron oxidises to ferric oxide, but the sulphur is simply discarded in the elemental state, unoxidised.(*x*)

(*x*) A. Wagner, *Dingler Jl.*, 1870, vol. 192; also, Prof. Pollacci, Internat. Congr. Appl. Chem., Rome, 1906

The formation of substantial quantities of sulphuric anhydride has been assumed on the analogy of the blister furnace. The point does not appear to have been investigated, but the assumption is open to doubt. The formation of the anhydride is only likely at fairly low temperatures. It decomposes at the very heat of its own formation when it is the direct result of the oxidation of sulphur, so that, except possibly towards the end of the copper finish, its existence is jeopardised.

Nature and Importance of Rôle Played by Silica.—The action of silica, supplied by the lining or otherwise, is an exceedingly important one. It has already been stated that it must be in the *free* state to act at all. No pneumatic process involving the maintenance of the solid products in a state of fusion is possible if it requires the removal of essential quantities of iron, as will no doubt always be the case, unless *free* silica is present to regulate the oxidation and to act as a balance-wheel in a combined physical and chemical sense. In the simultaneous presence of free silica and free air or oxygen, under the general conditions of pneumatic smelting, the iron will only burn to protoxide, and will at once unite with the silica to a silicate of a definite composition, forming a slag which, in the presence of matte, will readily seek a supernatant position, and so facilitate the mechanical separation of the two. The determining influence of silica is not often referred to, but its action follows fixed laws which one cannot over-ride and which narrowly circumscribe the pneumatic processes. What we call silica is in reality simply the anhydride of an exceedingly strong acid, which becomes active only in an igneous condition, but then seeks its base the same as any other mineral acid. As far as its chemical relations to iron are concerned under the conditions existing in the converter, that element (iron) behaves exactly the same as it does at ordinary temperatures in the presence of ordinary free acids. Hydrogen sulphide will not precipitate iron in the presence of hydrochloric acid, for instance, and, similarly, iron will not form sulphides at high temperatures in the presence of free silica. Conformably, therefore, sulphur already combined with iron can be driven out and burnt in an oxidising atmosphere when uncombined silica is present, the iron and silica uniting. One of the most striking features of the converting operation is that this union follows set lines, controlled by the heat generated within the converter and by the formation-heats of definite silicates. Only that particular silicate of iron will form which *can* form at the temperature evolved, and no other. Against popular expectation, the formation of a silicate approaching a bi-silicate is indicative of a lower temperature than the production of a singulo-silicate. For the sake of the best utilisation of the lining, or, in other words, its consumption to the smallest possible extent, a basic slag should be looked forward to. Fortunately, the thermal energy of copper-converting is vigorous enough to permit of the generation of the singulo-silicate of iron. Its formation temperature has been synthetically determined as about 1,270° C., a figure which agrees with direct measurement of the temperature in the converter, as also with calculation of same from the analyses. The presence of scorifiable bases other than iron modifies the resultant heat and slag; but, in a general way, these remarks characterise the position. No variety of manœuvring will get more silica, or more iron, into the slag than the thermal conditions allow. The system of forces in the converter, being left entirely to itself, only creates that phase of results which is the easiest for itself.

Behaviour of Copper as regards Loss, &c.—Needless to say, one of the most satisfactory features of copper-converting is the small actual copper loss sustained through the oxidation of the metal. With the establishment of this fact fell the main dread entertained with regard to the process. It seemed, *a priori*, inevitable that the rapid oxidation of mattes should lead to a marked copper scorification. There was the evidence of the Welsh process, with its heavy locking-up of values in slags, in spite of its slowness, to support the suspicion. And yet the latter was entirely unfounded. Except for mechanical losses, there is no reason for anxiety—if the process is intelligently handled—that a noteworthy copper loss will be suffered. And, in any case, the method being properly only a refining method, its slags are available for return to previous treatments, as is usual, if rich. As long as there is a sufficient cover of protosulphide of iron, or sulphur enough to chemically bind the copper, no apprehensions need be felt. In terms of oxygen the heat of formation of copper oxide is only about one-half that of ferrous oxide, while, as a further safeguard for the copper, its heat of combination with sulphur, in terms of equal weights of sulphur, is nearly the same as that of iron. On the one hand, therefore, the energy required to decompose the one, as compared with the other, finds the same resistance in both, and there is no choice, while, after decomposition, and relatively to the oxygen, the heat developed by the combustion of the iron is twice as great as that from copper, and this reaction, perforce, preferentially asserts itself. The protection of the copper is thus complete, as long as there is a sufficiency of iron sulphide. In addition, the potent bearing of the sulphur in combination is quantitatively evidenced in favor of the copper by the circumstance that the same weight of the metalloid covers and protects about two and one-quarter times as much copper as it does of the corresponding iron.

It may be proper to remark, however, that since the days of the first pneumatic experiments with mattes the position of copper in relation to sulphur has been assigned a much weaker place than was given it in Fournet's empirically established series some 70 years ago. His determinations placed copper at the head of the list in point of affinity for sulphur—a position which, in ordinary metallurgical experience, would seem to be its proper station. In descending order the series was: copper, iron, tin, zinc, lead, silver, antimony, arsenic. The preciser knowledge of thermo-chemistry now, however, arranges the metals in the following order, according to the respective heats of formation of their sulphides: aluminium, magnesium, manganese, zinc, cadmium, iron, cobalt, lead, copper, nickel, mercury, silver, with antimony and arsenic about on a level between zinc and iron. The relative degree of affinity of copper for sulphur has thus been considerably lowered from its ancient eminence. However, as a matter of actual practical importance, where the question of the decomposition of the metallic sulphides enters, in the presence of oxygen, the position is governed by the heats of formation of the respective oxides, and the results appear to follow Berthelot's principle of maximum heat. Here copper occupies a subordinate position compared with the metals with which it is commonly associated in mattes—an inferiority which shields it from attack, *i.e.*, scorification, except under the reversing influence of relations of mass, &c. This last reservation holds good for the after-blow on white metal, where, if scorification were to ensue, the modicum of iron sulphide present would be powerless to protect the copper. However, in that period, after the removal of the ferrous silicate slag, the roast-reaction taking place is effected wholly independent of the lining, and the latter might as well be basic or neutral.

In addition to the above, the elective dissociation of the ferrous sulphide, as compared with that of cuprous sulphide, is fostered by the relatively easier elimination of elemental sulphur from it, in high temperatures (even without oxidation), in a neutral atmosphere, which latter must obtain in portions of the bath. The metallic iron simultaneously liberated remains dissolved in the balance of the monosulphide. At the fusion temperature of the latter, the vapor tension of sulphur is nearly equal to one atmosphere, and, theoretically at least, it should be possible to fully decompose the compound *in vacuo* at 900° C. (*y*) This pronounced volatile tendency of the sulphur in combination with the iron paves the way for the facile and rapid oxidation of both constituents, in distinction from all other metallic sulphides that come into consideration here as heat-producers.

A further circumstance shielding the copper from scorification in the slagging period is the more vigorous active part taken by the iron in the formation of a silicate, not only quantitatively, but thermally. For want of specific data on the subject, it is to be assumed, on general evidence, that the heat of formation of cuprous silicates is lower than that of ferrous ones, and that, therefore, ordinarily the latter will form by preference. This particular subject has, however, scarcely been investigated, only the formation heat of the bi-silicate of iron being listed so far. It is to be hoped that we may soon have some information on the thermo-chemical data of the much more important singulo-silicate, the want of which hampers alike the copper, lead, and nickel metallurgist.

Review of State of Thermo-Chemical Investigation of Process.—The thermo-chemical investigation of the copper-converting operation in detail, or even with positive satisfaction in rough outline, has not yet been carried out. This is the weak side of all metallurgical knowledge at the present day—an apathetic state of things which will not be remedied until our successors form the habit of currently thinking in terms of physical chemistry. Some crude approximations, not tied to the full analytical data of any one or any series of observations in

(*y*) H. Le Chatelier and Ziegler, "Sulfur de Fer, &c.," *Bull. Soc. d'Encourag.*, 1902; also, von Jüptner, "Grundzüge der Siderologie," 1904, III., p. 98.

actual work, have been made; but a painstaking investigation of concrete cases is still to be looked forward to. Next after Bode's (1872), Hollway's and Professor Akerman's (1878), and Professor Balling's (1882) theoretical calculations of the pyrometric intensity develcped by the combustion of the ordinary natural (pyrites) and metallurgical sulphides (mattes), the first to apply a similar test to the pneumatic treatment of mattes by Bessemerising was the last mentioned. In his text-book of 1885 he calculated the temperature evolved in the blowing of the *matte blanche* of Eguilles (77.61 per cent. copper) as 1,862°, exclusive of losses by radiation, &c., but accidentally omitted to take into account the calories absorbed in the decomposition of the ferrous sulphide. No excess of air was assumed to be injected; but in this respect the tendency has subsequently been to make allowances far exceeding all necessities. Only that particular practice must be conceded to represent the type that should be striven for, *i.e.*, the normal one, which utilises for serviceable work as nearly as possible 100 per cent. of the oxygen blown in; and it is wholly unnecessary, and altogether detrimental, to apply twice the theoretical amount of air, as has been assumed, or even more.

The most elaborate attempt so far published to elucidate the thermo-chemical mysteries of matte-conversion is that of Jannettaz (1902) (*z*). It is, however, after all, only a mere approximation like its predecessors, not executed at the hand of analytical data derived from any one specific case, or series of tests, and therefore goes quite astray. A temperature of as high as 2,009° is calculated for the slagging period, which figure is then modified to 1,450° by the introduction of an excess of air based on the practice at Eguilles, where, it is said, 2,500 cubic meters of air are blown in for 1,500 kilos of 30 per cent. matte, being one-third more than is required. But even this reduced temperature is too high, for direct measurement, by means of Seger cones encased in iron bottles thrown into the vessel, showed the temperature to be only 1,260°. The heat relations for a blow on regulus are not gone into by this writer, though equally as interesting as those of the slagging period, and at least equally as important, because affording the proof of the very significant fact that the final temperature in the converter leaves the metallic copper in a sufficiently superheated state to guarantee absolute liquidity.

This point was incidentally touched upon by Roesing (1892) in a paper (*a*) devoted to the Bessemerising of argentiferous lead-bullion, in a steel converter, into enriched lead and litharge, an accelerated cupellation process in which the heat relations are rather more favorable than they are in matte-conversion. For purposes of comparison the above-mentioned Eguilles white metal (77.61 per cent. copper), with an assumed initial temperature of 1,000°, is calculated to a finish at the melting point of copper (1,054°), with 10 per cent. radiation loss, and the proof is given that an excess of 23 per cent. of air will nullify the process. The same figures, extended and corrected for the actual

(*z*) P. Jannettaz, "Les Convertisseurs pour Cuivre, Paris, 1902."
(*a*) *Stahl u. Eisen*, 1892; *Eng. and Min. Jl.*, vol. LIII., 1892.

excess of air during the copper-forming period, which would be taken high at an average of 5.8 per cent. of air by volume, give a final temperature of 1,173°, and, for no excess of air, of 1,223°. The initial temperature assumed for the white metal is, however, much too low, and the actual figure would appreciably increase the final heat. Yet, even as they stand, these results more nearly approach the truth than any other calculated results given in the literature of the subject. By means of the optical pyrometer of Mesné and Nouel, controlled by Le Chatelier's thermo-electrical pyrometer, Jannettaz ascertained the temperature for 30 per cent. matte in the selecteur, at the beginning of the blow, as 1,016°, during the blow as 1,260°, and at the end as 1,200°. Under Professor H. M. Howe's direction the temperatures were similarly measured, in a small upright converter of early type, as rising from 1,234° to 1,393° during the first blow, and as standing at from 1,220° to 1,239° in the after-blow. A repeat test gave the figures as 1,090° to 1,305°, and 1,192° to 1,164° respectively. It is obvious, from the paucity of data, how the subject has been neglected, though it is one of the most interesting in all modern metallurgy. Incidentally, the results confirm the inference logically to be drawn from the chemical features, that while there is a rise of heat in the slagging period there is a gradual fall of temperature in the copper-forming period—a circumstance which occasionally demands special attention in actual work, and is remedied by throwing in a small amount of carbonaceous material or ordinary matte. Finally, it may be remarked that tests with small laboratory converters have established temperatures, when using ordinary air, of 1,240° to 1,280° for the slagging period and of 1,170° to 1,200° for the copper period.

Use of Oxygen Gas.—It need scarcely be remarked that it has long been suggested to use oxygen gas, or air enriched with oxygen, nor that the only obstacle up to date has been the cost. The problem of the cheap production of the gas on an industrial scale, suiting metallurgical requirements, is, however, daily drawing nearer solution, and the regular application of oxgyen gas in this and numerous other branches of the smelting art is only a question of time. So far, only laboratory experiments (*b*) have been made in the Bessemerising of copper and nickel mattes. They have indicated most striking improvements. Even slight enrichments of the oxygen in the atmosphere, not exceeding an increase from 25 per cent. to 29 per cent. by volume, have given splendid results. The temperatures were throughout increased by from 100° to 200°, and the velocity of the reactions was so accelerated that the same work could be done in two-thirds to one-half of the usual time. Further effects were a smaller volume of waste gases, and higher contents of same in sulphurous acid, the percentage being nearly doubled for air enriched to the slight extent mentioned. Practical consequences are that a given converter plant will be enabled to double its capacity, and the gases will be rendered more suitable for acid-making than they now are, owing to the difficulty of preventing dilution with outside air. It is reckoned, on general data,

(*b*) Brandt, *Metallurgie*, vol. II, 1905 ; Hesse, *ibid.*, vol. III., 1906.

that even under present conditions of cost, the expense of producing blister copper would be increased by not more than one-sixth, an increment well outweighed by the other benefits.

The Metal Losses.—The most important industrial point about any metallurgical process is that of the unavoidable metal losses which it entails. The custom of seriously controlling these is, however, only a very recent product of modern commercial and scientific thrift, scarcely half a century old. The deplorable wastes incurred in the endless re-treatments to which metals were subjected in the past were suffered for want of something better, and a deeper interest in losses was obliterated by the inability to avoid them. In the copper industry, too, the general tractability of the metal induced a spirit of reliance on its invulnerability which engendered a negligence of its own, and copper metallurgists have been notoriously supine in the matter of metal losses. The volcanically intense activity of the converter, however, early led to serious apprehensions in this connection, and the subject was at least cursorily investigated at once, fortunately with practically gratifying results in all cases where the scheme of work was truly large. Absolutely systematic investigations still remain to be made. Some attempts at such, unfortunately on a cramped working scale, or else mere laboratory experiments, have yielded disparaging results, which would long ago have killed the method if they were anywhere near true.

The question of losses is, of course, of most importance in connection with the precious metals. As regards copper itself even a serious scorification could be tolerated with equanimity, because the slags can be re-treated, and the volatilisation of copper would be slight at the worst; but in the case of gold and silver a heavy volatilisation loss would be an enormous drawback. With regard to these two metals the copper industry shows a decided change of front during the last quarter century. The first third of the last century was practically still ignorant of the economic importance of the collecting power of small amounts of copper for the precious metals, and continued to prefer much lead instead. The growing dearth of this metal in many districts, however, has forced the use of copper as a vehicle into greater prominence, and, since the perfection and widespread introduction of the electrolytic process of copper-refining, it may be said that copper as a collector is quantitatively fairly rivalling the older metal. This is especially so in America. In this, the adopted and vaster home of the pneumatic process, the latter naturally soon came in for its share of anxiety as regards the precious metal losses. The very first investigations, however, antedate the present argentiferous days, so that, in the beginning, only the copper waste was considered, and taken philosophically in view of the re-smelting of all middle products, slags, &c. In those early days when, in America for instance, besides the other charges, the refiner did not pay for silver unless it ran 35ozs. to the ton of matte, and most of the latter was poorer, the crude estimates and surmises entertained as to the silver losses were scarcely reliable, and afforded a good opportunity for a severe adverse criticism of the converter process. Furthermore, lack of manipulative skill then still allowed occasion for the formation of slags rich in copper to arise, and this circumstance, together with the absence of fluedust chambers, &c., for condensing the fumes, was the cause of disparaging balance-sheets. Investigation confirmed the suspicion that, though the loss of silver by volatilisation might be slight in the slag-making period, it was higher, and possibly very serious, in the after-blows on white metal, and for a number of years a corresponding note of alarm was sounded to the detriment of the process, and is still current in some quarters. As a corrective it was suggested to simply blow the matte up to white metal or regulus, and to run this to blister in the ordinary reverberatory furnace way, or to subject it to the so-called "direct" process, or one of its older or more recent variations. Still more recently the direct electrolysation of the regulus is being urged as the proper means for circumventing heavy losses in silver (and gold). Meanwhile, however, quite cognisant of the fact that the item of losses was the particular feature by virtue of which their marvellous plants might become magnificent mistakes, the large establishments of America and its technical dependencies have continued to blow hundreds of thousands of tons of matte into blister, and have produced millions of ounces of the precious metals, undismayed by the apprehensions that were disquieting more purely academic circles.

The difficulties in the way of a correct determination of the losses are principally of a practical, *i.e.*, mechanical nature, and reside, in the last instance, in the obstacles which the extremely irregular distribution of the three metals, in all the products involved, opposes to true average samples. An amount of careful sampling of materials very difficult to sample is required, which is calculated to appall the works managers of to-day. Stoppages and clean-ups, *i.e.*, interruptions of current operations, would be necessary which even the strongest metallurgical curiosity cannot condone to the disadvantage of the business end of the work, and so the losses in copper-converting have generally been taking care of themselves. As intimated, they have, in a few isolated cases, been crudely determined at large plants with a general result that they might be worse, and no attention is being paid to them in this complacent temper.

Some of the figures available from the literature of the subject are the following. In the older Anaconda plant (1890-4), on very clean ores, the copper loss appeared to be 4 per cent., and that in silver 5 per cent. But this plant had very imperfect dust-catching arrangements, and the censurable practice of cooling the vessels by filling them with water aggravated the copper loss. In the newer plant (1895) the losses ran out at copper 2 per cent., silver below 1 per cent. This was on a scale of production of 45,000 tons of copper annually. About this time unspeakable losses were attributed to the square-shaped vessels in use at Durango, Colorado, which prejudiced the process considerably. On the best of authority it may be stated that the losses were incurred, but that they were due to the use of linings made of silicious silver ores, carrying lead, which ores, furthermore, were incorrectly sampled, so that the metal balance was thrown out of order. Before that time, Vivian's, in Swansea, claimed a loss of 2 per cent. in copper in blowing up to white metal, and considered the losses in further blowing the latter prohibitive. In 1894 Dr. Peters (*c*) gave the figures for the treatment of a small parcel of matte which, on account of 2.2 per cent. of bismuth, had caused an unintentional exceptionally careful clean-up. They were 2.9 per cent. for copper, 5.6 per cent. for silver, and no appreciable loss in gold. These results he then regarded as approximately characteristic of average American practice at that time. Later, in 1895, (*d*) he estimated the loss, with good dust-chamber facilities and not too many volatile metals in the matte, as 1 per cent. to 1.5 per cent. of the copper and 2 per cent. to 2.5 per cent. of the silver. The loss in Bessemerising leady mattes, containing 10 per cent. to 15 per cent. lead and 40 per cent. copper, he placed at 33 per cent. to 50 per cent. of the silver. Dr. James Douglass, in 1895,(*e*) on the showing of admittedly inconclusive data, mentions losses of 3 per cent. in copper, 5 per cent. in silver, and again, 1899, (*f*) 4.6 per cent. in silver and 8.2 per cent. in gold. Since then, however, apprehensions have become very much pacified by greater intimacy with the process, and it is the custom nowadays to rest satisfied that, given good condensing arrangements for the fluedust and fumes, the losses are merely nominal. In any case they are held to be much lower than they would be in the only alternative pyro-metallurgical method—that of roasting: a method, too, which, under the spell of two centuries of supreme sway, has itself generally been left quite untroubled by any serious probing for avenues of loss and the special degree of their influence. A modern French view on the subject of the converter losses is that of M. Vuigner, at Eguilles, 1902, who expresses the opinion that copper is mostly lost by volatilisation, never amounts to 2 per cent., and is taken largely if put down at 1 per cent.; that the silver loss never surpasses 4 per cent., but is frequently over 2 per cent. when lead and antimony are present; and who considers that perfect dust and fume deposition will guarantee a practically full recovery of all the three metals.

Undoubtedly the extent of the actual losses depends largely upon the magnitude of the scale of operations, small plants suffering through channels of incomplete apparatus, &c., against which large plants are protected. As an instance may be cited the interesting case of a careful, systematic determination by Juon, in 1903, (*g*) at the antiquated works at Bogoslowsk, in the Ural Mountains, which was made on a very contracted scale: 882 pud (14 tons) of 29 per cent. matte were melted down in a reverberatory furnace, blown to white metal in a small, inefficiently constructed converter, in eight charges, poured, remelted, and then finished in four charges to black copper of 98 per cent. Taking

(*c*) *Mineral Industry*, 1894, vol. III.

(*d*) "Modern Copper-smelting," 7th ed., 1895.

(*e*) "Recent American Methods, &c.," Cantor Lecture, *Jl. Soc. Arts*, vol. LXIII.

(*f*) "Treatment of Copper Mattes, &c.," *Inst. Min. and Met.*, 1899.

(*g*) *Oesterr. Zeitschr. f. B. u. H.*, 1903, vol. LI., No. 30.

accurate account of all products except fluedust, for the deposition of which there were no adequate facilities, the deficiency was 11.26 per cent. of the copper. The ores were not argentiferous, hence the silver question was not touched. More damaging to the pneumatic method still are the results of recently made laboratory experiments by Günther, 1905, (*h*) conducted with suitable apparatus and with all scientific care and precision. The quantities of matte used were 50 kilos to 90 kilos, divided into several smaller parcels, which were blown under pressures ranging from 2lbs. to 7lbs. per square inch. After slagging, the two products were poured, and the united white metal was then blown to blister. The first period of blowing showed losses of 1.77 per cent. copper and 2.78 per cent. silver: and a duplicate, 0.37 per cent. copper, 1.59 per cent. silver. The blowing of the white metal (71 per cent. to 77 per cent.), however, gave disastrous-looking figures, viz., respectively, 20.14 per cent. and 21.11 per cent. loss in copper, and 22.12 per cent. and 23.42 per cent. loss in silver. The mattes were from Mansfield, where they are not specially impure—chief impurity, 3.7 per cent. to 7.4 per cent. zinc. There is no doubt that losses as grave as these are not characteristic of copper-converting on a proper scale, for they far transcend even the aggregate losses sustained at the present day in the whole smelting procedure from raw ore into blister copper.

It is obvious that, provided the operation is conducted on reasonably careful lines, the pneumatic treatment of mattes cannot lead to any other losses than, first, that suffered through the non-condensation of the volatile products, *i.e.*, the chemically or mechanically entrained elements in the fumes and gases; and, second, that which is encountered in the subsequent treatment of the slags, old linings, fluedust, vessel refuse, and similar middle products, in the prefatory smelting process. There need be no other source of leakage of a palpable nature. As far as the entrainment of silver and gold is concerned, the decrement incurred through non-condensible elements and compounds, which cannot be recovered even with the most perfect condensing system, must, however, be exceedingly slight. Again, the losses incident to the passage of the middle-products through the antecedent operations, etc., will be but inconsiderable when reckoned on the original contents of the matte converted.

The metallurgical records of Mount Lyell, which, it may be asserted, are practically unique, for copper-smelting plants, in the painstaking care and attention with which the metallic balance-sheet is kept, afford a means of determining the copper and precious metal losses with exemplary closeness, and for one period out of many, covering the production of 4,000 tons of blister, are as follows. Crediting the full contents of all the middle-products made by the converter in addition to its direct metal output, the abstraction of copper through the channels that cannot be further controlled amounts to 1.17 per cent. of the copper in the matte. If the losses incident to the resmelting of the middle-products in the ore blast-furnaces are added, then the total

(*h*) *Metallurgie*, vol. II., No. 22.

copper loss is 2.02 per cent. Of this total 58 per cent. is incurred in the converting operation and 42 per cent. in the blast-furnacing of slags, linings, &c. Efficient dust-collecting arrangements render the simultaneous silver loss very slight. The direct loss in the converter is only 0.68 per cent.; but the re-treatment of slags, fluedust, linings, etc., increases this to 1.18 per cent. Here, again, that portion of the total loss which is sustained direct in the vessel is 58 per cent., while the middle-products suffer a loss corresponding to 42 per cent. (*i*) It will be noted that the direct conversion losses are inconsiderable. In fact, they come within the range of abstractions which may ordinarily be attributed to mere mechanical causes, *i.e.*, short comings of fluedust deposition, &c. The greater direct recovery in silver than in copper follows from the nature of the case. In gold there is a decided plus over the showing of the matte and ore, due to the almost inappreciable loss sustained in the gold assay of ores and mattes. Compared with the very much larger quantities handled by the metallurgical plant, this shortage is relatively greater than the actual loss incurred in that plant. Hence the gold recovery apparently—but only apparently—exceeds 100 per cent. as a rule. The ascription to the converter treatment of the combined loss in vessel and furnace, as expressed in the higher figures, is obligatory and just. The large amount of middle-products which has to be furnaced, all of them too rich to throw away, is an unavoidable accompaniment of the process; but, if not worked up, their non-recognition would render the yield quite as unsatisfactory as the early experimentalists deemed it to be. From the nature of the work, the direct vessel output varies a good deal. Copper moves between 95 per cent. and 80 per cent., the balance going into the middle-products. Silver favors higher figures.

Deficiencies of Present-day Method.—Although the matte-converting process of to-day seems to have reached its climax of perfection, and nothing further appears capable of addition except the use of oxygen, in the chemical direction, and a still further increase in size of apparatus and the well-known desideratum of greater power-efficiency of the machinery, in the mechanical direction, it is nevertheless still weak in certain vital metallurgical respects.

The improvement of the mechanical features may be left to pursue its own course; but the application of oxygen will probably follow in the wake of its introduction in the steel Bessemerising practice for small charges ("Kleinbessemerei"). It is somewhat singular how the two contemporaneous methods have developed along independent lines, notwithstanding close chemical and intimate mechanical analogy. Even their constructional features have not actually reacted on each other to any tangible extent, notwithstanding the prominence given to the question of side-blowing, &c., in the small steel-converters. However, localised blowing and other points affecting the homogeneity of the steel product are of no interest in copper, on the one hand, and, on the other, the inconvenience caused by the formation of superabundant slag out of mattes is a point of which the steel practice is

(*i*) The agreement of percentages is purely accidental, and has no signification.

fortunately free. Hence there has been no similarity of difficulties. A further significant difference influencing the rationale of the work, and tending to alienate the two methods, is one bearing on the duration of the blows, there being only some 5 per cent. to 10 per cent. of substances to oxidise in cast iron, while in mattes from 40 per cent. to 65 per cent. of the constituents have to be burnt, and this must be done in two stages. However, it is fair to assume that the accelerating influence of the use of oxygen will bring the two methods nearer together, to the benefit of the treatment of our own metal.

There is, however, a direction in which, doubtless, the pneumatic treatment of mattes up to the white metal stage is capable of improvement, and that is the means and conditions which now control the chemical process of the first period, *i.e.*, the slag-formation. Of all apparatus for the mere scorification of iron by the heat of iron and sulphur, the converter is the least suitable in point of efficiency and capacity. We have already discussed the question of linings, and the desirableness of avoiding the latter altogether by the introduction of silicious material from the outside. The conclusion was arrived at that the converter should not properly be used for smelting purposes which can be otherwise achieved, and the same conclusion holds in the connection now broached. The converter vessel, even when ultimately provided with suitable vertical or bottom tuyeres, as is the hope of American adepts, and efficient as it is in point of absorption or utilisation of the oxygen in the blast, is still tainted with the defect of unnecessarily prolonging the pneumatic action, and thus lowering the thermal effect.

There are three ways of accomplishing the oxidation of the iron in the matte: by injection of a current of blast into the body of matte; by percolation of the matte through the current of blast; and by projecting the blast on to the body of the matte, and providing means for the constant presentation of a new surface. In each case the rapidity and completeness of the scorification will depend upon the particular degree of intimacy of mechanical contact between the nascent oxide and the silica which the conditions permit.

The first-mentioned case is that of the present method, the silica constituting the containing vessel. It is obvious that, between the oxidation of the iron and its union with the substance of that vessel, the bulk of the particles oxidised must suffer a period of chemical inertness, however short under the circumstances, during which they are on the hunt for their respective particles of silica on the surface of the surrounding lining. The general consequence is a delay in the scorification, which means a delay in the formation of protoxide, the two being coincident. It is likely that a higher oxide momentarily forms in the absence of silica, which, for the unit weight of oxygen, produces less heat than the protoxide, though more for the unit weight of iron. At the final moment of contact with silica this higher oxide would be reduced by the ferrous sulphide, and scorification effected, with the associated greater evolution of heat. In any case, however, the combustion of the iron cannot be called complete until the formation of the silicate has actually taken place, and if this formation is retarded by any mechanical circumstance it follows, from the general law covering the subject, that the temperature must be prejudicially interfered with. The temperature reached depends on the rapidity of combustion, and is a function of time, as well as of the spatial concentration of the substances reacting on each other for combustion.

Another feature of the converter vessel which militates against the best effect is that the indifferent products of combustion of a solid form, the slags, are ordinarily allowed to remain until the iron sulphide is completely oxidised, *i.e.*, the slag is not withdrawn the moment it is formed, but it is tossed about with the body of matte, and doubtless mechanically interferes with the mutual contact of oxygen, iron, and silica, &c. It is held that its presence is an advantage, as conserving the body of heat in the boiling mass, but the depressing effect of its interference with the rapidity of oxidation may more than balance this good. The point here raised, it is obvious, also applies to the introduction of silicious material through the nose. Even though ore-bearing, its specific gravity is much less than that of the bath of matte, and generally less than that of the slag formed. It will, therefore, necessarily occupy an uppermost position, notwithstanding all the agitation in the vessel, and its chances for assimilation with iron in the entangled maze of itself, the slag and the surface layers of the matte, must be relatively slight.

Improvement of Slagging Action.—Theoretically at least, the present converter vessel thus is not a very efficient apparatus for the slagging off of the iron. An apparatus embodying the principles of the second case, *i.e.*, percolation against the blast, would be a marked improvement. This principle would most efficiently be realised by allowing the molten matte to flow through a network, or honeycombed mass of silica in lumps, with the blast passing through the same interstices between them, in the opposite direction. In effect the arrangement would be tantamount to that of the shaft furnace, and, in particular, of the pyrite furnace, in which, in fact, this very same juxtaposition of iron sulphide, silica, and blast is the precise physical equipment which supports its action. There cannot be any practical difficulty of moment of which the experience so far gained with pyrite-smelting is incapable of suggesting a solution. Oxidation would be done on the "counter-current principle," and it is obvious that the contact of the three substances reacting would be vastly increased, and brought as near perfection as the axiom—that no two bodies can occupy the same space at the same time—permits of. Incidentally, all the other physical features which render the shaft furnace the most perfect present-day metallurgical apparatus in point of utilisation of the heat generated would tend to an improved conservation of heat. Such are the concentration of the combustion to a small zone, or nucleus, with consonant intensity of oxidation, &c., within same; the complete absorption or assimilation of the oxygen in the air by the sulphides within that zone (as demonstrated by the action of the pyrite furnace in this regard); the ascent of the gases of combustion, and the transfer of their heat to the descending masses, thus the advantage of the retention of a body of heat which is now wholly lost; the immediate withdrawal of the slag and the white metal after they are formed, and the possibility of a constant discharge of same; finally, an easy and continuous separation of these two products by gravity, accompanied by a lower mechanically suspended matte tenor of the slags. The enriched matte or white metal itself would remain available for pneumatic conversion in the usual way, without remelting. In fact, since the temperature in the pyrite furnace is higher than that developed in the converter, there would be no obstacle in the way of a direct transfer to the vessel, subject to a passable magnitude of the scale of operations.

The scheme thus outlined is nothing more than a suggestion to utilise the pyrite-smelting principle on high-grade mattes, and to carry it one point further than is now customary in matte-concentration by that principle, by making white metal of 70 per cent. to 75 per cent. copper, instead of the current grades of matte to from 35 per cent. to 55 per cent. It would mean a considerable curtailment of the work now being done in the converter, would solve the difficulty of the linings by removing it practically altogether, and would reduce the size of the converting plant for the same output of metal. There is nothing insuperable in the proposal, and it adheres strictly to metallurgical principles of husbandry and execution, which our present method violates.

Improvement by Superficial Oxidation—Matte-cupellation.—The last case, the projection of the blast on to the surface of the matte, and the providing of a constantly new surface, takes us constructionally into a direction which has had a strong attraction for the luminaries of steel, when applying their wider vision to copper-converting, and dissatisfied with its heavy production of slags. Howe early (1883) (*j*) proposed the use of a Siemens-Martin regenerative furnace for the oxidation of medium-grade mattes to white metal, under the influence of a powerful heated blast directed on to the bath, and with the addition of silicious flux, also of rich oxidised ores and refinery slags, if available. The slags that formed were to be skimmed as often as necessary, and the final cuprous sulphide was to be brought to black copper in the same furnace, with continued use of the blast. Von Ehrenwerth later (1895) (*k*) suggested the use of a basic-lined, gas-fired, tilting reverberatory furnace, arranged for the use of a blast and the introduction of silicious substances, and provided with a slag-overflow for intermittent or constant use. These suggestions are modern transcripts of the old processes of cupelling, or blowing, of impure arsenical, antimonial, and leady mattes (Steintreiben, Verblasen), or the purification of dirty coppers (Spleissen), to modern steel-plant apparatus; but it is doubtful if they will find an entrance. The superficial oxidation of a bath of matte, even under the most powerfully active con-

(*j*) *Eng. and Min. Jl.*, 1883, vol. XXXV.
(*k*) Official Report on Chicago Exposition of 1893, Vienna, 1895.

ditions, does not present very strong attractions from the point of view of efficiency since the days of Bessemer, when he demonstrated the perfect action of a thin column of blast forced through a bath of molten material, with portion of which it may combine. Nor does the necessity of a certain amount of separate firing, which these innovations impose, commend itself to modern demands on pneumatic self-smelting processes.

However, to round off this review of medium-forced oxidation methods, and as a pendant to the more genuine pneumatic type from a direction in which the latter has failed through excessive metal losses, a brief statement of the most important of these methods which have been used may be in order. The observation that a blast is more efficacious in purifying very dirty, leady, arsenical, or antimonial mattes than oft-repeated calcinations is centuries old. The work was done in high-roofed, square (latterly circular), reverberatory furnaces, with a hearth of about 100 square feet in size, fired on the long side, and the blast was strong and copious for the historical period implicated. Modernised examples of about 40 years ago are the following.(*l*) At St. Andreasberg, in the Hartz Mountains, leady matte from the matte concentration operation (fourth smelting), was subjected, in 2-ton charges, to an air-blast oxidising smelting for eight to 10 hours, skimmed and tapped. A small amount of metallic lead liquated out. The partly purified matte product was sent through a low blast-furnace with leady materials to effect a desilverisation and a further purification of the copper, portion of the antimony and arsenic joining the resultant lead-bullion. The matte was then repeated in the reverberatory furnace in charges of 2½ tons, with a blast pressure of 20ozs., and an air consumption of 255 cubic feet per minute; this second exposure lasting 12 to 16 hours, and resulting in slags, lead-bullion, and 10cwts. to 16cwts. of matte, carrying 20 per cent. to 25 per cent. copper, and deprived of an essential proportion of the worst impurities. The further concentration and refining of this matte was conducted in the ordinary way. At Altenau, in the same district, desilverised coppers, with about 76 per cent. copper and 24 per cent. lead, from the liquation process, were treated in a similar furnace in charges of 40cwts. to 44cwts. at a time, under a strong blast, the exposure lasting about 20 hours, and yielding a slag with 61 per cent. lead and an improved copper product, which was then further refined into black copper under a blast. In fact, the oxidising smelting of copper middle-products with a strong blast was an important link in the lengthy chain of operations practised in the olden days.

Examples of modern applications of a medium-forced oxidation are those at Oker, in the Hartz Mountains district, and at Brixlegg, in the Tyrol. They represent the nearest approximations to actual Bessemerising which present-day metallurgists can devise for the treatment of difficult materials, which, possibly, are permanently beyond the pale of more energetic pneumatic work. At Oker.(*m*)

(*l*) Kerl, "Oberharzer Hüttenprocesse," Clausthal, 1860.
(*m*) Huhn, *Glückauf*, 1905, vol. XLI., No. 37.

arsenical middle-products, with from 26 per cent. to 52 per cent. of copper and 16 per cent. to 35 per cent. of lead, are subjected to a blast of 12ozs. in a modernised side and bottom water-cooled reverberatory furnace, of small dimensions (60 square feet hearth), and with a removable roof and an acid bottom, which stands from 12 to 18 charges. The exposure lasts 56 hours for 13 tons of speisse, and consists of alternating calcinations and fusions, and yields a product of 90 per cent. purity in copper, with a coal consumption of 28 per cent. to 30 per cent. At Brixlegg (*n*) a similar method is in vogue for arsenical and antimonial copper material, carrying 46 per cent. copper and 29 per cent. lead, after liquation. A peat-burning, gas-fired reverberatory furnace is employed (75 square feet hearth), lined with magnesite, and provided with an air blast. The latter is put on after complete fusion and the first skimming, quartz sand being added to slag the oxides formed, the slags assaying 20 per cent. to 50 per cent. in copper. The duration is 44 hours, in which time 9.5 tons of speisse are charged. The product is metal of 95 per cent. copper. As remarked, these working schemes would seem to belong to an inferior category of pneumatic work, but if, as is the case at Oker, they are sufficiently perfect to have warranted the *intentional* production of speissy lead-copper mattes for the purpose of purifying the ordinary copper-work, they suggest the question whether they cannot be replaced by the proper converter process for the beneficiation of this commonly exceedingly unwelcome material.

Finally, the most recent rival of the converter process is a type of proposal belonging to the superficial oxidation class, which is ingenious and modern enough to harbor a certain amount of promise. It consists of the projection of a mixture of compressed air, steam, sand, and copper oxides, through numerous tuyeres, on to the surface of a large bath of medium-grade matte in a reverberatory furnace. This blast of materials causes a vivid oxidation at the point of impact, supported by the oxides blown in, and accompanied by the (expected) removal of volatile elements by the steam, in addition to the usual scorification of the iron, &c., without corroding either the walls or the bottom. An advantage is that the blast constantly impinges on a clear surface, and that there is no mixing up of the furnace contents, as in the converter. The supernatant layer of slag can be blown in the direction of a continuous overflow. It is claimed that the treatment is applicable to much larger quantities than are customary in the converter, and that 50 tons of matte can be slagged in six hours. The resulting white metal can be brought to copper in the same furnace, with blast, if desired. The suggestion has an up-to-date pneumatic ring about it, which will cause further developments along this line to be watched with interest.(*o*)

Bessemer Principle Applied to Ores.—So far, the theme of the treatment of copper mattes. It yet remains to mention the important topic of the application of the forced pneumatic principle to sulphide

(*n*) Kroupa, *Oesterr. Zeitschr. f. B. u. H.*, 1906, vol. LIV., Nos. 6 and 7.

(*o*) "Reacteur" process of Thofehrn and St. Seine, 1905-6.

ores of copper. The subject, though very young, is so very wide that only a brief recital of the principal events in the course of progress can be given here. The purely chemical features can be almost wholly passed over, since they are virtually identical with those of the Bessemerising of matte, except for a few points incidental to the peculiarities of mineral sulphides of iron, as also to the apparatus employed. The latter is *par excellence* the blast furnace, though attempts to use the Bessemer converter have not been uncommon. It is patent, however, from the outset, that the proper aim of all smelting processes by means of which *ores* are to be beneficiated should be sustained continuity of operation. The work should, if possible, be so done that great tonnage capacity, coupled with an uninterrupted flow of products, is achieved. Only under these conditions may it be hoped to utilise to their utmost the various chemical energies involved, to minimise losses of heat, and to reduce the formation of middle-products, and, generally, to achieve the speediest and cleanest results, coupled with the greatest economy of time, labor, and cost. The special points of difference between the action of the blast furnace and the converter, consequent on the difference in the relative disposition of the materials reacting on each other, have already been referred to. In extension it need only be said that, whereas an intermittent mode of operation, such as that which is functionally characteristic of the converter-vessel, may be tolerated, for want of something better, on material as rich as mattes, it is out of place on material as low in value as the ordinary run of copper ores. And that it can be avoided is clearly proven by the best existing practice, the results of which even reflect the possibility of radical improvements in our current converter practice, as above contended.

The pneumatic treatment of ores in blast furnaces, however, only yields an unfinished product, *i.e.*, the matte, which has to be (or may be) further enriched and brought to blister copper in the converter by a direct continuation of absolutely the same principle. Since the metallurgical principle may thus be the same throughout, it may be asked, why cut the operation in two—why not make the complete transition from ore to metal in a single apparatus, be it blast-furnace or converter? Here, unfortunately, serious difficulties confront us. We are still only *en route* to this very desirable simplification. It has not yet been even partially achieved, notwithstanding that there has been no lack of suggestions and trials. Even in the days before the true pneumatic self-smelting notion arose attempts were made to produce metallic copper direct in the blast-furnace out of sulphide ores (*e.g.*, Tessié du Motay, 1871), and the proposal has since been fairly extensively ventilated and its execution essayed (*e.g.*, Garnier, 1884; C. M. Allen, 1893; Garretson, 1896, *et al.*), always with disastrous results. What is being done in the newer employment of the so-called basic-lined converter, above referred to (p. 95), is not identical with these efforts, since the pyritic constituent, or, more properly, the matte derived from same, is here prepared outside of the vessel in which the charge is blown, and the operation is thus a twofold one.

As far as the completion of the step from ore to copper by this type of treatment is concerned, Mr. Hollway was comparatively in advance, for he might as well have brought the 50 per cent. matte which he blew out of a 1.8 per cent. ore, in 1878. to a finish in the same vessel, had he not too exclusively devoted his attention to regulus as a final product. In fact, the Bessemerising of low-grade copper ores up to blister in the converter vessel in one continuous operation is altogether within easy reach of accomplishment with repeated additions of charges of raw ore and silica, or with a sufficiently heavy lining, but it is necessarily a tedious, costly, and quantitatively unsatisfactory operation, and, therefore, is not being practised. The solution of the problem is being worked on from the blast-furnace side of the question for the sake of the rapid reduction of a large tonnage of ore, but, as remarked, it is only in embryo still. It cannot be said that the considerable difference in blast pressure between blast furnace and converter is a cause of failure, although this difference is a prominent trait of the two present practices. There is no fundamental reason why converter blast pressures should not be used in the blast furnace, and, on the other hand, the converter does not exclusively depend on its higher air-pressure for its action. Pressure is merely a matter of the depth of matte to be penetrated for complete absorption of the atmospheric oxygen. A fundamental point of difference, however, resides in the respective quantities of air required, and no doubt it is somewhat hopeless to expect to force the full volume demanded by the entire amounts of iron and sulphur (as far as they are actually oxidised), through a small accumulation of matte at the bottom of a furnace shaft, with the special intention of reducing metallic copper out of it with a modicum of the air, while leaving all the rest of the blast available for the column of charge in the shaft above. Nor is it quite apparent how the hearth can individually be supplied with a small quantity of air for the matte, and, simultaneously, the shaft, also individually, with a vastly greater volume sufficient for the ore. A pneumatic equilibrium injurious to the proper reduction of the matte must inevitably assert itself at once, unless the two portions of the furnace are wholly isolated from each other. The problem will probably find its solution along this line, in other words, by a compounding into one continuously operating, but double structure, of the really essential features of the furnace and the converter vessel. Unless this is done it even is difficult to see how the descending matte, out of the ore. can be prevented from interfering with the proper precipitation of copper out of the bottom layer of matte. The modern, twofold practice, where the furnace matte is taken to the converter vessel in a molten condition, is, furthermore, so simple and convenient in every respect that it may be doubted if it can be improved by the substitution of a single compound apparatus, in which the irregularity of work in the furnace portion must always hamper the efficiency of the converter portion.

But leaving this outlook into the future, let us return to the past.

The intentional use of raw, unroasted pyrites in the blast furnace is comparatively modern. It is one of the many creations of the movement to greater intellectuality known as the Renaissance period of history, having been first introduced in the middle of the sixteenth century in Saxony. Its object, however, was not directly connected with copper-smelting. Its purpose was mainly the circumvention of the use of an excessive amount of lead as a vehicle for the collection of the precious metals in the blast-furnace treatment of ores. By first concentrating them into a small bulk of iron matte, preferably non-cupriferous, it cut off the source of very serious lead losses. Desilverisation of this matte could be effected subsequently, with a smaller quantity of lead, but copper, being an obstacle herein, was, if possible, avoided. The departure was considered so happy and beneficial an one at the time that Barthold Köhler, the inventor, it is recorded in the archives of the day,(*p*) received the liberal gift of 2,000 florins from the Elector, in recognition of this service to the princely treasury, coupled with certain other improvements in metallurgical procedure, which rendered lower grades of ore profitable. The operation constituted what is now known as raw-smelting (Roharbeit), or, as Dr. Percy named it, "pyritic smelting." It continued to be extensively practised in Europe, as a preliminary concentration method, until the middle of the last century, when the advent of the method of roasting the pyrites for our present sulphuric acid manufacture put an end to it. It thus became almost a lost art, only surviving on a very limited scale at Kongsberg, &c. But during its three centuries of currency, as remarked, copper was as far as possible designedly eschewed in connection with it. Neither was this entire time marked by any appreciation whatsoever of the fuel-value of the raw pyrites used. As a late instance we may mention Henkel, who, in the middle of the eighteenth century, (*q*) published a most elaborate disquisitive work on the value and importance of pyrites from all possible points of view—mineralogical, chemical, metallurgical, and otherwise—but does not betray the slightest notion of the "pyritic effect." This was only possible after general chemistry had placed the knowledge of the true nature of the atmosphere at the disposal of the arts. Yet, as above stated, though the loss of sulphur was noticed and correctly explained in the earlier days of this knowledge, the calorific usefulness of the constituents of sulphide substances was not definitely discussed until nearly a century after the discovery of oxygen (1774) and the recognition of the nature of sulphurous acid (1775). A single prominent exception to this rule, in which a Bessemerising action in the blast furnace was surmised to take place, is the case of the La Pise and Pontgibaud treatment of pyritous lead ores. It was the practice there, in the sixties, to add cast iron to the charge, and it was noticed that an increase of this addition allowed a reduction of coke to be effected. Thus, at La Pise, the increase of such iron from 2 per cent. or 3 per cent. to 7 per cent., lowered the coke consumption from 25 per cent. to 22 per cent. and 20 per cent., while at Pontgibaud, when smelting 50 per cent. lead ore, the increase of the metal from 10 per cent. to 12 per

(*p*) K. A. Winkler, "Freyberger Schmelz-hüttenprocesse," Freyberg, 1837.
(*q*) J. F. Henkel, "Pyritologia," Leipsic, 1754, 2nd ed., transl. into English, 1757.

cent. brought the coke from 9 per cent. to only 7 per cent. At the same time no matte separated out. Gruner, therefore, concluded that the iron was oxidised, and acted as a fuel. But Percy (*r*) contended that, in the reducing atmosphere of the furnace, this oxidation was impossible. At the present time one would be inclined to subscribe to the former.

It was Bode (*s*) who, in 1872, in a pamphlet devoted to the manufacture of sulphuric acid, combated the idea, then still current, that the amount of heat liberated in the combustion of sulphide substances was directly commensurate with their sulphur contents, and calculated the pyrometric intensities developed by 15 different sulphide minerals and mattes, his special object being, however, merely to lay stress on the oxidation of the metallic bases, and to prove that the compounds were capable of self-supporting calcination. Nevertheless, the most important step towards the recognition, that the temperatures sufficed for smelting purposes also, was thus at last taken.

Six years later John Hollway drew the last conclusion that was to be drawn from all the foregoing, and courageously brought to both a theoretical and practical focus the pyritic principle thus gradually instilled in the professional mind, and gave it a definite metallurgical expression and existence. This is not the place to go into a recital of his elaborate large-scale trials. Suffice it to say that they were made with the use of low-grade Rio Tinto pyrites at Messrs. Cammell & Co.'s steel plant in 1878-9, the ordinary Bessemer paraphernalia being employed. The pyrites was melted down in a cupola furnace, and blown in regular 6-ton vessels with 20lbs. air pressure. All phenomena were scientifically scrutinised, temperatures, flame, composition of gas and molten products, &c. Among other things Mr. Hollway succeeded in running one converter on pyrites and quartz for 14 consecutive hours, with repeated charging, and with the total exclusion of carbonaceous fuel other than that used to provide the blast. Altogether his trials demonstrated to the members of the Society of Arts, for whose benefit a special exhibition was given, as well as to the world at large, that pyrites carrying copper could be made self-smelting, and was a metallurgical fuel of the utmost efficiency; that the waste of its fuel qualities, which was being incurred in the current process of preparatory treatment by calcination, could be obviated; that a high rate of concentration of copper tenor was achievable; that a complete utilisation of the atmospheric oxygen was effected, &c. Mr. Hollway's essay (*t*) on the results of these trials is one of the classics of modern metallurgical literature, and his experiments themselves are a brilliant contribution to the annals of empirical research along this line of work. He availed himself of the Bessemer plant chiefly as a matter of convenience, and was convinced that it was unsuitable because of its intermittent operating

(*r*) "The Metallurgy of Lead," London, 1870, p. 349.

(*s*) F. Bode, "Beiträge zur Theorie u. Praxis der Schwefelsäure-fabrication," Hanover, 1872.

(*t*) Read before the Society of Arts on February 12th, 1879; title cited above.

nature, the method, essentially, being adapted to blast-furnace work. As stated above, he limited it to the production of rich regulus, though the possibility of producing metallic copper occurred to him. The gases were, of course, to be utilised for the manufacture of sulphuric acid, and the elemental sulphur, which sublimed off as the loosely bound atom in the pyrites, was also to be caught. This point was considered as more essential than it really deserved. In a subsequent attempt to repeat the operation in a small blast-furnace somewhat resembling a stationary Swedish converter, the loose sulphur atom very deplorably became the ruin of the entire scheme. It choked up the condensation flues, thus creating a back-pressure which caused the furnace to break out, after which, as in Parry's case (p. 66), no further repetition was forthcoming, the financial supporters probably becoming disheartened. In consequence, the idea languished and became the butt of professional ridicule and satire. The conservatism of English copper-smelters militated against its further prosecution and perfection, and conditions elsewhere were not ripe for it.

Intellectually, however, a most useful seed had been sown. Never before had any set of practical demonstrations outside of iron and steel been conducted with the convincing force of equal magnitude and impressiveness. Then, in addition, Mr. Hollway had supported his essay on the subject by an interesting thermal calculation of the temperatures generated in the oxidation of iron pyrites (and other sulphides) in the presence of silica, which had a special academic conclusiveness, particularly as it was supplemented by a parallel one by Professor Akerman. A simplified statement of the problem was embodied in one of Professor Balling's text-books in 1882 (*u*). These early thermo-chemical proofs left no doubt as to the feasibility of the general pyritic idea. It only remained to so conduct the practical management of any particular instance of its application as to conform to the ordinary mechanical or physical desiderata of smelting processes, such as continuity of flow of molten products, ready separation by differences of specific gravity, &c. In the case of pyritous copper ores the proposition in these respects appeared comparatively simple, and the incidental causes of Mr. Hollway's apparent lack of success were not insuperable.

Thus we find the rapid oxidation theory at last brought to a certain amount of practical prominence in the treatment of sulphide copper ores. Moreover, the Bessemer smelting of ore gained in desirability all the more with the contemporaneous permanent establishment of the Bessemer converting of copper mattes. It became a metallurgical aim to treat both ores and mattes by the same method. But there were still serious difficulties. Unfortunately, the fascinating idea of utilising the two most abundant mineral substances in the earth's crust, *i.e.*, silica and pyrites, in igneous chemical play, with such startling economical results, was greatly hampered by the comparative scarcity of the second-mentioned mineral in larger ore deposits, and hence few

(*u*) C. A. M. Balling, "Compend. der Metallurg. Chemie.," Bonn, 1882.

localities were fitted for hopeful experimenting. In fact, so great were the obstacles from one source or another that the whole scheme fell into serious disrepute.

Pyrite Smelting.—The revival, however, came in due time, brought about by economic conditions, in the smaller mining districts of the United States. Here the special circumstances of ore supply, and particularly the great lack of lead, were locally causing a reintroduction of "pyritic smelting" (or Roharbeit), in the older sense of raw smelting, for the concentration of the precious metals in a matte, with this significant difference, however, that the presence of copper was now encouraged, because its value as a collecting medium had meanwhile become fully appreciated. In view of the great cost of coke, &c., the interest in the rapid oxidation of sulphide ores as spontaneous fuels was revived by W. L. Austin. He and others took up the raw-smelting innovation, and perfected it in the new light; for the temptation to force the pyrites to act in a threefold capacity of fuel, flux, and collecting vehicle was too near-lying. Following in the footsteps of Mr. Hollway, and modernising his operative scheme, the true pneumatic pyritic principle, but supported by the use of a hot blast, was at last brought to some degree of practical perfection, with as much success as a renewed multitude of untoward obstacles of every possible nature permitted. This was effected in Montana, from 1887 to 1891, and subsequently further pursued in Colorado. The chief drawback continued to be a dearth of pyrites. The method also again met with the usual reluctant attitude on the part of the established copper smelters, who feared heavy copper losses by scorification, although the daily evidence of their copper converters, properly transferred to the new blast-furnace scheme, ought to have convinced them of the contrary.

It was, however, reserved for Australia to demonstrate, finally and conclusively, that "pyritic smelting" in the newer sense, or, more properly, "pyrite smelting," is wholly suitable for copper ores of any grade, and is not afflicted with a greater wastefulness through scorification, or any other source, than current older methods, either the Welsh process or the roast-reduction process—on the contrary. The special opportunity came at Mount Lyell, Tasmania, in 1896, where the pneumatic blast-furnace treatment of a heavy pyrite, with 4½ per cent. of copper, it may be said, settled the scorification bogy in a couple of hours after the first furnace was started, *i.e.*, through the freedom from copper of the first slag that ran out. Since that time the process has been permanently taken up by the companies beneficiating the larger pyritic ore bodies of the world (Rio Tinto, Ducktown, Keswick, Kosaka, Sulitjelma, Cobar, Clifton, and others, in some cases with local modifications of apparatus and procedure), though it may be claimed that, so far, the honor of greatest fidelity to the ideal features of the method is unreservedly Australia's.

The process, as at present carried out, is, however, not as perfect as it might be, chiefly because the full energy of reaction which pyrites and silica in proper proportions are capable of is not yet excited by the methods and appliances employed. The main defect is the necessity of still using at least a modicum of carbon. Complete emancipation from the introduction of carbonaceous fuel is, of course, the ideal; but even the best existing practice still finds necessary the application either of a hot blast, with or without coke, or of about 1 per cent. to $1\frac{1}{2}$ per cent. of coke (figured on the weight of furnace charge) when cold blast is used. One reason is that under present conditions of furnace height there is too great a loss of heat at the furnace top—not so much through the non-combustion of the volatile portion of the sulphur as because the low columns used allow the gases to escape with too high a temperature. Wholly against a prevailing notion, the low column of the converter vessel should not be imitated. It is only an incidental feature of that vessel. Compliance with the true Bessemer principle first of all requires complete absorption of the oxygen blown in, therefore adequate height of column. The gases should leave the furnace free from uncombined oxygen, and the charge should be kept as high as at all compatible with the ready descent of the stock. The height of the stock line is consequently a function of the air-supply, and, to prevent waste of heat on the one hand and to achieve a proper transmission of the heat of the ascending gases to the descending masses on the other, it should be kept at as high an elevation as is conformable with the annoying peculiarity of iron pyrites to agglomerate under the influence of a low heat, thus impeding the descent of the charge. Pyrrhotite ores and mattes, when re-treated for concentration purposes, are free from this drawback, and can be run with cold tops. Pyritic ore furnaces usually exhibit the combustion of the sublimed sulphur a little distance above the stock line, where the gases come into contact with the atmosphere; but this spurious "over-fire" is not disconcerting, or a real waste of heat. The latter arises when the gases and sulphur vapors, as they issue out of the top of charge, are too hot.

The inner working of the pyrite furnace differs essentially from that of the ordinary coke-fed furnace treating partially oxidised material into matte. In the first place there is, or should be, no oxidising action anywhere except in the slag-forming zone itself. This is situated at a somewhat higher level than in the coke-fed furnace, especially when a cold blast is employed, and in it the oxidation of the special compound of iron and sulphur which arrives at this point, and the scorification of the iron, take place simultaneously. Below it there is no special chemical action and no further generation of heat, and above it there is none of the latter, but a decided progressive disintegrating alteration in the composition of the molten sulphide itself. The pyrites, after losing its volatile sulphur atom a few feet below the top of charge, and being thereby transformed into a compound very similar to magnetic pyrites, is fused by the heat of the escaping neutral gases—which, in this region, are solely composed of nitrogen, sulphurous acid, and carbonic acid (out of limestone and coke)—long prior to reaching any great depth. Subsequently, while coursing down the furnace to lower depths, it suffers a further desulphurisation, without oxidation, simply under the influence of the gradually rising temperature. A roasting action does not take place anywhere. The particular combination of iron and sulphur which finally reaches the actual zone of simultaneous oxidation and slag-formation is generally lower in sulphur than the protosulphide. The whole action is self-directive or autonomous. The silica remains chemically inert from the top down to the oxidation zone, and also below that zone, though exceedingly active within it. At the same time it is physically, *i.e.*, mechanically, of the utmost importance in these other levels through building up a honeycombed or vesicular aggregate, in the interstices of which the molten sulphide, blast-borne, trickles slowly down against the upcoming gases. In the "laboratory" proper, roughly in the centre of this porous structure, the mutual assimilation of the silicious pieces and the oxidising sulphide corrosively destroys the individuality of both; but, on the one hand, there is a contraction of mass by the union of silica and protoxide for the formation of slag, and, on the other, an explosive expansion of the gas volume due to the sudden elevation of temperature engendered by the combustion of the iron and the sulphur, assisted by the slag-formation. The condition of porosity is thus practically preserved in this particular spot by the action going on there, while it is the duty of the metallurgist to see that it is suitably maintained elsewhere in the furnace shaft. The furnace must be kept properly open, both above and below the fiery nucleus. In fact, it may truly be said that the proper maintenance of this purely mechanical feature is one of the principal secrets to success. In distinction from an opportune coke-bed for the charges to rest on in their descent, there is only this silica skeleton to rely on for a proper furnace movement, and the situation is one far removed from a "bed of roses." "Eternal vigilance" is indeed required, and liberty from freeze-ups—and a minimum coke bill—can be secured for no other price.

The special slag composition which falls is wholly subject to the self-governing relations which happen to be established between the air blown in and the iron sulphide and silica. The presence of coke and limestone, or other substances yielding chemical bases, affects the result, but we can only consider the general features. The general tendency of the furnace conditions, as at Mount Lyell, for instance, is to form a singulo-silicate, identically as in the converter vessel. The introduction of heat from an extraneous source, such as through a heated blast, or by an addition of coke sufficient to live down to the oxidation zone, raises the acidity of the slag, but also decreases the calories developed by the sulphide, relieving and interfering with the work of oxidation. The matte then leaving the furnace is greater in quantity and lower in tenor than in the opposite case. The matte formed is obviously only that part of the particular sulphide supporting the action in the oxidation nucleus which happens to be in excess of the influence of the blast. The copper, for its part, may be regarded as practically inert throughout the whole furnace-action, and simply goes through the furnace under cover of the protection of the iron sulphide

Given a set adjustment of matter and force within the furnace, tending towards a certain slag composition, the latter cannot be varied by decreasing or increasing the amount of free silica on charge. It is true that this substance constitutes the direct available means for raising or lowering the degree of concentration of ore into matte.

But an addition of silica is to be understood as having the effect of raising this degree without affecting the composition of the slag. There is *more* iron oxidised and slagged off, but the result is, not to make the slag more ferruginous, but simply to increase its quantity. Too great an excess of silica remains undigested, and chokes the furnace. Too small an amount simply causes a lower grade of matte to fall, *i.e.*, the amount of matte increases, which depresses its copper tenor, and the amount of slag decreases, but without altering its composition.

This, in outline, is the action of the pyrite furnace. Needless to say, the practice varies in important respects in different localities. The chief point of difference, perhaps, is the use or non-use of a heated blast. A hot blast is only derivable from specially fired stoves, not from the furnace gases themselves, though a tepidly heated blast may be derived from hot-top furnaces. The extra paraphernalia and fuel-consumption introduced by the stoves is, however, an economic encumbrance, so that, after six years of experience, it was gladly discarded at Mount Lyell in favor of a more energetic furnace manipulation, which was found to be capable of more than replacing the extra increment of heat supplied by the hot blast. This radical improvement was accomplished by simply supplying to four furnaces the entire quantity of air which had formerly been sent into eight. The effect was most marked, in every direction. The rate of concentration and the furnace capacity increased, and costs decreased ; also, essentially, the already small percentage of coke used. The present disposition is to regard the application of hot blast in the development of true pyrite smelting as a transitional phase fully outgrown, and in the light of as unnecessary an adjunct as it is in converting.

The grade of matte striven for naturally will depend on its destiny, and, if designed for converting, will vary between 35 per cent. and 55 per cent. in copper, depending on local considerations of cost and expediency. The original copper assay of the ore, and the individual furnace practice decide whether the desired grade can, or is to be, achieved in one, two, or three smeltings. The concentration of low-grade mattes presents no difficulties, and it early became an established rule at all works. Unfortunately, it appears to be so still, while, as a matter of fact, a single smelting should suffice, unless the ore is extremely poor. The single exception appears to be Mount Lyell. That establishment probably treats the lowest average grade of ore now being similarly furnaced anywhere, viz., 2 per cent. to $2\frac{1}{4}$ per cent. of copper, but it concentrates this in the ratio of 18 to 20 into 1, with a single smelting, without difficulty. The whole question is virtually one of a great blast supply, assisted by a low coke percentage, a high column, and constant watchfulness. Yet the blast delivery must not be excessive, only adequate for the oxidation of sufficient of the sulphide. The Mount Lyell ore-supply permits of using about two parts of heavy pyrite to one of silicious material (containing 70 per cent. silica), and it will be of interest to learn that, of the large amount of iron present, never less than 95 per cent. is burnt, or oxidised, the small remainder going into the matte. This oxidation factor is of great importance, since it controls the grade of the matte in copper.

Under given conditions the rise from 95 per cent. to 96 per cent. of the iron enriches the matte from 40 per cent. to 50 per cent. of copper.

Pyritic Smelting.—Not all pyritic ores, however, are sufficiently low in associated earthy matter, or gangue, to be amenable to the almost cokeless variety of pneumatic treatment. Fortunately, a deficiency in iron and sulphur can be quite made up by a proper addition of carbonaceous fuel, commonly coke, the three fuels burning conjointly without interference, except, of course, that the carbon arrogates to itself the first allegiance of the oxygen. Barring the introduction of the "pyritic effect," this special work does not very materially differ from the older raw smelting. It will always require the use of an essential proportion of carbonaceous fuel. It may, therefore, be dismissed as a side issue of our subject, because it is only a partial materialisation of our main theme. The conditions of work are quite distinct from those characteristic of true pyrite-smelting, and much more facile. As the latter will always be applicable to a few localities only, it may, however, be stated that the compromise treatment of semi-pyritic ores here referred to, or modern "pyritic smelting," is destined to greatly surpass the purer form, or "pyrite-smelting," in general economic importance, as time goes on. Too much stress cannot be laid on its very decided utility, and it is not an overestimate to say that it will yet be found to be the special channel through which the general mechanical and operative media of blast-furnace smelting, other than iron, will be chiefly improved and further enlarged in the future. The method is bound only to a modicum of copper, but may treat any percentage; it has in its favor the greatest latitude in point of slag composition, both as to acidity and relative proportions of metallic and earthy bases; it allows of any concentration ratio whatsoever, dependent on the ore composition, and it permits of enormous tonnages; also, on profitable grounds, of the reinstatement of hot blast.

Apparatus for Ores.—With regard to the apparatus required for the pneumatic treatment of ores. it need only be remarked that the blast furnaces used follow the general lines of construction characteristic of modern copper-matting furnaces, the most salient special peculiarity, perhaps, being a very large number of tuyeres. Other constructional demands, which the furnace action would seem to make towards conformable departures from established types, are not yet sufficiently clearly understood to have led to any positive innovations and the fixation of a special design, though, needless to say, there are innumerable inventions and tentative improvements before the profession. The blast paraphernalia calls for no observation, beyond the remark that its capacity should be ample, and that blast pressures are steadily rising, 3lbs. per square inch now being merely middling. As in ordinary copper-smelting, rotary blowers continue chiefly to be used, though their place is disputed by piston-blowing engines, while the turbo-blower is the latest rival of both.

Summary.—We have now followed the development of the rapid oxidation processes, applied to copper mattes and ores, through to the present day as completely as the limits permitted, and have dwelt more fully on the particular phases of pneumatic treatment which more strictly embody the essential features of the general conception. Historically it is clear that the materialisation of the latter has found its most adequate industrial expression for mattes in that modification of Bessemer's magnificent invention which was first investigated on a working scale, at the suggestion of Semennikow, by von Jossa and Laletin, in 1867-8, and which was subsequently perfected into a permanent success by the efforts of Manhès and David. For ores, the kernel of its success already lies in Hollway's process of 1878, but has been brought to a workable pitch of perfection in its more modern derivatives.

Metallurgically speaking, the pneumatic treatment is not likely to be supplanted by anything better for a very considerable time. It reaches down to and utilises basic forces of nature with just that spontaneous unhampered licence which is characteristic of those forces themselves, when, obedient only to inherent self-restrictions, they mutually strive for states of equilibrium.

It is thus safe to say that, in general principle, the modern copper-converting operation and its metallurgical confrère, pyrite-smelting, have come to stay. Their extension has been remarkable. Slow of growth at first they are now, where the circumstances at all warrant it, as naturally the first thought of the metallurgist as the notion of smelting itself. Both are alike conditioned by the sulphide nature of the prevailing ores of copper, and considerations of metallurgical convenience and husbandry will continue to enforce the preliminary enrichment of those ores into a matte. However, just as in the science of mathematics there are clever, intellectually artistic, as well as ploddingly roundabout ways of solving the same problem, so also the pneumatic copper processes must be pronounced to be the "most elegant solution" possible of the problem of liberating the metal out of the bonds of the strongest, closest chemical affinity which it is subject to. There is but one force in the service of man at the present time which, in disruptive power, surpasses those enlisted in the pneumatic processes. Yet, until electricity shall be obtained from the skies at a merely nominal cost, it may safely be predicted that it will not completely supplant the rapid oxidation methods in the treatment of copper sulphides. The pyro-metallurgical processes offer such advantages in point of capacity and economy that the direct electro-metallurgical treatment of the ordinary poverty-stricken ores will not replace them. But even in the case of mattes, on the whole, it will remain less costly, more convenient, and not more wasteful of metal to create the energy required for their decomposition out of inherent combustible constituents which fully serve the purpose and lie at hand free of cost, than to apply electric forces. For some time to come the latter will be derivable only from other natural, but dearer fuels, or from natural powers, like water, and even the most sanguine regard for the science of mechanics cannot guarantee any early radical improvement in the present unsatisfactory economic state of that science, where transformations of energy are concerned. In addition, the liberation of the metal free from contamination with other metals that are present, which is a mere bagatelle for the converter and the pyrite furnace, even on the largest scale, is a serious task for the electric furnace.

Economic Benefits.—The economic benefits of the intensified pneumatic methods cannot be over-estimated. In their special field they have reduced the expenditure of carbonaceous fuel, labor, and materials, and last but not least, of time, to a stupendous degree. In the mere matter of fuel alone their practically complete emancipation from all natural sources of supply of either wood or coal is conferring incalculable boons on industry at large by cutting off the prolonged additional ravages incident to a continuance of the older methods. In point of labor and time they have contributed to condense a toilsome series of calcinations and roastings into a single operation, proceeding, literally, on the wings of the wind. In point of administration, business has been extraordinarily simplified by them. Along the old lines it would be physically impossible to achieve modern tonnages. At Mount Lyell, for instance, where the pneumatic method is applied to ore as well as to mattes, it is safe to say that 4,000 men would be required—furnace-men, woodcutters, and all—to carry on what 1,000 are doing now. The dispersion of an equivalent quantity of older, numerously duplicated apparatus over the necessary vast area of ground would, furthermore, practically frustrate efficient management, altogether aside from questions of transportation and the fuel bill.

The extent to which this superiority is realised by the world is clearly manifested by the manner in which the introduction of the rapid oxidation of mattes has found a foothold in the copper industry. In 1886 there were but two establishments using it, practically only tentatively, *i.e.*, the parent works at Eguilles and the Parrott Works at Butte. Three years later it was installed at the great Anaconda plant, at Swansea, at Bogoslowsk in Russia, Maitenes in Chili, Leghorn in Italy, Jerez-Lanteira in Spain, Röros in Norway. It has since become established in Mexico, Japan, Canada, and British Columbia, Servia, and Australia, including Tasmania. Its real camping ground, however, are the United States of America. There 30 converters were in continual operation by 1899, annually producing about 160,000 tons of copper, together with 9,000,000ozs. of silver and 30,000ozs. of of gold. Since then the converter process has immenesly progressed there in size and perfection of apparatus and number of localities. It has permitted out-of-the-way works to send out blister, where before they would have dispatched matte—an important circumstance, which itself has worked a complete reformation in the commercial features of the industry, far-reaching but not to be gone into here. In 1905 the production of copper in North America alone was, in round figures, 480,000 tons, of which about 75 per cent. were poured out of converters, and for the production of which, roughly, about a sixfold tonnage of air was blown into the vessels.

Scientific Benefits.—However, there is another direction in which the growth of pneumatic smelting has, in a marked degree, made for advancement. Its caloric features and peculiarities have widened, and will continue to widen, the horizon of the practising metallurgist.

Since it has forced upon him an economical feeling of abrogation with respect to the employment of carbonaceous fuel, the practical man can no longer idly foster his mental comfort at the expense of wood, coal, or coke. Instead of cultivating ease of mind in terms of carbon, he is constrained to scheme and plot in terms of air, silica, iron, and sulphur, and is obliged to put more science into his work, also to commune more freely with his professional fellows.

The pneumatic idea has perforce riveted the attention of the metallurgical fraternity firmly to the oxidation theory. In the words of Sir Roberts-Austen (*v*), it is indeed being "felt that, as the eighteenth century has closed with a clear statement as to the true nature of oxidation, the nineteenth century has seen its magnificent application in the Bessemer process." The words, however, have a wider meaning than the speaker knew he conveyed. The Bessemer idea is not now limited to what, in the more restricted sense, is interpreted as the "Bessemer process." Its application has grown to most comprehensive limits, transcending even the boundaries of steel and copper. One need only point to the progress being made in the utilisation of the same fundamental metallurgical principle in the domain of lead, in the refining of the precious metals, and related departments. Witness the revolution already wrought in lead-smelting by the Huntington-Heberlein, Savelsberg and Carmichael-Bradford processes and their followers (of which an exceedingly important one for copper is that of McMurtry). Languid half-way imitations these, it is true, of the genuine Bessemerising method, as far as the atmospheric energy displayed is concerned, but, nevertheless, potential stepping-stones to something more complete and conclusive—possibly the final commercial realisation of the proposals of Hannay (*w*), Germot-Catelin (*x*), and others for the pneumatic treatment of sulphide lead ores with the direct reduction of the metal. Note the renewed interest bestowed on the question of the purification of metals by means of forced oxidation; as, for instance, expressed in Rose's suggestive researches on gold bullion and cyanide precipitates (*y*). It is not too much to say that, without the precedent of the surpassing success of the pneumatic treatment applied to copper and iron sulphides, these promising departures from established beaten tracks in other metals would have been delayed very many years.

But the study of metallurgy is becoming increasingly more elaborate and theoretically refined, and in this connection the pneumatic idea has materially assisted in elevating the general scientific level of the art. It is, furthermore, incidentally drawing the metallurgists of the day persuasively into an interested appreciation of modern corollaries of the oxidation theory in the department of physical chemistry. This fundamentally essential branch of our mother science is now demanding a degree of attention for the best metallurgical work from which further progress will allow of no relaxing; and, aside from all material, practical benefits, this superior subjective advancement is in itself a tremendous gain.

(*v*) Pres. Addr. Iron and Steel Inst., 1899. (*w*) *Proc. Royal Soc.*, 1893, *et seq.*
(*x*) *Echo des Mines*, 1902. (*y*) *Trans. Inst. Min. and Met.*, 1904-5, vol. XIV.

Section C.

GEOLOGY.

ADDRESS BY THE PRESIDENT,

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Government Geologist of Western Australia, and formerly of the Geological Survey of Queensland.

RECENT ADVANCES IN THE KNOWLEDGE OF THE GEOLOGY OF WESTERN AUSTRALIA.

(WITH A GEOLOGICAL SKETCH MAP. PLATE I.)

My first duty in assuming the position of the presidentship of the Section of Geology, is to express to you my deep sense of gratitude for your confidence in my devotion to the welfare of our science implied in the election of one, who, owing to the exigencies of official life, has had few opportunities during the last 19 years of becoming personally acquainted with the majority of the "brethren of the hammer" in Australia. The honor, however, is enhanced by the fact that in addressing the members of this section of the association in Adelaide I am speaking in the capital of a State which has contributed—in the persons of Messrs. H. Y. L. Brown and H. P. Woodward—so much to the progress of official geological research in Western Australia.

The civilising value of scientific investigation, such as is evidenced by a gathering of this kind, where the hammerers from the West meet those from the East upon common ground, for the purpose of discussing, consolidating, and recording the work of the past, must tend to link all parts of this continent together, and time, perhaps, will show that it may fall to the lot of the Australian men of science to materially assist in the solution of the problem of preserving those harmonious relationships and the strengthening of those ties which are so severely taxing the combined resources of political diplomacy.

It is, I believe, customary for the occupant of the presidential chair to offer a few observations on some special department of the science which seems, in his opinion, worthy of attention, and I am, therefore, unwilling to depart from what must be regarded as traditional usage. On looking over the list of subjects reviewed by my predecessors in this chair, and the contributions of the different members read before the section, I find few dealing with those portions of Australasia with which I am personally familiar, viz., Queensland, British New Guinea, and Western Australia.

After due consideration, therefore, I have chosen to invite your attention for an academic hour to a succinct account of the recent advances in our knowledge of the geology of the western portion of this continent, to the investigation of which my attention has been more immediately directed during the last decade.

In a broad and general way the geology of Western Australia offers many interesting points of analogy with that of South Africa and India.

In the present condition of our knowledge of the geology of the State it is almost impossible to deal systematically with the various formations as a whole, for, owing to a variety of causes, geological inquiry up to the present has consisted merely of a series of unconnected observations, to the co-ordination of which we must look to the future; nevertheless, our observations have been so widely extended as to permit of certain broad generalisations.

Geologically the rocks of the State may, for the purpose of this address, be divided into three distinct groups, viz.:—

(*a*) The Crystalline, Schistose, and Metamorphic Rocks, a group, the members of which have certain features in common, occupy definite areas, and various lines of inquiry point to being of considerable geological antiquity, possibly of Archæan Age, though, in the present condition of our knowledge, I prefer to adopt the safer term—Pre-Cambrian;

(*b*) The Sedimentary Rocks, which extend, with many blanks, from the Lower Cambrian to the most Recent; and

(*c*) The Volcanic Rocks, which are so largely developed in the northern portion of this State.

(*a*) *The Crystalline Schists and the Metamorphic Rocks.*—The Pre-Cambrian crystalline schists and metamorphic rocks constitute the principal mineral region of Western Australia, and, so far as is at present known, the area occupied by these venerable beds is about two-thirds of the total superficial extent of the State, which is 975,920 square miles. As our knowledge advances, however, this estimate of the area occupied by the Pre-Cambrian rocks may be subject to some modification.

There are probably few parts of this continent which can boast of a finer development of these older rocks than Western Australia, and perhaps no more promising field can be found for their investigation.

Considerable interest in connection with these rocks centres—so far as petrographical questions are concerned—in the transmutation of both the igneous and sedimentary formations into crystalline schists. Observations in the field point to the possibility of the mechanical movements to which the rocks have been subjected having modified or obliterated structural features previously impressed upon them, and that they may contain formation belonging to different geological systems. Sections in the Nullagine district show these beds to be made up of cleaved conglomerates, some of whose pebbles consist of a pre-existing conglomerate from an earlier series of which no trace has yet been found. With a possible exception—alluded to later on—it is important to note that this ancient metamorphosed sedimentary series, so abundantly represented in Western Australia, have yielded no fossils as yet.

If, perhaps, I dwell at a somewhat great length upon these older rocks, it is that their economic importance has necessitated the attention of the geological survey being, up to the present, principally devoted to their investigation, rather than to that of the strata lying unconformably above them.

Time will hardly admit, though there is the inclination, of trespassing upon your time by affecting comparisons with the geology of similar areas of Pre-Cambrian rocks in other countries, nor discussing many of those theoretical questions arising out of the data which have been amassed.

These older rocks have been studied in more or less detail at different localities throughout the State, distributed over 14° of latitude. They consist of rocks of very different types; many of them are in a crystalline condition, and form coarse crystalline schists and gneiss, which differ but little from granite and other rocks of like origin, as well as basic rocks, which have been more or less crushed, foliated, and completely converted into greenstone schists.

A very important feature of these basic schists is the presence among them of unfoliated rocks, which sometimes occur in the form of lenticular belts of considerable extent—diabase, dolerite, diorite, epidiorite, pyroxenite, porphyrite, amphibolite, &c.

In some localities these basic rocks can be seen passing by scarcely perceptible gradations into hornblende schists, while in others are bands of magnetite schist, in the centre of some of which are large phacoidal-shaped masses of greenstone occurring in such a way as to indicate that the margins only of the masses have been ground down into schists.

Some of these older rocks are of sedimentary origin, and are practically unaltered; others are quartz, mica schists, and granulites. Whilst these represent the two extremes, there are intermediate forms which link them together. The less altered members of these older rocks make their appearance in many portions of the State. The rocks consist of a great variety of types of indurated slates, quartzites, and conglomerates, together with igneous rocks, some of which there are very good grounds for believing to have been originally lavas and ashes.

Many of these old crystalline rocks have been so altered as to possess characters which cannot be looked upon as original, because many of them have lost not only their individuality but also their geological identity.

A remarkable and very noticeable feature of these older rocks in most localities in which they have been examined are those bands of laminated quartzites and jaspers (which often contain oxide of iron to such an extent as to warrant their being classed as iron ores). These extend as roughly parallel bands, sometimes several miles in length, in the form of attenuated lenses, which, owing to their serrated ridges, stand out in bold relief, thus acquiring a conspicuousness perhaps out of all proportion to their real stratigraphical importance. These beds vary from almost pure quartz through varieties of banded hornstone, jaspers of great beauty, to almost pure hematite.

In certain localities these jaspideous beds present a very brilliant appearance, due to the interlamination of red, white, and dark-colored bands with intermediate varieties, the differences of color being due to the occurrence of iron in the form of either limonite, hæmatite, or magnetite.

These bands are often intersected by numerous faults, which in some districts are of considerable economic importance, for it is along these fault-lines, generally at right angles to the strike of the quartzites, that rich shoots of gold often occur. In some cases these iron-bearing jaspers attain a very great thickness, over 1,000ft., and have been very much plicated and contorted, whilst in places they have been faulted in a direction parallel to the strike, the fault fissures being often filled with a fault breccia of jasper recemented by secondary silica. In all cases these jaspers and quartzites are vertical or inclined at high angles. In many localities these quartzites and jaspers contain magnetite in such quantities as to render the use of a compass in the vicinity almost impossible. These beds have been styled quartzites, a term implying that they are sedimentary; they are, however, not of detrital origin, numerous sections in many of the fields show them passing by almost insensible gradations into the enclosing basic schists, the whole appearance suggesting a gradual replacement of the original rock along lines of maximum compression or foliation by silicification—in other words, they represent a case of metasomatosis on an extensive scale.

It may be of interest to note that these beds invariably occur in the basic schists, in intimate association with auriferous quartz reefs, and are at times themselves auriferous. In order that the present confusion, arising through the want of a name to distinguish infiltration or metasomatic quartzites from indurated sandstones, may be obviated, I hope someone may be able to suggest a convenient means of escape from possible civil war between the field man and the laboratory man, to which the present unsatisfactory system of nomenclature rather tends.

In 1905 the various divisions of these older crystalline rocks, as developed on the Norseman Goldfield, were carefully mapped and investigated, the salient features of which may be briefly summarised. The staple formation consists essentially of a series of highly inclined sedimentary rocks, estimated to reach a thickness—making due allowance for repetition by folding—of about 800ft.

No argillaceous slates appear to occur in the Norseman district, though associated with the metamorphic sedimentary rocks is a bed of very coarse conglomerate. Some of these ancient sedimentary rocks appear to have been permeated by secondary silica and oxide of iron to such an extent as to form very conspicuous bands of laminated quartzites and jaspers, which make a pronounced feature of the field. Associated with the metamorphic sedimentary beds of Norseman are a series of interbedded igneous rocks, some of which are distinctly amygdaloid, and, although most of their original characters have been almost entirely obliterated, there seems every reason to believe them to be ancient lava flows which were poured out at practically the same geological period as the associated sediments. In addition to these undoubted lava flows, there are a series of diorites and epidiorites, which seem to be interbedded with the former in such a way as to suggest the possibility of their being intrusive sills and dykes. These igneous rocks have been subjected to considerable dynamical alteration, and in places appear as mica and chlorite schists.

Another very important feature in the geological structure of Norseman is the occurrence of a large number of quartz porphyry dykes, which traverse the eastern portion of the field in a general north-west and south-east direction. These acidic dykes vary much in appearance, color, and texture, the crystallisation in some cases being such that the rocks look not unlike somewhat fine-grained indurated sandstone. These acidic dykes contain crystals of pyrites, and are occasionally slightly auriferous. These dykes in all probability form the apophyses of that large granite mass which lies to the east of Norseman. There are, in addition, a few isolated veins and dykes of dolerite, one of which is seen intersecting the quartz reef in one of the mines. The newest igneous rock on the field is the intrusive norite, which forms an east and west range, varying from a mile to half a mile wide, and which extends in an uninterrupted line to Mount Norcott, about 12 miles to the east, and for a considerable distance both east and west.

The earliest observer in this district, Mr. S. Göczel, indicates on his Geological Sketch Map of the Auriferous Region of Western Australia, the greenstones and allies of Norseman as being of Palæozoic Age, whilst the micaceous and talcose schists of the same district are referred to the Archæan.

The crystalline rocks of the type just described may be traced as far as the Kalgoorlie Goldfield, the wealth of which—coupled with the skill which directs both the mining and the metallurgical operations—has raised Western Australia to the front rank of mining countries in the British Empire.

As is well-known, the productive area comprises a relatively small block of ground, which, by reason of the richness of the lodes by which it is riddled, has become known throughout the world as "The Golden Mile." This area includes the well-known "Great Boulder," "Ivanhoe," "Horseshoe," "Perseverance," "Oroya-Brownhill," "Associated," and "Lake View Consols" mines. The deepest shaft at present is the Great Boulder, which has reached 2,050ft., while the greatest depth to which the lodes have been followed is over 2,000ft. The country laid open by mining for investigation, as judged by the number of drives and crosscuts, amounts to several miles, whilst the rocks have been riddled with bore-holes in all directions and at all angles, thus affording opportunities for the scientific study of many of the rocks in critical localities, and in their relation to the ore deposits, such as are hardly found in any other single mining field of the globe.

The geological structure of Kalgoorlie is not of that extreme simplicity which at one time had been anticipated. The staple formation consists, as at Norseman, largely of certain schistose rocks, some of which are distinctly of sedimentary origin. The sedimentary beds are represented by rocks, which range from soft shales to jasperoid slates, grits to flinty quartzite, fine conglomerates or breccias to a fairly coarse boulder conglomerate.

In intimate association with the sedimentary beds are a series of hornblendic rocks; but whether these occur in the form of lava-flows, or are intrusive, is as yet by no means clear. There are, however, in addition to these, certain undoubtedly intrusive igneous rocks, sodafelsite, and porphyrite.

Most of the rocks of Kalgoorlie appear to have been highly altered by dynamical causes, with an accompanying recrystallisation of their constituents, many of them have been carefully analysed and microscopically investigated in the laboratory of the Geological Survey and the results made available. Time will not admit of detailed reference being made to the deductions to be drawn from these investigations, beyond the fact that the "lode formations," for which the field is famed, consist of a series of almost vertical banded schists of lenticular habit, and apparently owe their origin to the dynamo-metamorphism of a plagioclase-augite rock. Many of these ore-lenses are of great length, and in some cases of considerable breadth; at times, however, the lateral continuity of the lenses is interrupted by overthrust and normal faults of very variable downthrow.

For a systematic study of the metasomatic history of the auriferous deposits, leading as such must do to the discovery of facts which will materially guide scientific mining, Kalgoorlie offers few, if any, rivals in Australia.

So far as observations have, however, at present been carried, there do not appear to be any scientific reasons for believing that the mines of Kalgoorlie have by any means reached the limits of ore deposition, or that the lodes will not prove, as a whole, productive in depth.

The Pilbarra district (lat. 21°) affords better and more continuous sections than are generally to be met with in any of the other districts which have been examined. It thus reveals geological structures which are not to be found in the more southerly districts, and on this account serves to throw light upon obscure points in connection with the geology of other fields. These sections furnish very important evidence regarding the terrestrial movements to which these older rocks have been subjected. The Pilbarra district contains very large areas of granite, granodiorite, and gneiss, which, however, are not the oldest rocks. In every case where their relation to the schists can be observed along the margin it is seen that these granites are intrusive, having gradually eaten its way into and partially absorbed them, and several sections may be noticed in which the granite sends out tongues and veins into them. One of the best localities in which the relation of the granite to the metamorphic rocks may be seen is at the Wodgina tinfield, which is situated on the head waters of the Turner River, about 24 miles from Port Hedland. The district consists of a series of metamorphic sedimentary and bedded igneous rocks skirting the margin of an extensive granite mass, several hundred square miles in extent. These sedimentary auriferous rocks are pierced by a multitude of granite veins, which in this district are of considerable economic importance by reason of the fact that they form the matrices of the tin and tantalite for which Wodgina is noted. Near the tinfield is an instructive section showing a much older intrusive granite rock, which has been invaded by the much newer (though still old) tin-bearing granite. These acidic veins are made up of a coarse-grained rock composed of mica, quartz, felspar, and now and then tourmaline, and may be described as pegmatite, using the term in the sense in which it was applied by Delesse for any coarse-grained granitic rock containing mica, quartz, felspar, and tourmaline.

No reference to these old granitic rocks would be complete without some mention being made of the large ice-like quartz reefs, which stand up to considerable altitudes above the surface like a wall, and which can, in some cases, be traced across country, with more or less interruption for miles. They may be described as veins or dykes of pure silica. In some of the mine workings in two fields veins of this character are to be seen cutting across the auriferous quartz reefs. The question as to the relationship of these acid intrusive dykes of the type just mentioned and these quartz reefs has recently been attracting considerable attention, and there is a growing tendency to associate some quartz reefs genetically with pegmatitic granite veins. In the Coolgardie Goldfield quartz reefs are often intimately associated with acidic dykes, and in some cases the latter gradually pass into pure quartz at their extremities. These acid dykes can be seen to pass by imperceptible gradations into the main mass of the granite at Coolgardie. Similar instances have been noticed in the Wodgina neighborhood, and doubtless there are numerous other instances, but possibly they may have been overlooked, and their significance unappreciated.

Now, a granite mass during the process of cooling gives rise to more acid pegmatite veins, and, by further elimination of the bases, pure quartz veins may result.

Various intermediate stages between granite and quartz veins have been noticed in Western Australia, and it is more than likely that many quartz veins are very probably intrusive rocks directly secreted from a cooling granite magma. Many pegmatitic granite veins contain tourmaline crystals as one of their essential constituents, and many pure quartz veins in Western Australia contain tourmaline also.

Up to the present time, however, no observations have been made in this State with the object of discovering whether there are any of those structural and mineral changes induced in the enclosing rocks by the introduction of the quartz such as may often be observed consequent upon the injection of granitic veins. Observations upon this head, which are much to be desired, would have considerable scientific and even more important economic value.

In the southern portion of the State the Darling Range, the Northampton district, &c., the fundamental complex is pierced by a much later series of basic dykes, where they sometimes preserve their dyke-like features across country without a break for miles. In the north-west district, however, they occur on a scale of magnificence as yet unknown in any other portion of Western Australia. Owing to the marked features which many of them exhibit, these dykes can be readily followed across country, and in certain localities they are of considerable value in working out the details of the geological structure. A feature of significance is the faulting these later dykes have undergone since their injection and consolidation. In the Warrawoona field—an important north-west mining camp—these basic dykes traverse the centre of the auriferous zone almost at right angles to its general strike. The regular continuity of the system of dykes (which extend across country for 30 or 40 miles) has been interrupted in the vicinity of their intersection with the auriferous series, and they have undergone considerable movement since their injection. The peculiar dislocation and apparent displacement in short segments are probably due to a development of step-faulting in a manner not as yet fully understood. The dykes are apparently cut into a curved and distorted segments, and displaced along more or less vertical planes which have a general tendency to shift the separate portions bit by bit, in one direction, the dykes being dragged to the north-west of their course.

A very important feature in the geology of the Pilbarra district is the evidence of great earth movements that affected the district.

In the neighborhood of the picturesque Doolena Gorge, on the Coongan River, very impressive evidence of a powerful rupturing of the crust is to be seen, represented, *inter alia*, by a line of dislocation which has been proved to extend for nearly 100 miles. The large quartz reefs to which allusion has just been made are seen to be abruptly cut off by this powerful fault, which presents a steep vertical escarpment—unscaleable in places—often over 150ft. in height. At some distance north of this main fault an instance was observed, on the eastern bank of the Strelley River, of one of these large reefs being not actually truncated, though subjected to deflection by a powerful thrust exerted in a direction approximately parallel to its strike. In this instance the compression has been so great that this reef, which is about 30ft. thick, was reduced to 6in. to 10in., whilst the horizontal displacement reached about 100ft.

The quartz reefs of the district also afford evidence of overthrusting, contortion, &c., and many of them present features which seem to indicate that they have been wrenched apart by movement along shear planes. A very important instance of this is to be seen at the mining camp of Warrawoona, where a line of reef of a peculiar type traverses the field along a powerful dislocation, which has been followed for two and a half miles.

This dislocation occurs along a persistent reef, portions of which have been torn apart and shifted in segments, producing the peculiar kidney or damper-shaped lenses of quartz, which vary from a few inches to a foot or so in width. The interval between each lens of quartz fluctuates within very wide limits.

The walls of the country enclosing these lenses are scored with striæ in the direction of the movement in a vertical direction, and the faces of the striations are often coated with fine films of gold. The abnormal richness—nearly 3ozs. per ton—of this type of auriferous reef has resulted in its being extensively prospected almost along the whole length, hence abundant opportunities are afforded for investigating its peculiarities both on the surface and below ground.

The ancient sedimentary beds of Warrawoona, which are highly siliceous rocks, dipping at varying angles to the north and east, consist of fine-grained flaggy quartzites, conglomerates, and quartz schists. Some of the conglomerates still retain traces of their original character, though in others most of the pebbles have been flattened out and stretched almost beyond recognition.

The oldest series of basic dykes, by which they are traversed, have also been crushed and sheared, and are now represented by bands of schistose greenstones. The rocks are also intersected by certain other acidic dykes now represented by quartz sericite schists, which may have originally been porphyries. One example from Warrawoona is a quartz sericite schist, with "eyes" of a fairly soft mineral, originally a potash felspar, around which the finer foliation of the matrix sweeps in very graceful curves. When submitted to microscopic examination it is found that these porphyritic crystals present that peculiar peripheral granulation so characteristic of crystals and fragments which have been subject to intense crushing.

All the features, both of the rocks and the reefs, coupled with other evidence, clearly indicate the presence of a number of overthrust and normal faults, and point to a series of movements along lines parallel to that of the main trend of the dominant structural features of the district, which is north-west and south-east. The disruption of the newest series of basic dykes, to which reference has been previously made, indicates that the enormous terrestrial stresses and strains continued in the same locality over a wide interval of geological time.

Traces of life may perhaps have existed in these old rocks of the North-West. Amongst the quartz schists which form the lofty serrated summit of the main axis of Warrawoona is a bed which here and there contains what at first glance appears to be fossil wood. A characteristic specimen of this silicified wood (?) has a length of about $4\frac{1}{2}$in.; cross sections of it are ellipsoidal in shape, the major axis being about $\frac{3}{4}$in. and the minor axis about $\frac{5}{8}$in. in length.

Microscopical sections, both transverse and longitudinal, were prepared and submitted along with the specimens to Mr. Etheridge, of the Australian Museum, who, however, was unable to detect any trace of organic structure in them. It is, however, quite possible that some form of organic life existed at the time these beds were deposited, and that the marked changes which they have undergone obliterated all traces of organic structure.

(*b*) *The Sedimentary Rocks.*—The sedimentary rocks, &c., include the whole of the beds which lie between the ancient crystalline rocks and the more recent strata. In spite, however, of the extensive area occupied by the complex of crystalline schists, Cambrian fossils have been as yet noticed from only one locality in the far north of Western Australia.

Mr. E. T. Hardman, of the Geological Survey of Ireland, was the pioneer geological observer in the far north of Western Australia, and his researches, carried out in the years 1883 and 1884, laid the foundation of our knowledge of the geology of the Kimberley district. This observer, however, obtained fossils from some limestones which have been referred to the Cambrian.

In 1891 Mr. H. P. Woodward made an extensive examination of the Kimberley district, and added considerably to the observations of Mr. Hardman.

Ten years later, in 1901, in company with Mr. Chas. G. Gibson, Assistant Geologist, I made a series of investigations in the King Leopold Plateau when searching for a reputed goldfield on the Carson River, between the 15th and 16th degrees of south latitude.

In the latter part of 1905 and the early months of 1906 Dr. Jack visited Kimberley, for the purpose of inquiring into the possibility of artesian being obtained in the district.

Mr. Woodward revisited Kimberley in the winter of 1906, and examined the country between Mount Broome and the coast on the west in the vicinity of Collier Bay and obtained, *inter alia*, a trilobite from a dun-buff colored limestone. The trilobite, which has just been submitted to Mr. Etheridge, appears to very closely resemble *Olenellus*.

Mr. Woodward describes these limestone beds as dipping at angles varying from 12° to 23° to the south-west. The basal beds, consisting of limestone and conglomerate, contain fragments and boulders of the schistose and granitic rocks which unconformably underlie them. This observation is of importance in that, with the specific determination of the fossils he collected, light may be expected to be shed upon the age of the crystalline schists.

We thus have a good many details regarding the geology of this far north region, though as our knowledge has advanced it cannot be said that the tangled skein has yet been unravelled.

In the course of his investigations, Mr. Hardman gathered a suite of fossils, which were critically examined by Mr. R. Etheridge and Mr. W. H. Foord and Dr. Henry Woodward.

Among the *disjecta membra* were the head and spine of a trilobite belonging to the characteristic Cambrian family *Olenellus Forresti*, and numerous pteropods—*Salterella Hardmani*—from a locality which unfortunately cannot now be identified. The discovery of the locality from which *Olenellus* was obtained by Mr. Hardman may be expected to go a long way towards setting at rest much that is at present puzzling regarding the geology of Kimberley.

Dr. Jack, writing in February of 1906, regarding the locality of *Olenellus Forresti*, says :—" The fossils described by Mr. Foord, in his notes on the Palæontology of Western Australia (*Geol. Mag.*, March and April, 1890), were collected by Hardman in 1883 and presented by him to the British Museum in 1886. Hardman's trip of 1883, described in his first report (1884), extended from Derby to the Leopold Range. Hardman's label on the trilobite in question was—' River south of base line ' . . . ."

" There are two base lines on Hardman's maps (F9-EB) ; at Mount Campbell (lat. 18° 13′, long. 125° 30′), and the other (WB-EF) at the Hardman Range (lat. 17° 40′, long. 128° 50′). If the *Olenellus* was collected in 1883 the base line referred to must have been F9-EB, since Hardman could not, in 1883, have mentioned a line which was not laid down till 1884. On the other hand there is *no* river ' south of base line ' (F9-EB) within the limits of Hardman's work, unless Christmas Creek be meant.

" There *is* a ' river ' (Hardman, in Irish fashion, called every small watercourse a ' river '), viz., the Turner, south of base line, WB-EF. It washes the S.W. side of the Hardman Range, but a good deal further from the range than Hardman's map gives it. The base line WB-EF could only be the one referred to on the supposition that Foord's information as to the date of the discovery was erroneous—that ' 1883 ' should read ' 1884 ' . . . .

" *But* the limestone indicated in *this* case is classed by Hardman as the lower member of his Carboniferous formation, and I saw what is no doubt its continuation resting on a considerable thickness of beds of basalt, which lie on the upturned Devonian of the Albert Edward Range. . . . . *Olenellus* is Cambrian. . . . .

" Altogether, we are confronted by so many contradictory conditions that I am inclined to conclude that the fossil must be ignored as having come from a locality unidentifiable."

Despite the fact of poor localisation of Mr. Hardman's fossils, it may, I think, be taken for granted that Cambrian beds *do* occur somewhere in Kimberley, about south latitude 18°. The recent discovery of *Olenellus* and *Salterella* in the limestones of the Daly River, in the Northern Territory, by Messrs. Brown and Basedow, is of considerable geological importance, indicating a somewhat wide distribution of Cambrian strata in Northern Australia, and makes the solution of the Hardman puzzle almost imperative, and more especially so in the light of Mr. Woodward's recent discovery in the Napier Range.

By far the largest area of the Kimberley division is occupied by a formation which extends from Mount Hopeless, near Collier Bay, *via* Mounts Hart, Broome, the Müeller, Saw, and Deception Ranges, Goose Hill, near Wyndham, to the South Australian border. These beds, which rest with a violent unconformity upon the crystalline schists, were provisionally referred by Mr. Hardman to the Devonian.

Considerable confusion has arisen, as has recently been pointed out by Dr. Jack, in a report on the Kimberley district now going through the press, in consequence of a discrepancy between the first and second reports of Mr. Hardman, in which he describes what recent observations have shown to be the same formation, first as Cambro-Silurian or Cambrian, and later as Devonian.

These Devonian beds of Kimberley have yielded the following fossils:—*Atrypa reticularis*, *Rhynchonella pugnus*, an *Orthoceras*, and two species of *Goniatites* and *Spirifera*.

A feature of interest and importance in connection with these beds is the evidence they afford of wide-spread contemporaneous volcanic activity. This was first noticed by Mr. E. T. Hardman, in 1883 and 1884, who described contemporaneous dolerites, volcanic breccias, and tuffs. It has beeen suggested that some of the igneous rocks occur in the form of intrusive laccolites.

In the year 1901, Mr. Gibson and I had abundant opportunities of investigating these beds during six months spent in the exploration of what may be called the King Leopold Plateau. Our observations extended from Wyndham to Mount Hart, near Collier Bay; the Prince Regent and Glenelg Valleys, rendered almost classical by the researches of Sir George (then Lieutenant) Grey, more than 70 years ago, and as far north as Admiralty Gulf. The result of the investigations indicated that the staple formation was made up of a series of quartzites, sandstones, fine conglomerates, and shales, disposed in a series of broad anticlinal folds. These beds extend as one continuous formation from Mount Cockburn to Mount Hart, a prominent summit on the King Leopold Range. Associated with the quartzites, &c., are a series of bedded and intrusive igneous rocks, the prevailing types being andesite, dolerite, and diabase. The individual characters of the different beds naturally present a large amount of variation, the rocks are sometimes amygdaloidal, and contain nodules of zeolites and agates. Beds of volcanic ash and breccia are common in certain localities.

In certain isolated portions of the district excellent sections are exposed, showing the intrusive nature of some of the igneous rocks; the sandstones are sometimes altered into hard compact quartzite, portions of which have been caught up in the body of the igneous rock. Other sections indicate quite clearly that the igneous rocks have, in some cases, found an easy passage along the bedding planes of the sedimentary rocks, and evidently occur in the form of sills. The lavas are traversed by almost vertical dykes of epidosite, which are tracable across country for long distances; whilst both the sedimentary and the igneous rocks are intersected by numerous segregation veins of quartz, some of considerable size and horizontal extent.

Mr. Hardman noticed, during his explorations in 1883-4, the association of fossils of carboniferous affinities with those characteristic of the Devonian rocks in the Kimberley beds. Dr. Jack noticed, in 1906, a similar association of Devonian and Carboniferous fauna from the beds near Mount Pierre, and makes mention of the carboniferous limestone region, consisting partly of limestone of an older date, and remarks that either there are in the Mount Pierre region separable

Carboniferous and Devonian strata or the same strata contain a Devono-Carboniferous fauna. It is possible that this apparent admixture of Devonian and Carboniferous fossils may have been brought about by Post-Carboniferous orogenic movements, of which there is abundant evidence in different portions of the State.

Three field seasons spent by myself in the Pilbarra Goldfield (situated in latitude 29° south) afforded an excellent opportunity for examining a formation consisting of sandstones, grits, conglomerates, and limestones, some of which are magnesian, together with a series of lavas, ashes, and agglomerates of as yet unascertained thickness. In its lithological characters, its behaviour, and general physical aspect it bears a very strong resemblance to the quartzites, &c., of the King Leopold Plateau, to which reference has just been made.

This formation, which has been designated the Nullagine Series, has a very wide distribution in the north-west, and the associated volcanic beds occupy a large area of country in the southern portion of the district. The series, which presents a plateau-like appearance, certain of the harder beds standing out in bold relief, presenting mural faces at different levels, plays a very important part in the geology of the north-west, in addition to being of some economic value by reason of the fact that the basal conglomerate of the series has been worked for the gold it contains in two widely separated localities, viz., Nullagine and Just-in-Time.

The Nullagine beds have been followed from the Oakover River, across the upper reaches of the Nullagine, Coongan, and Shaw rivers, as far as the western boundary of the Pilbarra Goldfields on the Yule River near Cangan Pool, from which locality they can be followed without a break to the vicinity of Roebourne. The same series constitutes the Hammersley Range, which contains Mount Bruce, the highest summit in the State. The Nullagine beds are probably continuous as far south as the Ashburton River, where both flanks of the valley are formed by extensive beds of magnesian limestone, which may be continuous with those which I observed in 1905, in the recesses of the Hammersley Range.

Regarding the southern extension of the Nullagine Series it may be noted that in a deep bore put down by the Government at Onslow, near the mouth of the Ashburton River, volcanic rocks identical with those in the type district were met with. It may thus be that these strata were pierced in the lower portion of the Onslow bore.

Undoubted Permo-Carboniferous rocks are known to occupy a large area of country in the watersheds of the Gascoyne, the Minilya, and the Lyndon rivers, hence the examination at present being undertaken of the country lying between Onslow and Lyndon should afford some valuable information as to the mutual relations of the Permo-Carboniferous and the Nullagine beds. So far as observations have at present been carried, there seems to be a gradually ascending geological series as we proceed southwards. What I am inclined to regard as outliers of the Nullagine Series occur in the Murchison Goldfield, near south latitude 27°. In 1904 Mr. Gibson mapped a considerable portion of the auriferous belt of the Murchison, and described a series of fine-grained volcanic ashes—lying almost horizontally on the granite of Mount Yagahong—about two miles south of the town site of Gabanintha. The beds have evidently a wide extent in the Murchison. At the town of Cue, some distance to the south of Gabanintha, there is a horizontal dolerite sheet capping what is known as Cue Hill, and some little distance to the west, on the lower ground, are a few outliers of quartzite on a lower horizon. These quartzites evidently form part of a much more extensive formation—of which there are but remnants left. There is very little doubt that these beds form part of the same series as the volcanic ashes at Gabanintha.

The igneous rocks associated with the series in the type district consist generally of acidic lavas. The great mass of the rocks consists of separate lava flows, each of no great thickness; some of the lavas are distinctly amygdaloidal, the cavities being filled with chalcedony. Some of the finer-grained ashy beds differ very little in general appearance from many of the banded lavas with which they are associated.

Undoubted volcanic *focii*, from which these lavas emanated, occur in many parts of the district, though they have been extinct long enough to allow the process of weathering to reduce them to mere stumps. There are also several acidic dykes which pierce both the sedimentary and the volcanic rocks, and these, in all probability, represent but another phase of that extraordinary volcanic activity which occurred in the northern portion of Western Australia during the Devonian period.

Considerable interest attaches to the Nullagine series by reason of the nature of the boulder beds at this base of the formation, for two important scientific reasons, viz.:—(*a*) The occurrence of flattened and striated pebbles to which a glacial origin has been assigned, and (*b*) the nature of the gold and iron ore in the conglomerate.

The basal conglomerate of the series is made up of rounded, ellipsoidal, or subangular fragments of the older underlying series. Many of these often include pieces which reach a length of 3ft. or 4ft. Some portions of the conglomerate contain flattened and striated pebbles of fine-grained sandstone and sandy shales, identical in character with those constituting the underlying strata. To these striated pebbles a glacial origin has been assigned by the late Mr. S. J. Becher, and subsequently by Professor David. The pebbles, however, seem to have had their striation induced prior to their taking part in the formation of the Nullagine series. The beds upon which the series rest, and to the denudation of which the boulders owe their origin, having, as has already been shown, been subject to intense mechanical deformation, it would only be natural to find some slicken-sided fragments and pebbles in newer rocks. Earth movements have caused the Nullagine beds to be thrown into a series of undulatory folds, but the deformation thus induced has not been of sufficient intensity to cause any striation of the component pebbles.

Such mining operations as have been carried out in the auriferous conglomerate have been, up to the present, confined to relatively shallow depths along the outcrop ; the conglomerate is in part marked by the presence of large quantities of iron pyrites and its oxidation products. In the unoxidised portion the pyrites occurs both as crystals, grains, and rounded or pebble-like forms. A certain interest attaches to the occurrence of these rounded pebbles and pellets of auriferous pyrites and hematite on account of the fact that they have been regarded as owing their shape to attrition, and that the gold and the iron are detrital, having been deposited with the pebbles of the conglomerate, as the result of the disintegration of the underlying auriferous rocks. The evidence respecting the origin of the gold in the Nullagine conglomerates indicates that it is a secondary and not an original constituent, and, further, that the primary source of the gold is the quartz reefs which occur in the underlying formation.

From the known occurrence of auriferous quartz reefs, which furnished no small portion of the pebbles of certain portions of the deposit, it is, of course, quite conceivable that a certain amount of detrital gold forms part of the conglomerate, but there are obviously no means of ascertaining what is the proportion of primary to secondary gold. There seems, however, good reason for believing that by far the greater bulk of the gold, together with the pyrites, was introduced by solution percolating down to the most porous portions of the conglomerate, this condition being facilitated by the downward inclination of the bed rock, and, possibly, accenuated in part by the folding which the strata have undergone.

One of the most important advances in Western Australian geology is the recognition of a glacial conglomerate in the marine Permo-Carboniferous rocks, near the Tropic of Capricorn.

The Carboniferous rocks of the State cover a wide extent of country, and bid fair to become a considerable economic importance.

The occurrence of Carboniferous rocks would seem to have first been made known through Sir George (then Lieutenant) Grey, in the year 1841, in his "Journals of the Two Expeditions of Discovery in North-western and Western Australia during the years 1837-9." There are four districts in which fossiliferous Carboniferous rocks are known in the State, viz. :—Kimberley, the Gascoyne, the Irwin River, and the Collie districts.

The Carboniferous rocks of Kimberley have recently been investigated by Dr. Jack, when in the quest for artesian water. This observer's work was carried out in the months of December and January, during one of the most severe droughts experienced in the district, and with a temperature often reaching 114° Fahrenheit. Despite the fact that the route followed in investigating these beds had perforce to be governed by considerations of grass and water, our knowledge of the Carboniferous rocks of Kimberley has been greatly extended. The formation is divisible into a lower or limestone series (in which limestones predominate), and an upper or sandstone series (made up largely of sandstones and other sedimentary beds). The two series have been seen to succeed one another conformably in the Haughton Range—south latitude 19° S., and east longitude 127° E. Both series have yielded an assemblage of purely Carboniferous fossils :—*Lepidodendron*, sp. ; *Stigmaria*, sp. ; *Stromatopora concentrica* (?) ; *Stromatopora placenta*, sp. ; *Pachypora tumida ; Zaphrentis*, sp. ; *Syringopora*, sp. ; *Actinocrinus*, sp. ; *Platycrinus*, sp. ; *Poteriocrinus crassus*, Miller ; *Pentremites*, sp. ; *Serpula ; Spirobis*, sp. ; *Fenestella plebeia* (*antiqua*), M'Coy ; *Productus giganteus ; Productus longispinus ; Productus semireticulatus ; Chonetes*, sp. ; *Chonetes Hardrensis ; Discina ; Orthis resupinata ; Strophalosia Clarkei*, Eth. fil ; *Rhynchonella pugnus ; Rhynchonella pleurodon ; Rhynchonella cuboides ; Orthotetes crenistria*, Phillips ; *Streptorhynchus crenistria ; Terebratula hastata* (?) *; Terebratula sacculus* (?) *; Pleurotomaria*, sp. ; *Toxonema*, small sp. ; *Natica*, sp. ; *Ceriopora*, sp. ; *Choetetes tumidus ; Stenopora Tasmaniensis ; Cyathophyllum*, sp. ; *Cyathophyllum virgatum ; Cyathophyllum depressum ; Lithodendron affine.*

So far as observations on the Kimberley Carboniferous rocks have been carried, no boulder beds have yet been recognised, though in view of the occurrence of glacial conglomerates in India within 18° of the equator their presence in Kimberley would cause little surprise. The necessity for a further more or less detailed geological examination of a portion of the Kimberley district is at the present moment under consideration by the Government, and the solution of the many economic questions involved in the stratigraphical research which such an investigation entails is of no less importance to the community than the purely scientific results which of necessity follow.

The Gascoyne beds cover a very large area between the 22nd and the 26th parallels of south latitude, and excellent sections of them may be seen in the valleys of the Wooramel, Gascoyne, Lyons, Minilya, and Lyndon rivers. Like their representatives in Kimberley, the strata are divisible into an upper or sandstone and a lower or limestone series. The sandstone series, which is seen resting conformably upon the limestone, is well exposed in the Carandibby, Kennedy, and the Moogooloo Ranges, making a bold outcrop of almost 200 miles in length. The beds forming these ranges were until quite recently regarded as of Mesozoic Age. The discovery, however, of *Spirifera*, *Athyris* (?), *Productus* and *Strophalosia* in the Kennedy Range, near Trig. Station K 37, on the northern bank of the Gascoyne River, definitely sets at rest the conflicting views until quite recently held regarding their position in the geological time scale.

The country to the east of the Kennedy Range is underlaid by fossiliferous beds of the limestone series, associated with which is the glacial boulder bed. This bed, which forms a valuable stratigraphical horizon, has been traced across country for a distance of about 60 or 70 miles.

At the most southerly locality at which the boulder bed has been detected in Wooramel Valley, the boulders are of very large size, and is composed of rocks identical in character with those forming the older underlying rocks to the east, *e.g.*, granite and other crystalline and metamorphic rocks.

Some distance northward, on the Wyndham River, is a boulder bed in the limestone series. The bed, which at this spot attains no greater thickness than 3ft., is crowded with boulders and pebbles of granite and crystalline rocks embedded in a calcareous fossiliferous matrix, a photograph of a specimen of which contains fragments of *Spirifera*, *Productus* and *Polyzoa*, in addition to *Aviculopecten tenuicollis*, will be found in the Annual Report of the Geological Survey for 1900. The pebbles and boulders have a large proportion of smooth and polished faces. The flats in the neighborhood are covered with boulders and blocks of crystalline rocks, evidently derived from the weathering *in situ* of a bed of conglomerate, which has a dip of about 3° to the south-west. In the bed of the Wyndham River beds of flaggy sandy limestone are to be observed passing beneath the boulder beds, indicating, what is perfectly obvious from numerous sections, that the glacial conglomerate does not lie quite at the base of the Carboniferous rocks.

Associated with the boulder beds of the Wyndham River are the following fossils :—*Hexagonella dendroidea*, Hudleston, sp. ; *Pleurophyllum Australe*, Hinde ; fragments of *Crinoid* stems and *Polyzoa ; Spirifera musakheylensis*, Davidson ; *Spirifera Hardmani*, Foord ; *Spirifera lata*, McCoy ; *Reticularia lineata*, Martin sp. ; *Athyris Maccleayana*, Eth. fil. ; *Chonetes Pratti*, Davidson ; *Productus* (*cf P. tenuistriatus*), Foord.

Northwards from the Wyndham River the *debris* of the boulder bed makes its appearance in great force. The flaggy sandstones immediately underlying it are covered with large boulders of crystalline rocks. Near Barragooda Pool, on the Arthur River, a thick bed of limestone directly overlies the boulder bed. This limestone has yielded the following fossils :—*Evactinopora crucialis*, Hudleston ; *Rhombopora tenuis*, Hinde ; *Athyris Macleayana*, Eth. fil. var. ; *Productus semireticulatus*, Martin ; *Aulosteges*, sp. nov. ; *Dielasma*, sp. ind.

A few miles to the north of this, near Trig. Station K.34, the Carboniferous beds are faulted against the older crystalline rocks, which, in this locality, consist of quartz and mica schists, associated with either dykes or sills of porphyry.

In the southern branch of the Minilya River, near Trig. Station K.49, the boulder bed is seen overlying beds of limestone and shale. The *debris* of the boulder bed consists of a heterogeneous collection of all sorts of crystalline and metamorphic rocks, and contains numerous ice-scratched pebbles—photographs of several typical examples appear as Plate IV. of the Annual Report of the Geological Survey for 1900.

It may be mentioned in this place that in a deep bore put down by the Government at Pelican Hill, near Carnarvon, that these Carboniferous or Permo-Carboniferous beds were met with beneath fossiliferous Mesozoic rocks at 1,406ft., and continued to a 3,011ft., the present depth of the bore. The Carboniferous strata are represented by calcareous shales and limestone. The cores from the bore have yielded *Spirifera*, *Aviculopecten*, *Anthrocoptera*, and *Favosites*. The bore, however, which did not pierce the whole thickness of the Carboniferous rocks, gave no sign of the boulder bed. From the few salient features pointed out it appears quite clear that the glacial conglomerate is associated and interbedded with the fossiliferous limestones low down in the Carboniferous series, as developed in this part of Australasia.

In the year 1897 I made a traverse up the Murchison Valley in an exceptionally dry season, which seriously interfered with geological investigation, and at a point in the bed of the river about 100 miles south of the boulder bed last mentioned a conglomerate and breccia composed of angular fragments of a quasi-vitreous quartzite dipping at a low angle to the east was met with ; the base of the conglomerate was not visible anywhere. The most important and significant feature in this section is the fact that many of the pebbles were covered with scratches, not unlike slickensides. A few yards lower down the river are a few beds of cross-bedded sandstones and fine conglomerates dipping east at an angle of about 20°. One of the beds has been scored to such a degree as to produce surfaces as smooth and polished as plate-glass. The question arises, is this a portion of a glaciated pavement, or is it due to faulting ? If the latter, the faulting is nearly horizontal. Some distance further up the river, near the 40-mile crossing and water reserve 1005, the sedimentary beds are interstratified with coarse conglomerates or boulder beds : the boulders are principally quartz, though pebbles of sandstone and granite occur. I detected no scratched boulders in this section, though circumstances did not admit of any detailed search being made. The important point in connection with these conglomerates containing the scratched boulders is that they form part of what is at present believed to be the southern extension of the Carboniferous series of the Gascoyne, and form a connecting link between the latter and the Irwin River series, to which reference will be made later.

Beneath the Jurassic rocks of the Champion Bay district, and in the valley of the Irwin River and its tributaries, is a fairly extensive development of Carboniferous and Permo-Carboniferous beds. In this district, as in Kimberley, it seems possible to divide the strata into two distinct series, viz., the lower, the limestone, and the upper, or sandstone, series.

Beneath the Irwin River coal seams are a calcareous shale and limestones, yielding a series of fossils, which have been carefully examined and described by Mr. Etheridge of the Australian Museum, and will shortly appear as one of the bulletins of the geological survey of Western Australia. The following fossils occur in these beds :—*Nubecularia Stephensi*, Howchin ; *Pleurophyllum Australe*, Hinde ; *Fenestella fossula*, Lonsd ; *Dielasma*, sp. ; *Seminula subtilita*, Hall ; *Spirifera*, sp. ; *Reticularia lineata*, Martin ; *Productus semireticulatus*, Martin ; *Productus tenuistriatus*, var. Foord, Eth. fil. ; *Productus undatus*, Defrance ; *Productus subquadratus*, Morris (?) ; *Chonetes Pratti*, Dav. ; *Aviculopecten Sprenti*, Johnston ; *Conocardium*, sp. Brown ; *Stutchburia*, sp. Eth. fil. ; *Bellerophon costatus*, J. de C. Sby., *Gastrioceras Jacksoni*, sp. nov. (the largest gonatite yet found in Australia, and of an entirely different type to the incomplete forms so far described).

The facies of these fossils is more akin to the Carboniferous than the higher Permo-Carboniferous, and only four species are with certainty identical with those found in the Permo-Carboniferous rocks of Eastern Australia, viz. :—*Nubecularia*, *Productus subquadratus*, *Fenestella fossula*, and *Aviculopecten Sprenti.*

Associated with the Marine Series is a boulder bed, the *debris* of which strew the surface for a considerable distance; but there has as yet been no opportunity of investigating these beds in any detail. So far I have seen no striated pebbles among the boulders.

About 25 miles lower down the river, in the vicinity of Mingenew, and close to the railway line, are a series of ferruginous sandstones, on a higher horizon than the limestones, which remind one very forcibly of the Sandstone Series as developed in the Kennedy Range of the Gascoyne River. These beds have yielded the following fossils :—*Dielasma nobilis*, sp. nov. ; *Dielasma hastata*, Dana ; *Spirifera*, sp. ind. ; *Spirifera avicula*, E. B. Sby. ; *Cyrtina carbonaria*, var. *Australasica*, Eth. fil. ; *Cleiothyris Macleayana*, Eth. fil. ; *Productus subquadratus*, Morris ; *Productus brachythoeris*, E. B. Sby. ; *Chonetes*, sp. ind. ; *Deltopecten subquinquelineatus*, McCoy ; *Modiola* (?) sp. ind. ; *Myalina* (?) *Mingenewensis*, sp. nov. ; *Fenestella* or *Protoretepora*.

On the whole it seems that the aspect of the fossils is that of the Permo-Carboniferous of New South Wales. It thus seems that there are in the Irwin River valley beds of a Carboniferous and Permo-Carboniferous Age, and that the coal seams may be possibly the equivalents of the Greta Coal Measures of New South Wales.

The Collie River beds, which attain a thickness of a little over 2,000ft., are of considerable economic importance by reason of the fact that they contain coal seams to a total thickness of about 137ft., and are of some scientific interest in their relation to the important question of the distribution of the *Glossopteris* flora.

The Collie River Coalfield lies to the east of Bunbury, and south of Perth, near the north-western edge of the tableland which succeeds the coastal plain. The field itself is traversed by the Collie River at an altitude of about 600ft. above the level of the sea. The area occupied by the Collie River Coal Measures is approximately 500 square miles. The beds consist of alternations of shales, sandstones, and grits, which rest directly upon granite schists and other crystalline rocks. The boundary of the field is, with one local exception, everywhere defined by faults : on the south-western side of the field the boundary fault has been estimated to have a down-throw to the north-east of at least 2,000ft.

There are several coal seams in the field, of variable thickness, they consist in descending order of—Cardiff No. 1 seam, 9ft. to 12ft. thick ; Cardiff No. 2 (or Boulder seam), 7ft. ; Collie Burn No. 1 seam, 9ft. thick ; Collie Burn No. 2 seam, 6ft. to 7ft. 10in. ; coal (no name), 8ft. ; Proprietary No. 1 seam, 4ft. to 8ft. ; Proprietary No. 2 seam, 5ft. to 7ft. 6in. ; Wallsend seam, 9ft. to 17ft. thick.

The coal seams are hydrous, semi-bituminous, non-caking coals, which approach very closely to lignite in some parts: between the various varieties the differences are only of degree, for there are no distinctive characters which would find universal application. Owing to the conditions of deposition the coals naturally vary in character, and in places pass insensibly, through forms containing a large proportion of earthy matter, to Carboniferous shales.

The question of the precise geological age of the Collie River beds is one about which there has been, and still is, considerable divergence of opinion.

In the year 1891 Mr. H. P. Woodward, then Government Geologist, assigned an early Mesozoic Age to the beds, basing his determinations principally upon the physical aspect of the field and the chemical composition of the coals.

A little later some fossils were submitted to the late Mr. R. Etheridge, sen., who detected *Glossopteris* or *Nœggerathia*, and concluded that the beds were Permo-Carboniferous.

In 1894 Mr. Woodward, basing his opinion upon the results of Mr. Etheridge's determination, referred the beds to the Upper Carboniferous.

In 1897 Mr. E. F. Pittman, Government Geologist, New South Wales, visited Western Australia, and in a report referred the strata to the Mesozoic—on the strength of Mr. Etheridge's (jun.), doubtful recognition of *Sagenopteris*.

Upon a geological map accompanying a report by myself, published in 1898, the age of the beds was defined as uncertain.

In 1898 Sir Frederick McCoy reported the discovery of *Glossopteris Browniana* in some fossils sent to him by the Premier of the State, and stated that the beds were of "the exact geological age of the great coalfields of Newcastle, New South Wales." I may add, however, that these fossils were not collected by, nor have they been seen by, any member of the geological staff of Western Australia.

Mr. R. Etheridge, jun., in his "Notes to Accompany a Miscellaneous Collection of Western Australian Fossils," submitted to him by myself in 1903, recognised undoubted *Glossopteris*—in a good state of preservation—from the Moira Collery, and constrained him to support the age assigned to the Collie River beds by his father, viz., Permo-Carboniferous. Mr. Etheridge carefully examined the *Sagenopteris* (?) obtained by Mr. Pittman, and in the same report abandons his previous determination, and now looks upon it as *Glossopteris*.

In 1904 Dr. Jack received a commission from His Excellency the Governor to fully investigate all aspects of the Collie coal industry, including, *inter alia*, geological conditions. Accompanying the Commissioner's report is an excellent geological map and longitudinal section; upon the former the age of the Collie River beds is set down as underternined. Dr. Jack, in his report, says:—"The evidence bearing on the age of the coalfield is at best inconclusive. High authorities have, indeed, expressed the opinion that it was of Palæozoic

Age—Carboniferous or Permo-Carboniferous—but all these opinions are founded exclusively upon the presence of the form *Glossopteris*, which is now known to range from Carboniferous to late Cretaceous. The shales are coarse-grained and incoherent, and badly adapted for the preservation of plant remains."

Dr. Jack draws attention to the fact that the various beds in the series are less coherent than is customary among the Carboniferous or Permo-Carboniferous formations of Europe, Africa, and Australia, and concludes:—"In a somewhat wide experience I have seen nothing which the Collie Coal Measures—coal seams included—so much resemble as the Oligocene Coal Measures of Croatia. While eagerly looking forward to the production of further evidence, and open to conviction, I am at present inclined to believe that the Collie coalfield will turn out to be possibly of Cretaceous Age—newer than the coalfields of Ipswich and Burrum" (of Queensland).

The next, and perhaps most important, evidence bearing upon the vexed question is contained in some "Notes on Fossils from the Collie Coalfield, Western Australia," in the "Collection of the National Museum, Melbourne," by Mr. F. Chapman, the Palæontologist to the Natural History Museum, Melbourne, just about to be printed as one of the bulletins of the geological survey of Western Australia. This writer recognised the plants:—*Glossopteris browniana*; *Glossopteris browniana*, var. *indica*; *Glossopteris browniana*, var. *communis*; *Glossopteris browniana*, var. *angustifolia*; *Glossopteris browniana gangamopteroides*; and, in the associated sandstones, the following foraminifera:—*Endothyra*; *Valvulina plicata* (U. Carb. Lst., England); *Bulimina* (Permo-Carboniferous, N.S.W.); *Truncatulina haidingeri* (Permo-Carboniferous, N.S.W.); *Pulvinulina exigua*.

The *Valvulina* of Collie, though very much dwarfed, is essentially a Carboniferous form, whilst the other species Mr. Chapman selected and described point in a general way to the Palæozoic Age of the series.

Mr. Howchin pointed out, in 1893, in his "Census of the Fossil Foraminifera of Australia," that the Australian Palæozoic foraminifera show a closer affinity with the Permian fauna of the Northern Hemisphere than the Palæozoic.

In view of all the evidence at present to be deduced from the plant remains, and the marine organisms in the beds associated with the Collie coal seams, despite the nature of the coal and the physical characteristics of the basin, I am constrained to admit that a Permo-Carboniferous Age of the series presents the strongest claims to acceptance. I make no excuse for the fact that my present views on this much-debated question are not those I previously held, but our most cherished opinions, like everything else, must yield to that stern logician—fact.

Jurassic rocks have been found up to the present in only one district, that of Champion Bay, near Geraldton; but the beds have not been investigated in any detail by the Survey, hence our information about them is, at the best, somewhat meagre.

Mr. Crick, of the British Museum, in a paper on " A Collection of Jurassic Cephalopoda from Western Australia," records Ammonites (*Perisphinctes*) *Championensis* from Cape Riche to the east of Albany, and naturally claims a Jurassic Age for the beds.

In 1898 I visited Cape Riche. The beds consist of sandy limestones, which extend between Cape Riche and Warriup, and are fossiliferous. The Cape Riche beds have yielded :—Impressions of a *Cycadaceous* leaf (?) ; *Hemiaster*, sp. ; *Pectunculus*, near *P. flabellatus*, Ten. Woods : internal casts of *Cytherea*, *Arca*, *Lima*, *Mactra*, *Amusium*, and *Voluta*, in addition to *Venus*, near *V. roseotincta*, Baird.

The Warriup beds have yielded :—*Cardium*, sp. ; *Cardium hemicardium*, Linn. ; *Trochus personatus* (?) Phil. ; and *Arca reticulata*, G. M. These strata would therefore seem to be either Recent or very young Tertiary. Even assuming that the Cape Riche series turn out on further investigation to be Secondary, I do not think the Jurassic can put in any claim for recognition. I am, therefore, inclined to think that Mr. Crick's ammonite recorded from Cape Riche has been wrongly localised, and really came from Champion Bay.

The Champion Bay Jurassic beds cover a fairly large area of country to the south, in the neighborhood of the coastline ; they are seen to rest with a violent unconformity on the Carboniferous rocks of the Irwin River valley. They also probably extend northwards, for in the deep bore near Carnarvon strata—high up in the Mesozoic series—have been recognised between 1,200ft. and 1,500ft.

The Champion Bay beds consist of oolitic limestones, clays, sandstones, grits, and conglomerates. Fossils are abundant, and they include a considerable number of *Cephalopoda : Belemnites*, sp. *Nautilus perornatus*, sp. nov ; *Ammonites* (*Dorsetensia*) *Clarkei*, sp. nov.; *Ammonites* (*Stephanoceras*) *Australe*, sp. nov. ; *Ammonites* (*Sphæroceras*), Woodward, sp. nov. ; *Ammonites* (*Sphæroceras*) *semiornatus*, sp. nov. ; *Ammonites* (*Peris phinctes*) *Championensis*, sp. nov. ; *Ammonites* (*Perisphinctes*) *robinginosus*, sp. nov. There have also been obtained :—*Trigonia Moorei*, Lycett ; *Myacitus*, *Sandfordii*, Moore ; *Luna*, sp. ; *Lima*, allied to *L. pectiniformis*, Gold ; *Cucullæa semistriata*, Moore ; *Pleuromya ; Astarte Cliftoni*, Moore ; *Gresslya*, sp. ; *Gryphæa*, sp. ; *Mytilus*, allied to *M. Gygerensis*, D'Orb. ; *Pecten frontalis*, Dumortier.

No estimate can as yet be made of the thickness of these Jurassic beds ; they have, however, been pierced by four bore holes in the Champion Bay district, the deepest being at Dongara. This bore was sunk for the purpose of the delimitation of the seaward extension of the Irwin River Coal Measures, which there are good grounds for believing to lie beneath the Mesozoic beds. The bore attained a depth of 2,111ft., when operations were stopped, owing to the capabilities of the boring plant being exhausted, without the base of the Jurassic rocks having been reached. There are thus over 2,000ft. of these beds in this locality.

The recognition by Mr. W. D. Campbell of the remnants of an extensive dolomitic limestone formation at an altitude of about 900ft.

above the level of the sea at Norseman, and distant about 100 miles due north from the coast at Esperance Bay (lon. 122° east), containing fossils of either Late Tertiary or Recent Age is, perhaps, next to the Carboniferous glacial beds, one of the most important of the recent advances in our knowledge of the younger geological formations.

Two small outliers of this formation occur on the western bank of Lake Cowan, and four near Lake Dundas. The beds, which in the vicinity of Norseman, occupy but a very small area, consist principally of a dolomitic limestone with several siliceous bands. These beds contain species of *Turitella*, allied to *T. terebra*, *Pecten*, *Cardium* (or *Cardita*), *Magellania*, and fragments of *Polyzoa*. These discoveries are of considerable importance, and must be thoroughly examined some day, as they involve a whole series of important conclusions which depend upon the age of the fossils the beds contain.

At Balladonia, some miles to the east, and in what is known as the Eucla Limestone Plateau, the flesh-colored limestones have yielded :— A Pecten, allied to *Chlamys asperrimus*, Lamck. Near Madoura Station a shell agglomerate yielded—*Venus peronii*, var. *conularis*, Lamck ; and *Tapes*, probably *T. Avaneosus Phillipsi*, a living species. These fossils seem to indicate a deposit of comparatively Recent Age.

Entering the State at its eastern frontier in the Nullarbor Plains, and extending without any interruptions as far as Israelite Bay, is a very large development of strata of Recent and Tertiary Age. These strata consist of flesh-colored limestones associated with sandy porous beds, into which the rainfall is rapidly absorbed, and discharged seawards in the form of fresh water springs, and are the western extension of the beds pierced in the five bores in South Australia.

These beds form what is known as the Premier Downs. An immense limestone plateau, extending from Goddard's Creek (E. long. 124°) to the South Australian frontier, terminating abruptly along its southern border by a conspicuous escarpment 400ft. high in some places. The limestone plateau extends for miles into the interior, and the average altitude (so far as can be ascertained) of the inland margin is about 1,000ft. above sea level.

The bore nearest the Western Australian frontier is at Albalakaroo, on or near the telegraph line, at about 45 miles east of Eucla. This bore attained a total depth of 1,084ft., and bottomed on granite at 1,073ft., after passing through (in descending order) 565ft. of (Eucla) limestone, 426ft. of clay (? shale), and 82ft. of a " hard rock," which those in charge of the operations could not determine.

Two bores have been sunk by the Western Australian Government near Madura : No. 1 bore was put down at a point 110ft. above sea level, and distant 30 chains south of the Eucla limestone escarpment, which is 350ft. high. The bore was carried down to a total depth of 2,041ft., and passed (in descending order) through about 766ft. of limestone, underlaid by alterations of clay shale, sometimes glauconitic, and dolomitic limestone. The bore ended in a soft mudstone. The second or No. 2 bore was situated 30 miles to the north of No. 1, on the limestone plateau, and about 300ft. above the level of No. 1. It was carried down to a depth of 412ft., and passed through nothing else but limestone—the Eucla limestone. The sequence of strata in the Western Australian bores coincides in its essential particulars with that indicated by the South Australian bores, and there can be very little doubt as to the identity of the two series of beds, whatever may be their age.

No mention of the recent advances in Western Australian geology would be complete without some reference to that extensive development of residual deposits which have been found over the whole length and breadth of the State.

The term "laterite" has been officially adopted, though in a somewhat more extended sense than its original application, for all the deposits resulting from the decomposition and re-consolidation of rocks *in situ*.

The laterites of Western Australia consist largely of hydrated oxide of iron and alumina, producing, on the one hand, deposits of excellent iron ore, and, on the other, bauxite. In some parts of the State the deposition of secondary silica in the lateritic deposits produces what are practically quartzites; these, by an increase in the ferruginous coloring matter, pass into a jasperoid form of laterite. There are thus three forms of these laterites: an aluminous, a ferruginous, and a siliceous, the composition being liable to vary considerably over a small area, it being largely governed by the nature of the underlying rocks. The structure is sometimes massive, and almost homogeneous, but is more frequently pisolitic and nodular, in which case the concretions are richer than the interstitial matter.

The lateritic deposits naturally vary in their lithotogical characters. They are often very porous, and weather into caverns and cavities of all sizes. The surface of the rock is often covered with a glaze of hydrated oxide of iron. When freshly broken the rock represents a mottled appearance, owing to the different shades of brown, yellow, and red. The rock passes gradually into the underlying rocks without any sharp line of demarcation. That ferruginous and siliceous laterites are more commonly met with is due to the fact that deposits of this type are better able to resist disintegrating influences than the softer varieties; they thus not only remain themselves, but act as a protecting cover for the rocks beneath.

Mr. J. Beete Jukes, writing in 1850, in his almost classic "Sketch of the Physical Structure of Australia," mentions the occurrence of these lateritic deposits—as seen by him in the country between Perth and York. He says:—"For a few feet below the surface the rock was a singular concretionary ferruginous compound, which looked like a clay or sandstone, that, being highly ferruginous, had formed itself into a mass of small balls and irregular concretions of a black oxide of iron or hematite. Below this ironstone (which is its name in the colony), wherever the rock was exposed it appeared for many miles to be granite, or some granitic compound."

In another place he mentions, as occurring in one of the lateral valleys of the Swan River, "A thin capping of ironstone, forming a line of small crags."

In 1861 the late Mr. F. T. Gregory gives in his paper, "On the Geology of a Part of Western Australia," an account of this lateritic deposit capping the Darling Range, and claims for it a Devonian Age. This observer mentions the important fact that the deposit blends gradually with the upper surface of the granite, and states that it would seem to owe its origin to the decomposition of the granite *in situ*.

The Rev. W. B. Clarke, in his "Sedimentary Formations of New South Wales," remarks :—"Mr. T. F. Gregory indicated on his map, and in his report, the existence of Devonian rocks near York, and in other parts of that colony. Having examined the rocks so indicated, I can only state my belief that they have no pretension to any such antiquity, and are probably mere collections of loose granitic matter, and other drift cemented by ferruginous paste, which has since become transmitted into concretionary nodules and hematite. There are also pebbles of trap, much decomposed, in the so-called Devonian. They may be, perhaps, more properly considered as representing the laterite of India."

It is on these historical grounds that laterite has been adopted in Western Australia as the name for these residual deposits, rather than the term "Saprolite," which American writers have suggested.

The various reports of the Geological Survey contain numerous descriptions of these lateritic deposits, and are often accompanied by analysis. These analyses show variations in alumina from 7.52 to 44.66 per cent. ; ferric oxide, 10.02 to 88.23 per cent. ; silica, 1.53 to 23.26 per cent. ; combined water, 8.10 to 26.44 per cent. ; and oxide of titanium, .59 to 3.10 per cent.

A recent analysis of a ferruginous laterite from Comet Vale (North Coolgardie) is of interest, "on account of the high percentage of chromium, mostly in the form of a hydrate readily soluble in hydrochloric acid, the balance being present in the form of chromite." The analysis gave 79.01 per cent. of ferric oxide, 5.30 per cent. of chromic oxide, 3.14 per cent. of silica, and of water 12.35 per cent. Some of the laterites have proved to be more than appreciably auriferous.

In the southern portion of the State, where the rainfall is greatest, the lateritic deposits support an abundant vegetation, the well-known karri and jarrah growing in all their splendor thereon. In fact, the mapping of the lateritic deposits of this portion of the State would define the areas over which both karri and jarrah occur.

Elsewhere in the State the laterites support but a scanty vegetation.

So far as our observations have been extended, the laterites, for the reason previously given, occur as disconnected outliers which once formed part of a continuous deposit. It is difficult to escape the conviction that since they were deposited a considerable time may have elapsed, hence the laterites may be of some geological antiquity, of which possibly the thickness and the state of consolidation may be some measure.

We have, however, as yet little authentic evidence on this point, though it may be mentioned that in a bore put down at Coolgardie, on

Reserve No. 23, certain plant remains were found in a deposit containing what is evidently the detritus of the lateritic beds. These plant remains have, on examination, been held to belong to the *Eucalypti.* McCoy has described definite eucalyptus foliage from the older gold drifts in Victoria, whilst Ettinghausen describes several species from the Upper Tertiaries of New South Wales and deep lead in the New England tinfield.

On this evidence, therefore, the laterites seem to be of earlier age than Late Tertiary, though there is but little doubt that laterite deposits are forming at the present time.

(*c*) *The Volcanic Rocks.*—Volcanic rocks have played an important part in the geological history of Western Australia, and the evidences of this igneous activity are to be found in the form of lava-flows, ash-beds, breccias, dykes, sills, &c., which make a prominent feature in certain portions of the State.

Many writers and observers, it must be noted with regret, treat volcanic rocks in such a fashion as to suggest that they constitute a more or less meaningless interpolation in geological history, and I have no desire to be included in the same category.

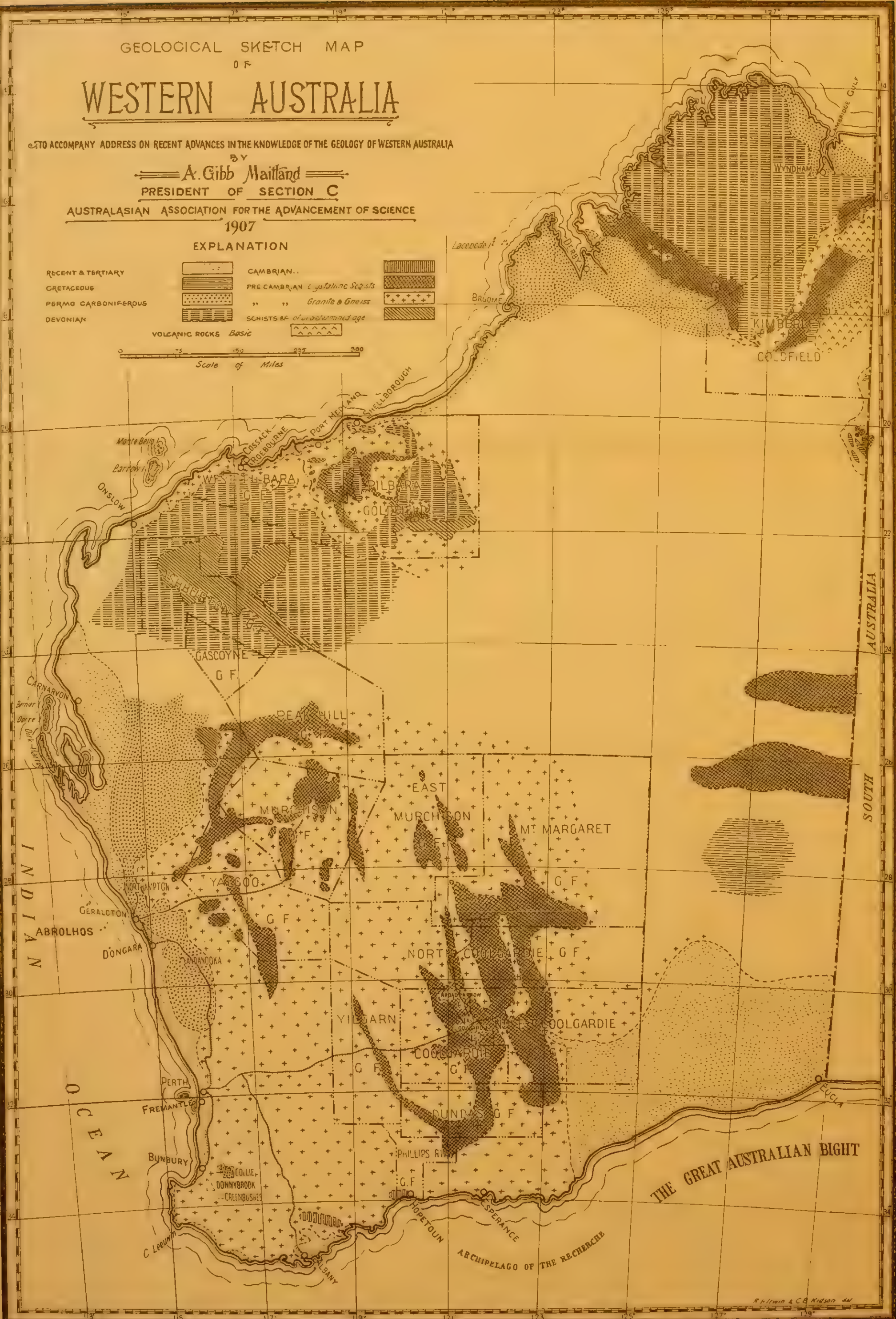
There are, so far as is at present known, three distinct periods in which Western Australia has been the scene of igneous activity of more or less intensity. These periods are :—

(*a*) In Pre-Cambrian time, prior to the deposition of the beds containing the *Olenellus* fauna. These old igneous rocks are of importance in the part they appear to have played in connection with the formation of the ore deposits of the State. These have been more or less fully described in the opening portions of this address.

(*b*) A period commencing early in Nullagine (Devonian) time, but ceasing before the Carboniferous. The interstratification of lavas and ashes with the sandstones and conglomerates point to subaqueous eruptions, though from the amygdaloidal nature of many of the lavas the bulk of these volcanic rocks must, I think, be sub-aerial. Several of the *focii* from which the lavas, &c., emanated have been noticed. The magnificent series of basic dykes of the north-west and elsewhere, to which reference has already been made, suggest to one who has examined the Devonian volcanic series that fissure eruptions, of which these dykes may form part, have been in some way responsible for the wide extent of the lava flows—which cover some hundreds of square miles.

(*c*) After the deposition of the Jurassic beds, and believed to be of Tertiary Age. They consist of basic lavas and ashes, which occur in great force in the Kimberley district.

In the Ord and Bow valleys there lavas appear to have levelled up the depressions formed therein (except certain knife-edge ridges of the older rocks, which still protrude above the level), and in places



SURVEYOR GENERALS OFFICE, ADELAIDE. A. Vaughan, Photo-lithographer

rest upon the Devonian volcanic plateau. On the Behn River, just above what is known as the "Gorge," Dr. Jack noted a dome or "Puy" of basalt, which apparently formed the focus from which some of these lavas issued.

At Bunbury, and one or two points on the coast round the south-west corner of the State, bedded columnar basalts occur. Over large areas and far into the interior, numerous volcanic ejectments, in the form of obsidian bombs, occur, and were probably derived from volcanoes of which no trace has yet been found: it is quite possible they may owe their origin to that volcanic region which skirts the northern coast of Australia.

The geological age of these basaltic lavas, in the present state of our knowledge, is a matter for inference only, but if we assume that they all belong to one period, they must be set down as Tertiary.

Some of the basic intrusive dykes, which are also widely distributed in the north-west, and form such pronounced features in the scenery, belong to a later period than the volcanic eruptions of Nullagine (Devonian) times, for many cases have been noticed in which they traverse the Nullagine beds for many miles. Since the Nullagine volcanic fires became extinct, Western Australia appears to have known no outbreak of igneous activity until pretty well Tertiary times.

The history of volcanic action in Western Australia is thus the history of Pre-Cambrian, Devonian, and the Tertiary periods.

It is hardly within the scope of a single address to consider the whole question of the geology of Western Australia. My object has been to point out what light has been thrown thereon through recent investigations, by merely touching the fringe of the subject, and my task has now been completed. In the fulfilment of the task I have endeavored to inflict, to the full, that punishment which, by the irony of fate, seems to be the recognised method by which a president conveys his appreciation of being made the recipient of one of the highest honors which his scientific brethren have within their power to bestow. Whether or not I anticipate your indorsement of, or disagreement with, the verdict that the "punishment fits the crime," I *know* that I am voicing your feelings when I say that during our efforts to wrest from mother earth those secrets which are graven in mystic characters on her face, we geologists, by merely wandering over the surface, exchanging the genial sunlight for the feeble flicker of the miner's candle, peering down the tube of the petrological microscope, calling to our aid the delicate chemical balance, or poring over the "Medals of Creation" in the seclusion of the museum cabinet, re-echo the sentiments of one of Germany's greatest poets and thinkers:

Oh Wünderschon ist Gottes Erde,
Und Schön auf Ihr ein Mensch zu sein.

Section D.

BIOLOGY.

ADDRESS BY THE PRESIDENT,

J. H. MAIDEN, F.L.S.,

Government Botanist and Director of the Botanic Gardens, Sydney.

A CENTURY OF BOTANICAL ENDEAVOR IN SOUTH AUSTRALIA.

In casting about for a subject, I have decided to choose one which will have local interest for South Australian botanists, and I trust my address may not be without value for them. I have been to some trouble to ascertain my facts; at the same time, while they cannot be absolutely complete, they may serve as a nucleus for further accretions.

Being a botanist I naturally choose a botanical subject, and then I reflect that a theme of general biological import would be appropriate for the Section. I also am reminded that I am the first botanical President of this Section, all my predecessors being zoologists or physiologists, with the important exception of the versatile Professor Tate, botanist, conchologist, palæontologist, and geologist. Adelaide was his home, the centre of his intellectual activity, and we regret that we shall see his genial face and listen to his clear-cut statements no more.

So that while many of my zoological friends will have the politeness to listen to a discourse in which they are not directly interested, I am sure they will pardon me when I remind them that botanical members of this Association have been very frequently in a similar situation.

It is not quite easy to classify some of the papers read before this Section, but I find that during the 10 previous meetings we have had, say, 99 zoological papers and 70 botanical ones. The botanists are numerically less than their zoological brethren, but it has occurred to me that they are strong enough to stand alone and to form a Botanical Section. I would submit that the establishment of separate Zoological and Botanical Sections would be an advantage. Botanists and zoologists are alike in that, in visiting a centre, they are anxious to get to work in the field, so that, if my proposal be given effect to, the botanists would not be delayed in this object until the whole of the zoological papers are read, and *vice versa*. The establishment of a botanical section of the British Association has undoubtedly resulted in the advancement of botanical science, and I ask consideration for my suggestion, which may perhaps be voted upon at our next Congress. If (which personally I do not fear) it should prove that we are substituting two weak sections for a strong one, there would be no difficulty in reverting to the present arrangement after the experience of, say, two or three meetings. The Zoological and Botanical Sections, if formed, could easily arrange for joint meetings for matters of mutual concern.

I think, also, that it would immensely popularise and enhance the usefulness of our Association if the papers were deposed from their present importance, or at all events supplemented by pre-organised discussions. For example, in the Botanical Section, it might be announced two years before that there would be a discussion on (*a*) the occurrence of natural hybrids; (*b*) the effect of the destruction of forests on the flow of streams in Australia. In this way we should get representative Australian scientific opinion on broad Australian scientific subjects in a way which must be of the highest value. We should also feel that we are doing something more than the reading of papers, work that is done very well by local societies.

Speaking of congresses, let me bring under your notice the work of the International Congress of Botanists, held at Vienna, 1905. I have brought the matter prominently before the Royal Society of my own State, and the utmost prominence should be given to it in all the States.

Let me remind you of the modern attempts to evolve laws for a settled nomenclature, beginning at the International Botanical Congress of Paris, 1867. An important congress was held at the International Exhibition of Paris, 1900, at which I was present, when the principle of quinquennial international botanical congresses was established, for the discussion of such matters of nomenclature as might be brought before them. The Paris (1900) Congress did good work, and decided to formulate a code for consideration at the Congress to be held at Vienna in 1905. From 1900 onward, various matters were brought before members, so that, at Vienna, they voted upon points which had been carefully considered beforehand. The result was the promulgation of a code which will go far to secure stability of nomenclature. The work of the Congress includes a list of Australian genera which form the *Nomina conservanda* which the Congress determined to agree to, irrespective of dates of priority. Vascular cryptogams and fossil plants remain to be dealt with at the next Congress, to be held at Brussels in 1910. Unfortunately no Australian botanist could be present at the Vienna Congress, but I feel that my brethren will loyally adopt the resolutions of this Congress, representative as it was of the botanists of Europe and America, and adopted as they were by substantial majorities, and, considering that Australian botanists have no principles at stake other than those affecting (and often to a greater extent) their brethren of the northern hemisphere. We have now a tribunal of nomenclature sitting every quinquennium to hear appeals, and its decisions no botanist can afford to disregard.

I will show presently that grand work has been already done in South Australia in the elucidation of her indigenous plants; but examination of the record shows (as was to be expected) that most of the work falls under the head of taxonomy. Philosophic generalisations in regard to geographical distribution have occupied less attention. Much requires to be done, however, even in these fields, while in the domains of morphology, anatomy, and physiology very little has been done in South Australia so far. Not that I am suggesting that the southern State is in any way lagging behind the others. The field of botany is so little trodden that every worker who enters it may hope to win his spurs. Many phanerogams remain to be recognised even yet, while many are imperfectly described and their life history and range little known. Whole groups of cryptogams have scarcely been touched. The ambitious young worker who turns to botany in South Australia, therefore, need not be haunted by the fear that he will exhaust his subject.

A plant ignores political boundaries, so that the botanists of the various Australian States are dependent on the work of each other. Australia has yet to be divided into plant-zones, and the working out of such problems in each State will lead to correlation which will be full of suggestiveness.

As a very general rule I recommend that a description of a new plant be published in the Australian State in which it is discovered. It is not expedient, or even possible, to do this in all cases, but acceptance of the principle will do much to put an end to a bane of Australian systematic botanists—the description of Australian plants in very many parts of the world, sometimes in publications not widely circulated and often without a bibliographical note in Australian journals. If an American were to describe his indigenous plants in Europe it would be regretted. It is submitted that it would be better for all parties to secure the publication of Australian plants in Australia. I am sure that, if the matter were properly put before European botanists also, they would, considering all the circumstances, see the reasonableness of the request to, as far as possible, publish Australian species in Australia. This, if carried out, would not merely be a convenience to Australians, but it would facilitate the work of students of the Australian flora in other parts of the world.

Let me remind you that the valuable "Second Census" of Mueller is now out of date, and that steps should be taken to bring out a third edition. The basis of the alterations would be the additions and corrections which are preserved in the working copies used by the staffs, and available to visiting botanists, of the herbaria of Melbourne and Sydney.

This brings me to consideration of a proposal to bring the "Flora Australiensis" up to date. That this is not a revolutionary idea will be evident when I remind you that vol. I. was issued 46 years ago. As regards Queensland, Mr. Bailey has seen fit to incorporate the "Flora Australiensis," as far as the Queensland species are concerned, in his Queensland "Flora," but my reverence for Bentham's work is such that I think that for some years all that is required is for each State to publish a supplementary volume, only including additions and corrections to Bentham's great work, and even this only as a temporary arrangement. The "Flora Australiensis," *per se*, is a classic, and its identity should not be interfered with.

The form of the new "Flora Australiensis" (which cannot be be published until Western Australia is more thoroughly explored botanically) will then fitly take the form of the most modern classification available, which, at the present moment, is of course that of Engler, although even that fine arrangement need not be slavishly followed in every detail.

We in Australia suffer much through our geographical isolation from the great intellectual centres of the Northern Hemisphere. That is our misfortune, but we should not fail in our endeavors to advance knowledge of the botany of this continent, and potent help in this direction would be the issue of an "Australian Flora" based on the most modern lines of taxonomic research, modified, indeed, by our own special knowledge of our own plants and their affinities.

II.—THE BEGINNING OF BOTANICAL INVESTIGATION IN SOUTH AUSTRALIA: THE SEACOAST.

It is very desirable that we should be acquainted with the history of botanical investigation in South Australia—to learn of the men to whom we are indebted for that foundational knowledge on which we build at the present day.

The subject has a very practical side to the botanist. If he cannot have access to the types described by the old workers, or consult their herbaria, often, indeed, in Europe, he can do the next best thing—he can go over their tracks once more, during the same month they col lected and also during other parts of the year. For example, let us carefully ascertain where the immortal Robert Brown collected, and let us have in some public institution in the city of Adelaide a collection of plants from Brownian localities. These will have a special practical value to the botanist that it is not necessary for me to dwell upon in a company of naturalists. I will, therefore, give some account of the evidence in regard to botanical investigation in South Australia, beginning at the basis of it all—Robert Brown's exploration in the *Investigator*, with Flinders. I make no apology for dealing with Brown's movements in detail.

The coastline of South Australia extends from 129° to 141° east longitude. Flinders was close to the western boundary on January 26th, 1802, and left the eastern boundary about April 19th. Let us trace any notes in his work (*a*) referring to botanical investigation along the South Australian coastline.

January 26th.—Let us note the horizontal cliffs in view 6, plate XVII. Flinders comments on the extraordinary continuity of these level cliffs, and surmises them to be the "exterior line of a vast coral reef."

(*a*) "A Voyage to Terra Australis," by Matthew Flinders, 2 vols. and an atlas. Vol. I., p. 96.

On January 28th he named Cape Nuyts, and anchored in Fowler's Bay, which he named. "The botanical gentlemen (*b*) landed early on the following morning to examine the production of the country. . . . . The botanists found the scantiness of plants equal to that of the other productions."

It would appear that Fowler's Bay was the first place in South Australia visited by any botanist or collector.

January 31st.—Point Bell and Sinclair's Rocks.

February 1st.—Purdie's Isles.

On February 3rd they landed on an island, nearly three miles long, one of a small group called by him the Isles of St. Francis. Here "the scientific gentlemen landed upon their respective pursuits."

On the 4th "the great heat deterred the naturalists from going on shore this morning, for the very little variety in the vegetable productions presented no inducement to a repetition of their fatigue."

February 5th.—Off Franklin's Isles and there "is a low projection of the mainland to which the name of Point Brown was given, in compliment to the naturalist; and four leagues further, in the same line, was a cliffy head, called Cape Bauer after the painter of natural history." Streaky Bay named this day, also Point Westall in compliment to the landscape painter.

February 6th.—Smoky Bay was named.

February 7th.—"The botanists preferred going on shore to the more eastern land, which, though low, was much more extensive than the island nearer to the ship. . . . . The soil at the top was little better than sand, but was overspread with shrubs, mostly of one kind, a whitish velvety plant, *Atriplex reniformis* of Brown."(*c*)

Denial Bay named to-day. "At two o'clock Mr. Brown and his party returned from the eastern island. . . . The anchor was weighed on the return of the botanists."

February 9th.—Petrel Bay and Cape Radstock.

February 10th.—Point Weyland and Waldegrave's Isles.

February 11th.—Here an island was visited; it is not important for our inquiry, for "Mr. Brown remarked that this was the first island where not a single novelty in natural history had presented itself to his observation."

February 13th.—At an island about five miles in length, where "the botanical gentlemen landed early." This, from its size, is apparently Flinders Island. The group of which it forms a part is the Investigator's Group. "The vegetation differed from that of other islands before visited, in that the lower lands were covered with large bushes, and there was very little either of the white velvety shrub (*Atriplex*) or of the tufted wiry grass. . . . . No other trees than a few small Casuarinas, at a distance from the anchorage, were seen upon the island."

February 15th.—Point Drummond.

(*b*) A favorite expression of Flinders, and usually taken to mean Brown and Ferdinand Bauer.

(*c*) Prod. Fl. Nov. Holl. p. 406.

February 16th.—Point Sir Isaac and Coffin's Bay were named, both after Vice-Admiral Sir Isaac Coffin.

February 17th.—Point Whidbey and Whidbey's Isles, Avoid Bay.

February 19th.—Cape Wiles and Liguanea Island. See view 7, plate XVII.

February 20th.—Isle Williams and Sleaford Bay. Isle Williams and Cape Catastrophe on view 8, plate XVII.

February 21st.—Landed on Thistle Island. "The island was pretty well covered with wood, principally Eucalyptus and Casuarina."

February 22nd.—"Mr. Brown and a party landed to walk along the shore (mainland) to the northward." In connection with the search for Mr. Thistle, Mr. Taylor and six men lost here; hence the name Cape Catastrophe.

February 24th.—Discovery of Port Lincoln. At p. 128 is a view by Westall, of "Entrance of Port Lincoln, taken from behind Memory Cove."

For a view of Thistle's Island see view 9, plate XVII., taken from Memory Cove, just north of Cape Catastrophe.

Memory Cove having been visited (*d*) it was doubtless well botanised over.

Flinders was a Lincolnshire man, and Port Lincoln and many places in the neighborhood were given Lincolnshire names.

February 26th.—"I landed with the botanists and ascended Stamford Hill."

"Amongst the various excursions made by the scientific gentlemen one was directed to Sleaford Mere, of which they made the circuit." They visited Boston Island. Speaking of Port Lincoln, "the wood consists principally of Eucalyptus and Casuarina."

Port Lincoln was finally left on March 6th, and Robert Brown had more abundant opportunities for botanising here than in any other part of South Australia so far.

March 7th.—Anchored off the north side of Kirkby Island, and "landed again with the botanical gentlemen." Sir Joseph Banks Group.

March 9th.—Going further into Spencer's Gulf. In view 10, plate XVII. we have a view of "Mountains at the head of Spencer's Gulph," with Mount Brown and Mount Arden.

March 10th.—"Messrs. Brown, Bauer, and Westall, with attendants, set off upon an excursion to the eastern mountains, intending, if possible, to ascend to the top of Mount Brown.

Robert Brown and party returned late at night (11th), after an arduous trip to the top of Mount Brown. Doubtless excellent botanical specimens were obtained.

March 16th.—Proceeded south down the Gulf, naming Points Riley and Pearce, Hardwicke Bay, Corny Point, and Cape Spencer.

Then discovered Kangaroo Island, naming Point Marsden and Nepean Bay on the north of it (March 21st).

(*d*) See also C. Hope Harris, Proc. A.A.A.S. pp. 468-96 (1893); also Stirling, Proc. R.S., S.A., 1892.

March 22nd.—Landed, and on the following day "the scientific gentlemen landed again to examine the natural productions of the island." View 11, plate XVII., is a view of Kangaroo Island, and view 12 is Cape Jervis, taken from the anchorage at Kangaroo Island.

"A thick wood covered almost all that part of the island visible from the ship."

On March 24th left Kangaroo Island to examine the mainland (from the ship) from Cape Spencer.

March 27th.—Investigator's Strait was named. Working up St. Vincent's Gulf.

March 30th.—"Early in the morning I went in a boat, accompanied by the naturalist, to examine more closely the head of the Gulf."

Mount Lofty had been named a few days previously, and Yorke's Peninsula was named March 30th.

April 2nd.—Back to Kangaroo Island, near their former anchorage, where "the naturalists went to pursue their researches."

April 3rd and 4th.—Naturalists landed; on the 4th ascended Prospect Hill.

April 4th.—Named Pelican Lagoon and slept ashore.

In Flinders's work is a "View on the north side of Kangaroo Island," by Westall.

April 6th.—Steered out of Nepean Bay, and Westall depicted view 11, plate XVII. (part of Kangaroo Island, with Kangaroo Head in the foreground).

April 7th.—Backstairs Passage and Cape Willoughby.

April 8th.—Here the French ship *Le Géographe*, Captain Nicholas Baudin, was encountered.

It is interesting to note that Robert Brown acted as Flinders's interpreter.

The meeting took place abreast of a bay, which was hence called "Encounter Bay." So that, as far as South Australia is concerned, Robert Brown was the first botanist from the western boundary as far as Encounter Bay, while from the eastern boundary to Encounter Bay the French were earlier. Leschenault de la Tour was the French botanist.

I do not wish to dwell upon the conflicting claims of the French and English to the discovery of the coast already referred to; Flinders's statement (*e*) appears clear enough. Peron and Freycinet (*f*) may be read on the other side.

Flinders then passed along the "coast discovered by Captain Nicholas Baudin, 1802." See plate V. of his atlas.

April 12th.—Opposite Cape Bernouilli.

April 13th.—Rivoli Bay and Cape Lannes.

April 15th.—Cape Buffon.

(*e*) *Op. cit.* I. p. 191.

(*f*) "Voyage de decouverte aux terres australes," redigé par M. F. Peron, Naturaliste de l'expedition. Vol. I., Paris, 1807. Vol. II. (edited and continued by Louis Freycinet), 1816.

This would appear to be the limit of the discoveries of the French at this time, for their Cape Boufflers had previously been named Cape Banks (*g*) by Lieutenant James Grant (*h*), of the *Lady Nelson*, on December 3rd, 1800. He also surveyed the remainder of the South Australian coast going east. Cape Northumberland was named by him, and also Mounts Schanck and Gambier.

I cannot find that any botanical specimens were collected by Brown or others on Flinders's expedition on the South Australian coast subsequent to Flinders's meeting with Baudin. The plants of Baudin's expedition are referred to at page 166. I cannot find that Grant collected on the South Australian coast at all.

Robert Brown, in his rough sketch of the stopping-places (*i*), makes but a cursory allusion to what is now the South Australian coast " . . . . and the remaining parts of the south coast (*j*), on five distant points of which we landed, as well as on seven of its adjacent islands, were still more barren, altogether producing only 200 additional species. The smallness of this number is to be accounted for, partly, no doubt, from the less favorable season in which this part of the coast was examined; but it appeared to depend also in a considerable degree on its greater sterility, and especially that of its islands."

Brown's plants were, of course, mainly described in his "Prodromus."

Following are some of Brown's stopping-places (*k*), on what is now South Australia:—Bay iii. (*l*); Fowler's Bay, a few hours; Memory Cove (*m*), three days; Bay x., Port Lincoln, seven days; Inlet xii., an anchorage on Kangaroo Island (*n*), three days; Inlet xiv., Gulf of St. Vincent, a few hours; Kangaroo Island (*o*), five days.

The botanist of Baudin's Expedition of 1802 was Leschenault de la Tour (*p*), Riedlé was head gardener, and Sautier and Guichenot

(*g*) Called "West Cape Banks" by Flinders to prevent confusion with the Cape Banks (Botany Bay) of Cook.

(*h*) See Grant, "The Narrative of a Voyage of Discovery, performed in His Majesty's vessel the *Lady Nelson*, during the years 1800-2, to New South Wales . . . Soil, Natural Productions, &c.," London, C. Roworth, 1803. Demy 4to. pp. 195.

(*i*) Appendix to Flinders's voyage, Vol. II., p. 534.

(*j*) He probably includes part of Victoria.

(*k*) Brown quotes a number of his collecting places. Hist. Rec. of N.S.W., Vol. IV., p. 778.

(*l*) There is a bay i., which is King George's Sound (see Hist. Rec., Vol. V., p. 181), but there is a bay i., which is apparently Lucky Bay. (Hist. Rec., Vol. IV., pp. 748 and 750.)

(*m*) See No. 9, Hist. Rec., Vol. IV., p. 751.

(*n*) Hist. Rec., Vol. IV., p. 778. But perhaps Spencer's Gulf—Hist. Rec., Vol. IV., p. 751.

(*o*) "On March 22nd and 23rd, 1802, Brown was on shore at Kangaroo Head. April 2-5, 1802, on shore at Kangaroo Head; boat excursion to American River and Pelican Lagoon; ascended Prospect Hill, situated on the isthmus connecting Dudley Peninsula with the main mass of the island. The collection was derived almost entirely from the littoral tracts, and he could not have seen the characteristic inland flora." (Tate, Proc. Roy. Soc. S.A., Vol. VI., p. 131, 1882-3.)

(*p*) *Infra* p. 175.

gardeners. Peron's work treats in the most cursory way of the plants. The expedition was at Terre d'Endracht (Shark's Bay, W.A.), Terre de Witt (North-West Australia), Terre d' Edels (also W.A.), and March 29th to May 8th, 1802, Terre Napoléon (including much of South Australia and Grant's and Flinders's discoveries).

Hooker (*q*) says—" They formed large collections, which are now in the Jardin des Plantes. They were collected principally on the islands of the north-west and west coasts in Tasmania and New South Wales. They were not published in a connected manner, but they gave rise to various papers in the " Memoires du Muséum " and " Annales du Muséum," by Desfontaines and others." (*r*)

As to the plants collected on Baudin's Expedition, Tate remarks (with especial reference to Kangaroo Island)—" Latour Leschenault . . . . sojourned off Kingscote from January 7th to February 1st, 1803, and he tells us that, " the island is sandy and without rivulets, that the vegetation is beautiful, and the plants very varied. I have discovered a great number of new species." (*s*)

F. Peron, the zoologist to the expedition, and the author of the narrative, writes—" At the head of this grand bay (Nepean Bay) there are forests which appear to extend far away towards the interior, and which are composed of different species of *Eucalyptus*, *Banksia*, *Phebalium*, *Acacia*, *Casuarina*, *Metrosideros*, *Leptospermum*, *Styphelia*, *Conchium*, *Diosma*, *Hakea*, *Embothrium*," &c., &c. (*t*).

From the narrative of the expedition it is uncertain if other opportunities were offered for collecting plants than during the long stay in Nepean Bay, unless it were at Hog Bay. Leschenault botanised at other parts of the Australian coasts, but the collection as a whole remains unpublished up to the present day. Desfontaines made a few selections from the West Australian plants gathered on this expedition ; but, with few exceptions, not any of the Kangaroo Island plants were described, though doubtless all have been identified. Mr. Bentham examined many of the plants of Baudin's expedition in the Paris herbarium for the " Flora Australiensis," but from that collection only two species are recorded for Kangaroo Island—*Eucalyptus incrassata*, erroneously attributed to Labillardiere, who was never on the island, and *Acacia dodonæifolia*. Leschenault (*u*) cites a few species, which he had observed on Kangaroo Island. A species of *Nicotiana*, which grows on the sands by the seashore, is certainly *N. suaveolens*. " A *Melaleuca*, with long filiform leaves," is doubtlessly *M. uncinata*, and " another, with yellow flowers," is probably *M. squarrosa*. " Many new species of *Eucalyptus*." " A very pretty species of *Anthericum* " (perhaps *Athropodium laxum* or *Bulbine semibarbata*). " A plant of the order Irideæ " (this is in all probability *Sisyrinchium cyaneum*, which grows abundantly about Kingscote). " A new species of *Solanum* " (*S. simile* is the only species excepting the European *S. nigrum* known to

(*q*) " Introductory Essay to the Flora of Tasmania," CXVIII.
(*r*) Including Adrien de Jussieu. (*s*) " Peron's Voyages," Vol. II., p. 366.
(*t*) *Op. cit.*, Vol. I., p. 76. (*u*) *Op. cit.*, Vol. II., p. 366.

occur). "A very pretty and very singular *Convolvulus* without stem." On Leschenault's specimens Choisy founded his *C. acaulis*, which, according to Baron Mueller, is clearly the minute state of *C. erubescens*. To the above there should be added *Eucalyptus diversifolia*, described by Bonpland in 1813 from specimens grown from seeds gathered at Kangaroo Island during Baudin's expedition. The specific name, as only applicable to the young state of the plant, has been discarded for that of *santalifolia* (see F. v. Mueller's "Eucalyptographia, Decade 8"). (Tate, Proc. R.S., S.A., VI., 131 (1882–3)) (*v*).

III.—LAND EXPLORATIONS (*w*).

Sturt.—We now pass onwards for a quarter of a century, until Sturt's time.(*x*)

Let us turn to "Two Expeditions into the Interior of Southern Australia during the Years 1828-31, &c.," by Captain Charles Sturt, 2 vols., 1833. (Southern Australia is not synonymous with our South Australia.)

In this work Sturt gives (*inter alia*) an account of his journey "From Camden to and along the Rivers Morumbidgee and Murray, across Lake Alexandrina to Encounter Bay."

All his travels on his journey westward of lat. 141° were, of course, in South Australia. They were along the Murray to its mouth. Very few botanical allusions are contained in this work; the map has notes on the vegetation.

Taking it out of strict chronological order we have—

"Narrative of an Expedition into South Australia . . . during the Years 1844-6, together with a Notice of the Province of South Australia in 1847." By Captain Charles Sturt, 2 vols., London, 1849.

This contains a "Map of Captain Sturt's route from Adelaide into the Centre of Australia (lat. 24° 30′ S.)," and is valuable for a list of early names, and for its observations on the nature of the country and its vegetation.

Vol. II., pp. 66-92, contains a Botanical Appendix by Robert Brown. Sturt brought home about 100 species, many of them of especial interest, and the Appendix, considering its author, is of course valuable.

The explorer is commemorated in the genus *Sturtia*, R. Br. (included in *Gossypium*, L.); *Gossypium Sturtii*, F. v. M.; *Hibiscus*

(*v*) Let me, at this place, invite attention to two South Australian bibliographical works:—(1) Gill, Thomas, "Bibliography of South Australia." Published for the Colonial and Indian Exhibition, 1886. 8vo., pp. 118. Government Printer, Adelaide. Most valuable. (2) Harris, C. Hope, "Geographical Nomenclature of South Australia." These Proceedings, V., pp. 468-96 (1893). A useful paper for reference, particularly as to the reasons why names were given.

(*w*) The Northern Territory is technically north of 26° N., but I have included papers, &c., on Central Australia which are within the political boundaries of North Australia, in the present sketch, as a matter of convenience.

(*x*) A useful digest of Australian exploration, with special reference to South Australia, will be found in Sir Samuel Davenport's Inaugural Address of the S.A. Branch of the Geographical Society, Adelaide, 1886.

Sturtii, Hook.; *Cassia Sturtii*, R. Br.; *Crotalaria Sturtii*, R. Br. (?); *Phyllota Sturtii*, Benth.; *Solanum Sturtianum*, F. v. M.; *Eremophila Sturtii*, Br.; *Grevillea Sturtii*, Br. = *G. juncifolia*, Hook.

Eyre.—"Journals of Expeditions of Discovery into Central Australia and Overland from Adelaide to King George's Sound in the Years 1840-1." By Edward John Eyre, 2 vols., London, 1845.

This gives an account of Eyre's marvellous journey. It valuably supplements on land Flinders's observations on the coast from shipboard.

Eyre gives useful notes in regard to the vegetation of the country through which he passed, but, as regards details of the species collected, all his earlier specimens were lost after they had been sent to Adelaide. "This loss has been irreparable." (Preface, p., viii.)

Hooker (*y*) says this journey "proved the utter sterility of the waterless coast which he traversed. Between the meridians of Streaky Bay and Lucky Bay there appears to be scarcely any vegetation at all, except on the outlying islands, on some of which Brown had botanised when on Flinders's voyage, and on which he appears to have found very little. At the meridian of 118° again the peculiar vegetation of south-western Australia commences."

Eyre was born in England in 1815, and died 1901. He arrived in Sydney in 1833, and early became an explorer. His connection with South Australia began in 1840. His journey along the coast from South Australia to King George's Sound is one of the most remarkable feats of pluck and endurance in the whole record of Australian exploration. *Pluchea Eyrea*, F. v. M., and *Pimelea Eyreii* are named after him.

For biographical details see "Mennell" (*z*), p. 152, and Mueller, Trans. Phil. Soc. (Vic.), II., 154. He was awarded the Clarke Memorial Medal of the Royal Society of New South Wales, see vol. XXXV., pp. xviii., xxxviii., xlii., xliv.

In the Library of the Royal Gardens at Kew the following MS. volumes are to be found:—

(*a*) South Australia: Botanical exploration (1854-83). Various papers, reports, and correspondence. (Adelaide, &c., 1854-83, fol.)

(*b*) Northern Territory, 1869-90. Printed reports, with occasional MS. (Adelaide, 1869-90, fol.)

Mueller.—Mueller, Ferdinand von. I have no intention of giving an adequate biographical notice of Mueller at this place, but I may remind you that for the first four years of his residence in Australia he was a South Australian. He arrived in Adelaide late in 1847, and left South Australia in 1852, to fill the newly-created post of Govern-

(*y*) "Introd. Essay Fl. Tas."

(*z*) "The Dictionary of Australasian Biography," by Philip Mennell. London: Hutchinson & Co., 1892.

ment Botanist of Victoria. He interested himself all his life in the development of the botany of South Australia, and notes of his work, while he was a resident in that State, will be found referred to at p. 181.

Herrgott.—"Report on the Plants collected during Mr. Babbage's Expedition into the North-western Interior of South Australia in 1858." By F. Mueller. Printed by the Victorian Government, 1858. Fcp., p. 21.

A valuable report, including descriptions of a number of new species. The plants were collected by Mr. David Herrgott.

The furthest north where plants were collected was 29° 12′; the extremes of longitude, 126° 56′ and 137° 56′. The route was from Flinders Range, north of Port Augusta; thence to Pernatty, west of the southern portion of Lake Torrens; west to Lake Hart; thence north to Stuart's Creek and Lake Eyre. It was fertile in botanical results, and Tate appears to have overlooked the record.

David D. Herrgott was the "General Assistant and Botanist" to Babbage's Expedition.

The new genera discovered were three, and the new species 17, while many of the plants were rare. Mueller says, "The herbarium itself was compiled by Mr. David Hergott, and does credit to his skill and industry." Mueller refers to Mr. Babbage's "collection" and "plants," but in the enumeration completely ignores Herrgott, and in the naming of the new genera and species pointedly omits the commemoration of the collector, although the names of other men are honored.

Herrgott was a native of Bavaria, and died in Melbourne, December 17th, 1861, in his 36th year. He was attached to Stuart's Exploring Expedition of 1860, when Stuart discovered the springs named by him after Herrgott.

But Hergott's (*a*) Springs are misspelt. The error is of long standing, *e.g.*, "Baillière's South Australian Gazetteer," 1866.

Mr. Thomas Gill, I.S.O., informs me that another member of Babbage's Expedition was T. Warrener, "General Assistant," and the northern railway station, "Warrina," was named after him.

Stuart.—John McDouall Stuart collected during his traverses from the Finke River to the Macdonnell Range in 1860-2. The plants, determined by Mueller, were published as an Appendix to the "Journals of J. McDouall Stuart" (London, 1864). Fifty-two species were catalogued, and seven new species were described in "Fragm.," vols. II. and III. (32 from the Larapintine (*b*) region).

Giles.—Ernest Giles made five expeditions, described in his work, "Australia Twice Traversed," and all were more or less in South Australian territory. He made a sixth expedition in 1882.

(*a*) Spelt "Herrgott" C. Hope Harris, *op. cit.*, but the man's name spelt "Herrgolt" by Mueller, perhaps through a slip.

(*b*) See below, p. 183.

His principal work is "Geographic Travels in Central Australia, 1872-4." (Melbourne, 1875.) This contains a list of 254 species (114 belonging to the Larapintine flora), named by Mueller. Giles's work in the Larapintine region was westward of the Finke River.

This was reprinted in the following form:—"List of plants collected by *Ernest* Giles, during his first and second exploring expeditions, 1872-4" (arranged by Baron von Mueller), at pp. 345-360 of Giles's "Australia Twice Traversed," vol. II. (1889).

Then we have "List of the plants obtained during Mr. *C.* Giles's travels in Australia in 1875 and 1876," by F. v. Mueller, *Journ. Bot.*, vol. XV., pp. 269-281, 300-6, 344-9.

Mueller's list was dated May, 1877, and he says, "The present index, as well as that issued in the volume on Mr. Giles's former expeditions, brings together, in a connected form, most of the plants now known from the more central regions of Australia." Some plants from other collections were also added.

In the title of this paper, and throughout it, the name *C.* Giles is given. It should be *E.* (Ernest) Giles. He had a brother C. (Christopher); hence the confusion is of some importance. I do not think Christopher explored, but *Pholidia Christophori*, F. v. M., was named after him. The following species were named after Ernest Giles:—

Cyperus Gilesii, Benth.; *Panicum Gilesii*, Benth.; *Eremophila Gilesii*, F. v. M.

For biographical details of Ernest Giles see, "Men of the Time in Australia" (Victorian Series, 2nd Edn., 1882), p. liii., 69, largely repeated in "Mennell," p. 183.

FORREST.—Forrest, John (Hon. Sir, K.C.M.G.), was born August 22nd, 1847. Formerly Premier of Western Australia and now Treasurer in the Federal Government.

Author of "Explorations in Australia" (London, 1875). Part II. is "From Perth to Adelaide." The second exploration was from Perth round the Great Bight to Adelaide, a journey (in the reverse direction) for the greater part traversed by Eyre 30 years previously.

Mr. (now Sir) John Forrest always endeavored to collect botanical specimens. These were determined by Mueller, and a list of some of them is given at pp. 325–7 of his work.

For biographical details see "Mennell," p. 171.

The collections of the Rev. H. Kempe on the Finke River are referred to at p. 187.

WINNECKE.—In Proc. R.S., S.A., VIII., 10 (December 14th, 1884), is a list of plants by Mueller, collected by Charles Winnecke in Central Australia between lat. 22° 30′ and 28° S. and long. 136° 30′ and 139° 30′ E. during his 1883 expedition. It was originally published in Winnecke's official report, but has received corrections by the author.

See also South Australian Parliamentary Paper No. 39 of 1884 ("Explorations, Northern Interior, 1883").

In Proc. R.S., S.A., VIII., 160, Mueller published a list of species collected by Winnecke near Stuart's Range in 1885.

Winnecke was also leader of the Horn Expedition of 1894.

Triumfetta Winneckeana, F. v. M., was named after him.

TIETKENS.—" Journal of the Central Australian Exploring Expedition, 1889," under command of W. H. Tietkens. Government Printer, Adelaide, 1891.

This expedition went westerly from Alice Springs, passed the South Australian border and encircled Lake Macdonald, Western Australia; then went south-easterly, *via* Lake Amadeus, to the vicinity of Charlotte Waters.

The journal contains a valuable " List of plants collected during Mr. Tietkens's Expedition into Central Australia," by Mueller and Tate (from Proc. R.S., S.A., vol. 13, p. 94, 1890). Tietkens thus traversed the northern part of the Larapintine region and added 58 species, including five new to science, to the Larapintine flora.

The results of this expedition were also published in the following form :—

" List of Plants collected during Mr. Tietkens's Expedition into Central Australia, 1889," by Mueller and Tate, Proc. R.S., S.A., XIII., 94–109. This was a collection of 250 species, eight being new to science, together with a number of new records for the South Australian flora.

Under the title " Supplemental Notes to the List of Plants collected in Central Australia," Mueller, *ibid*, pp. 170–1, has interesting notes on four species.

For some particulars of the life of this meritorious explorer, who has for some years been in the Public Service of New South Wales, see *Public Service Journal*, Sydney, 1906.

HELMS.—" Journal of the Elder Scientific Exploring Expedition, 1891–2," under the command of D. Lindsay. Government Printer, Adelaide, 1893, p. 207, and two large maps.

A summary of the work done is given at page 12. The expedition traversed a considerable area of country in South Australia, continuing the exploration into West Australia. The notes and the maps give useful information concerning the vegetation. R. Helms was the botanical collector. The botany was worked out as follows :—

Lichenes, J. Mueller, Proc. R.S., S.A., XVI., 142–9 (reprinted from *Hedwigia*, Heft 5, 1892); fungi, M. C. Cooke, *ibid*, p. 150; characeæ, Dr. Nordstedt, *ibid*, p. 150; phanerogams and vascular cryptogams, Mueller and Tate, *ibid*, 333–83.

TATE.—" Journal of the Horn Scientific Exploring Expedition, 1894," by C. Winnecke, together with maps and plans and report of the Physical Geography of Central Australia, by Professor R. Tate and J. A. Watt. Government Printer, Adelaide, 1897.

This journal contains a number of useful references to the vegetation.

Of the botanical results of this expedition I will speak in some detail. See page 186.

IV.—BIOGRAPHICAL NOTES.

Let me suggest to you that four names stand out pre-eminently in the botanical history of South Australia—Robert Brown, George Bentham, Ferdinand von Mueller, and Ralph Tate. I believe that their work will endure as long as the flora of the southern State has devotees; at the same time, few scientific men are worthier than they of an important national memorial. The community is small, and she has produced many distinguished men. When the time comes for national memorials let not the claims of the grandmasters of the gentle science of botany be ignored.

Following are some brief biographical notes of men who have advanced South Australian botany. They are arranged in alphabetical order and supplement other references to their work. It is our duty to collect biographical details in regard to botanical workers. Apart from the value based on sentiment, they are indispensable to an adequate knowledge of the flora.

Angas, George French.—Author of "South Australia Illustrated." London, 1847, fol. Sixty beautiful colored plates, of which Nos. 2 and 55 depict the flora, viz., Grass-trees (*Xanthorrhoea*) at Yankallilah; botany, native flowers.

Eldest son of George Fife Angas, born at Newcastle-on-Tyne, England. In September, 1843, left London on an art tour through Australia and New Zealand, and the above work was a product of this tour. He also published "Savage Life and Scenes in Australia and New Zealand," 1847, 2 vols., post 8vo. He returned to South Australia, where he was resident when his father went out in 1850. He died in London, October, 1886.

Backhouse, James, born July 8th, 1794, died at York, England, January 20th, 1869, was a member of a distinguished firm of nurserymen at York. He was a Quaker of strong religious convictions, and conceived the idea of visiting Australia, Norfolk Island, South Africa, and other parts of the world as a missionary. His reports on his religious pilgrimage were voluminous and contain many valuable observations on the botany of the countries visited, for he was a sound botanist.

See "A Narrative of a Visit to the Australian Colonies," London, 1843.

Chapter XLIII. of this work is almost entirely devoted to a visit to South Australia in November–December, 1837. At pp. 510–11 are notes on the plants of the Adelaide plains, also p. 515; pp. 519–20 give notes on a visit near to Mount Lofty.

See also "Extracts from the letters of James Backhouse when engaged in a religious visit in Australia, accompanied by George Washington Walker." Fifth part, London, Harvey and Darton, 1839, pp. 13–23 refer to South Australia.

There is a valuable account of his life in *Journ. Bot.*, VII., 5 (1869), from the pen of J. G. Baker, of Kew. See also "Mennell," p. 21; Britten and Boulger (c), p. 8.

Hooker dedicated the Australian myrtaceous genus *Backhousia* to him, while the following species were called after him :—

Correa Backhousiana, Hook. = *C. speciosa*. Ait., var., *Backhousiana*; *Helichrysum Backhousii*, F. v. M.; *Ozothamnus Backhousii*, Hook. f. = *Helichrysum Backhousii*, *F.* v. M.; *Wilsonia Backhousii*, Hook. f.; *Beyeria Backhousii*, Hook. f. = *B. opaca*, F. v. M.; *Octoclinis Backhousii*, Hill = ?; *Blandfordia Backhousii*, Lindl. = *B. marginata*, Herb.

Baxter, William, was in Kangaroo Island in 1823, and there is a plate of *Correa pulchella* in Sweet's "Flora Australasica" grown in 1824 from his seed. This is the only part of South Australia he visited. There is no doubt the *Eucalyptus santalifolia*, var. (?) *Baxteri*, Benth. (B. Fl., iii., 207) was collected by him in Kangaroo Island. He was a well-known collector, and collected for the Sydney Botanic Garden and also for private firms. His collections of West Australian plants are best known, and therefore I propose to reserve biographical details of him for my list of Western Australian botanists.

Behr, Hermann H.—A medical man, long resident in South Australia. He collected many plants, especially in the fourth and fifth decades of the nineteenth century. He described plants with Mueller and Miquel (*e.g.*, *Eucalyptus odorata*), but as a rule his plants were described by Schlechtendal, in *Linnea*, and by Mueller.

He contributed a paper on the character of the South Australian flora to vol. XX. of *Linnea*. See p. 180.

He left for California, and in 1884 published a "Synopsis of the Genera of Vascular Plants of San Francisco." (8vo., San Francisco.)

He died a few years ago.

The following species were named after him, and offer clues to the collections and collecting places of a worthy South Australian citizen, of whom few biographical details appear to be available :—

Abutilon Behrianum, F. v. M. = *A. Avicennae*, Gaertn.; *Cryptandra Behriana*, Reiss. = *C. tomentosa*, Lindl.; *Lasiopetalum Behrii*, F. v. M.; *Lavatera Behriana*, Schlecht. = *L. plebeia*, Sims; *Malva Behriana*, Schlecht. = *Lavatera plebeia*, Sims; *Trymalium Behrii*, Reiss. = *Spyridium subochreatum*, Reissek; *Acæna Behriana*, Schlecht. = *A. ovina*, A. Cunn.; *Loudonia Behrii*, Schlecht.; *Argyrophanes Behrii*, Schlecht. = *Helichrysum Baxteri*, A. Cunn.; *Aster Behrii*, Schlecht. = *Vittadinia australis*, A. Rich.; *Baeckea Behrii*, F. v. M.; *Calythrix Behriana*, Schlecht. = *C. tetradonta*, Labill.; *Camphoromyrtus Behrii*, Schlecht. = *Baeckea Behrii*, F. v. M.; *Chrysocephalum Behrianum* Sond. = *Helichrysum Baxteri*, A. Cunn.; *Eriochlamys Behrii*, Sond. and Muell.; *Eucalyptus Behriana*, F. v. M.; *Senecio Behrianus*, Sond. et F. v. M.; *Halgania Behriana*, F. v. M. = *H. littoralis*, Gaud. var.

(c) Britten, James, and Boulger, G. S. "A Biographical Index of British and Irish Botanists." (1893.)

glabrifolia; *Pentataphrus Behrii*, Schlecht. = *Astroloma conostephioides*, F. v. M.; *Eremophila Behriana*, F. v. M. = *Pholidia Behriana*. F. v. M.; *Grevillea Behrii*, Schlecht. = G. *ilicifolia*, Br.; *Pholidia Behriana*, F. v. M.; *Prostanthera Behriana*, Schlecht.: *Caladenia Behrii*, Schlecht. = ?; *Diuris Behrii*, Schlecht. = *D. pedunculata*, R. Br.; *Pimelea Behrii*, Schlecht. = *P. octophylla*, R. Br.; *Aristida Behriana*, F. v. M.

Bentham, George (1800-1883), one of the greatest systematists of his age. When it is stated that he was the author of the "Flora Australiensis," it is at once obvious that South Australians owe him a great debt of gratitude.

Brown, John Ednie, Conservator of Forests of this State from 1879-1890, and afterwards Director-General of Forests of New South Wales (1890-2), was the author of "A Practical Treatise on Tree Culture in South Australia" (Government Printer, Adelaide, 1881), and also of "The Forest Flora of South Australia," being nine parts of a colored demy work, each plate depicting a tree or shrub indigenous to the State. He was born in Scotland in 1848, and died in Perth, Western Australia, in 1899, of which State he had been Conservator of Forests since 1895.

De Mole, Miss F. E., author of "Wild Flowers of South Australia." Twenty plates. Adelaide, 1861.

Dutton, Francis Staker.—Under *Eremophila Duttoni*, F. v. M., Pl. Babbage Exped. 16, Mueller says. "This magnificent plant bears the name of the Hon. Francis Staker Dutton, the Minister under whom the South Australian Exploration Expedition was fitted out," &c.

Then we have a paper by Mueller, "On *Duttonia*, a new genus of *Myoporinæ* from South Australia," the species being *D. gibbifolia* (with a plate), from Mount Barker Creek, South Australia (Hooker's *Journ. Bot.*, vol. VIII., p. 73, 1856).

Mr. Dutton is styled "a good South Australian collector," and is included in Hooker's list.(*d*)

Francis, George W.—Born in England, 1799; died in Adelaide, August 9th, 1865. Emigrated to South Australia in 1849. He leased the old Botanic Garden, north of the Torrens, and was ultimately (in 1855) appointed Director by the Government, a post he held until his death. Author of "Catalogue of Plants Under Cultivation in the Government Botanic Garden, Adelaide, South Australia." Adelaide, 1859.

"Poison Plants," *The Farm and Garden*, vol. IV., pp. 83-101. (1861-2).

"The Acclimatisation of Harmless, Useful, Interesting, and Ornamental Animals and Plants." Read before Philos. Soc. Adelaide, Adelaide, 1862.

(*d*) "Introd. Essay to Flora of Tasmania," LV

An obelisk was erected in the Botanic Garden, Adelaide, to his memory. A portrait of him is in the Museum of the same garden.

Calocephalus Francisii, Benth.; *Pachysurus Francisii*, F. v. M. = *Calocephalus Francisii*, Benth.; *Hakea Francisiana*, F. v. M. = ? were named in his honor.

Heuzenroeder, Heinrich.—Born at Duderstadt, Hanover, Germany, August 17th, 1820; died November 12th, 1898, at Collinswood, North Walkerville, South Australia. He came out in the same ship to Australia, in 1847, with von Mueller, and collected botanical specimens for him in Kangaroo Island. See "Sealey."

His daughter, Miss L. H. Heuzenroeder, copied a label in Mueller's handwriting in the following words:—"*Heuzenroedera dysphanoides*, Ferd. Mueller. *Ad ripam fluminis Murray, armosam juxta*, Morunde, Febr. 1851."

Hillebrand, Dr. Wilhelm.—The following species were named after this collector:—

Eriostemon Hillebrandii, Muell. = *Phebalium bilobum*, Lindl.; *Veronica Hillebrandii*, F. v. M. = *V. distans.*, R. Br. "South Australian specimens have been distributed under the name of *Hillebrandia australasica*" (Mueller, Trans. Phil, Soc. Vict. I., 10.)

"The species received its name in appreciation of many services rendered by Dr. Will. Hillebrand for promoting the investigation of the South Australian flora" (Mueller Pl. Vict., I., 127). I have no further particulars concerning the gentleman.

Krichauff, F. E. H. W.—Born in Schleswig (then Denmark, now Germany), December 18th, 1824; died in Adelaide, October 29th, 1904.

He served an apprenticeship of three years in the Botanic Gardens of the University of Kiel, Germany (then Denmark). As the result of certain examinations, he was allowed a stipend by the Danish Government to travel as gardener and botanist, but the war of 1848 took away that privilege. He came to South Australia in 1848, and settled at Bugle Ranges. He and the late Baron von Mueller were lifelong friends. Mueller collected many specimens at Bugle Ranges. Mr. Krichauff took the liveliest interest in forestry matters, and was for many years chairman of the Central Agricultural Bureau of South Australia. He always took the greatest interest in the botanical development of South Australia, and often collected for Mueller.

Hibiscus Krichauffianus, F. v. M., is named after him. For biographical notices see "Mennell," p. 263, and *S.A. Journ. Agric.*, October 1st, 1904, p. 137.

Leschenault de la Tour, Louis Theodore, was botanist to Baudin's Expedition.

He joined the *Naturaliste* at Timor, October 7th, 1801; joined the *Géographe* at Port Jackson November 3rd, 1802, and was left sick at Timor June 2nd, 1803.

He was born November 13th, 1773, at Chalons-sur-Sâone, France, and died at Paris, March 14th, 1826. Besides his long voyage of circumnavigation (1800-7), in which he visited Australia, Timor, Java, etc., from 1816-22 he visited India, Bourbon, Cape of Good Hope, &c. In 1823-4 he visited Brazil and British Guiana.

His name is commemorated by *Leschenaultia*, R. Br., a genus of *Goodeniaceæ*, which includes *Latouria*, De Vriese, also named after Leschenault.

Species named after him include—

Hemistemma Leschenaultii, DC. = *Beyeria Leschenaultii*, Baill.= *Beyeria opaca*, F. v. M.; *Indigofera Leschenaultii*, DC. = ?; *Calythrix Leschenaultii*, Schau.; *Beyeria Leschenaultii*, Baill. = *B. opaca*, F. v. M.

[Anselme Riedlé was head gardener (jardinier-en-chef) in Baudin's Expedition. He died at Timor, October 21st, 1801. *Cycas Riedleyi*, Gaudich. (= *Macrozamia Fraseri*, Miq.), was named after him.

Antoine Sautier was gardener (garçon jardinier) of this expedition, and died at sea, November 15th, 1801.

Antoine Guichenot was also gardener. I have no further details concerning him.]

SCHOMBURGK, RICHARD.—Born at Fribault, Saxony, 1811; died at Adelaide, 1890. Portrait in the Museum of the Botanic Garden, Adelaide.

He was from 1865 Director of the Botanic Garden of Adelaide, and did much to bring them to their present fine condition. He concerned himself little with pure botany, but wrote several papers and larger works on economic botany. There is a list of some of his works in "Gill's Bibliography," p. 40. Others not mentioned therein are—"Tobacco Culture" (Adelaide), 1872. 8vo. "Papers read (chiefly on Economic Botany)," Adelaide, 1873. 8vo. "The Grasses and Fodder Plants . . . . in South Australia" (Adelaide), 1873, 8vo. (Another issue), *ibid.*, 1874. 8vo. "On the Grasses and Fodder Plants of South Australia" (supplement *South Australian Gazette*, January 15th), Adelaide, 1874. 4to. "The Flora of South Australia" (from the "Handbook of South Australia"), Adelaide, 1875. 8vo. "Botanical Reminiscences of British Guiana," Adelaide, 1876. 8vo.

"On the Urari: the deadly arrow-poison of the Macusis, an Indian tribe in British Guiana," Adelaide, 1879. 4to.

For biographical references see "Mennell," p. 404.

SEALEY (? Sealy), EDMUND GREY.—Younger son of John Sealy, of Bridgewater (? South Australia); lived from 1861–63 at Hugh's Wells, Sandergrove, near Strathalbyn, South Australia, and died October 31st, 1864, *aet.*, 41.

"For nearly half a century from the date of the visit of the second of the two memorable expeditions Kangaroo Island was unvisited by any collector or scientific observer. Between the years 1849–51, Messrs. E. G. Sealey, Bannier, and Henry Huezenroeder went at different times to Kangaroo Island, and it was on the special solicitations of Baron Sir (then Dr.) F. von Mueller that they brought back plants. Forty-four species, previously unrecorded, were brought to notice by them, though in the 'Flora Australiensis' the credit is inadvertently given to Baron Mueller, who had never visited the island, but by whom the species were transmitted to Mr. Bentham." (Tate in Proc. R.S., S.A., VI. (1882–5), p. 132).

Parlatore (DC. Prod. XVI. (2), 447) notes Cypress Pine from "Sealey" from Cape Willoughby and Pink Bay, Kangaroo Island.

TATE, RALPH.—He was born at Alnwick, Northumberland, in March, 1840, and died in Adelaide, September 20th, 1901.

His first contribution to botanical science was "Flora belfastiensis; the plants around Belfast, &c." Belfast, 1863, 16mo.

In *Journ. Bot.*, iii., 263, *re* his Shetland Islands expedition, he is spoken of as "a member of a commission appointed by the Anthropological Society."

Then we have a paper "Upon the Flora of the Shetland Isles," by Ralph Tate, secretary to the Shetland Anthropological Commission, *Journ. Bot.*, iv., 2-15 (Jan., 1866). We have in this early paper evidence of the author's capacity for comparing floras and taking comprehensive views. Another paper on "A New Variety of *Andromeda polifolia*" will be found in the same volume, page 377.

Professor Tate came out to Australia in 1875 as the first occupant of the Elder Chair of Natural Science in the University of Adelaide, and thereafter actively labored to advance a knowledge of the flora, fauna, and geology, primarily of South Australia, but leading up to the consideration of questions of an Australian or Australasian character. In addition to an extensive series of papers comprised in the 25 published volumes of the Transactions of the Royal Society of South Australia, Professor Tate also contributed others, at some time or other, to almost every scientific society in Australia. Special mention may be made of his Presidential Address to this Section at the first Sydney meeting of 1888, in which he proposed a threefold division of the endemic Australian flora according to subregions; also of his Presidential Address to the Association at the Adelaide meeting of 1893, in which he treated of a century's geological progress in Australia. Professor Tate was a member of the Horn Scientific Expedition to Central Australia in 1894, and an important contributor to the botanical, conchological, and geological sections of the published results of that great undertaking. He was also the author of a "Handbook of the Flora of Extra-tropical South Australia," published in 1890.

I do not propose at this place to give an enumeration of his botanical works; I have done so in another part of this address.

Ralph Tate was one of the fast disappearing school of natural history students who took up more than one branch of natural history. In the old days universities styled their chairs "Natural History," and required the occupants of them to teach botany, zoology, and geology. The fields of science have so broadened that it is impossible for one man to do justice to three such vast subjects at the present day. Tate was a sound botanist; I believe he was a good zoologist (especially in conchology); he was a palæontologist and geologist also.

Tate possessed the critical faculty in a very high degree; he was also gifted with the power of philosophic generalisation. For many years he was incomparably the most distinguished botanist in South Australia, and I hope that one result of this paper will be to show the depth and breadth of South Australia's indebtedness to the great naturalist whose genial presence we no longer enjoy at these gatherings.

He largely added to, by original research, the plants found in South Australia. He purified records by means of his critical faculty which led him to examine all things, while he consolidated the flora as lawyers do the statutes of a country. In a word, if one requires accurate information in regard to the flora of South Australia, one turns to Tate as a matter of course. Tate has an indelible memorial in his botanical work in South Australia; at the same time, it would be a graceful act to commemorate him, say, by a complete edition of his works, a medal, or mural tablet or statue. Although the memory of Tate can never die so long as botany is studied in South Australia, the living may honor themselves by doing honor to the memory of a brilliant Australian. And may I remind you that the memorials to Australian scientific men are very few.

Mueller dedicated the genus *Tatea* to him, also *Xanthorrhœa Tateana.*

WATERHOUSE, F. G.—He was a zoologist and Curator of the Adelaide Museum.

"He was sent in 1861 by the South Australian Government to search for insects and other zoological objects, and as a result of bye-work, about a hundred species of plants were collected, which passed into the hands of Baron F. von Mueller, by whom the novelties were specially dealt with in vol. IV. of his *Fragmenta Phytographiæ.* Five species new to science were the chief results of Mr. Waterhouse's labors, and 83 species-names added to the list of the local flora. Mr. Waterhouse had his headquarters on the Cygnet River, at a few miles from Kingscote, and spent there the spring and summer months. His collection of plants was gathered chiefly from the wooded banks of the river and the heath-ground adjacent thereto." (Tate in Proc. R.S., S.A., VI. (1882–3), p. 133).

See also his work, "Features and Productions of Country on Stuart's Track Across Australia. Report on Fauna and Flora, Natural History, and Physical Features of Australia on the line of J. McDouall Stuart's Route Across that Continent from the South to the North Coast." (South Australian Parliamentary Paper No. 125 of 1863.)

The following species commemorates his name:—*Spyridium Waterhousii,* Muell. = *Stenanthemum Waterhousii,* Benth.

WHITTAKER.—" Who has sent valuable collections from Port Adelaide " (e)

I regret I have no biographical details concerning him. (Was he a resident of Robe ?)

Drosera Whittakeri, Planch. was named in his honor.

WILHELMI, CARL.—" Notes on some edible and useful Australian plants in a letter from Mr. Carl Wilhelmi, of the Botanic Gardens, Melbourne, Victoria, from a letter addressed to the editor of the *Argus*, Melbourne." (Hook., *Journ. Bot.* IX., 265, 1857.) The letter is dated April, 1857. He refers to his travels in Port Lincoln in 1851 and 1854.

He was Acting Director of the Botanic Gardens, Melbourne, during Mueller's absence on the North Australian Expedition (1855–6).

He was assistant in the Melbourne Herbarium as late as 1864.

He wrote an important paper entitled " Manners and Customs of the Australian Natives, in particular of the Port Lincoln district " (Trans. Roy. Soc. Vic., 1860, 164–203). His collections from the Port Lincoln district, where he acted as Assistant Protector of the Aborigines, are often referred to in the " Flora Australiensis."

The biographical details known to me are very sparse. He was a native of Dresden, Germany, and he returned to that city about 1864, where he kept a seed shop. He was alive in 1872, but he died since ; I do not know in what year.

The following species bear his name :—

Lasiopetalum Wilhelmi, F. v. M. = *L. dasyphyllum*, Sieb. ; *Acacia Wilhelmsiana*, F. v. M. = *A. calamifolia*, Sweet, var. *Wilhelmsiana* ; *Verticordia Wilhelmii*, F. v. M.

WOODS, TENISON, J. E.—The Rev. Julian Edmund Tenison-Woods was born in London November 15th, 1832, and he died in Sydney, October 7th, 1889. He arrived in Tasmania in 1855, and was ordained priest in Adelaide in 1857. He does not seem to have contributed botanical papers to the Philosophical Institute of Adelaide or Royal Society of South Australia, although he communicated important papers to both of them. Yet this naturalist, in the widest sense, possessed a considerable knowledge of Australian botany, and, as far as South Australian is concerned he contributed many specimens from the Tatiara country, which are referred to in the " Flora Australiensis."

For a number of years, although he travelled a good deal, his headquarters were in Sydney, and I had the honor of his acquaintance, and often noted the breadth of his knowledge of the Australian flora. He certainly advanced South Australian botany.

There is an excellent sketch of his life and bibliography of his works in Proc. Linn. Soc., N.S.W. (2) IV., 1301–9. See also " Mennell," p. 521 ; Britten and Boulger, p. 185.

Leucopogon Woodsii, F. v. M., and *Angophora Woodsiana*, Bail., are named after him.

(e) Hooker, " Introd. Essay Fl. Tas."

My biographical notes deal with those botanists who have passed away from us. Of living South Australian botanists I will simply enumerate the following, who are doing good work and who are valued correspondents of mine :—

Otto Tepper, whose papers will be referred to in detail in this address; Samuel Dixon, the well-known authority on the fodder value of South Australian indigenous plants; Walter Gill, Conservator of Forests, Adelaide, a sound dendrologist, who has done so much to spread a knowledge of the trees of his own State; Dr. F. S. Rogers, a distinguished authority on the orchids of South Australia; J. M. Black, a well-known critical botanist, who studies both the introduced and endemic flora of this State; and Max Koch, an admirable collector, who, by his work at Mount Lyndhurst in particular, has advanced the botany of the northern area.

V.—DEFINITIONS OF PLANT REGIONS OF SOUTH AUSTRALIA.

It is interesting to trace the evolution of generalisations in regard to the botanical areas of South Australia. To satisfactorily generalise about the flora of such a large territory requires extensive local knowledge and mature judgment. Nevertheless, the early observers made remarkably shrewd statements in regard to the classification of the territory with respect to the prevalent vegetation. This is a subject to which the late Professor Tate paid special attention, but extensive as were his local explorations, and sapient as were his generalisations, much requires yet to be done in working out details of the botanical map of South Australia, and co-ordinating them with botanical areas in the other States. For we must remember that plants ignore the political boundaries of the States, so that South Australian botanists are interested in the work of their brethren in the other States who are engaged in defining botanical areas.

Let us trace certain works in chronological order—

1. "On the character of the South Australian Flora in general," by Dr. H. Behr (translated from the German in Schlechtendal's *Linnæa*, Bd. XX., Heft 5, by Richard Kippist, Librarian, Linnean Society). (Hooker's *Journ. Bot.*, III., 129, 1851.)

Behr divides the flora of South Australia into grass-land and scrub.

"One variety of the grass-land is the pit-land (Bay of Biscay land)," consisting of undulating plains or gently inclined slopes, which resemble a sea suddenly frozen during the beating of the waves.

A second variety of the vegetation of the grass-land is afforded by the beds of rivers when dried up in summer.

The scrub differs from the above-described forms of vegetation by the utter want of a turf; its almost entire want of herbaceous plants is compensated by a profusion of bushes and small trees.

One variety of these forest districts is distinguished under the name of "pine forest." The "sand plains" are more evidently distinct from the true scrub.

He observes that there are only two seasons—a dry and a wet one. The principal plants of the various divisions referred to by the author are enumerated.

2. "The Flora of South Australia, displayed in its fundamental features and comparatively," by Dr. Ferdinand Mueller, of Adelaide. In a letter to R. Kippist, translated and communicated by Mr. Kippist. Read before Linn. Soc. December 7th, 1852. (Hook. *Journ. Bot.*, V., 65.)

A valuable review of the flora of South Australia as known at that time.

Hooker, in his introductory essay to the "Flora of Tasmania," p. lv., has a note "On the Flora of Countries around Spencer's Gulf." He notes the western genera which find their eastern limits in South Australia, the tropical element, the absence or rarity of *Proteaceæ* etc., and the prevalence of *Compositæ*, &c., as affording proofs of the tropical and desert character of the South Australian flora.

3. "The Flora of South Australia," by R. Schomburgk. 8vo., 64 pp. From the "Handbook of South Australia." Government Printer, Adelaide, 1875.

This was the first flora of the province. He divides the country into the scrub-land region, the grass-land region, the intra-tropical region, and gives a list of the naturalised plants of South Australia.

The list of species is mostly compiled from the "Flora Australiensis," vols. I.-VI.

4. "A Census of the Indigenous Flowering Plants and Ferns of Extra-tropical South Australia," by Ralph Tate. Read February 3rd, 1880. Proc. R.S. S.A., III. 46-90.)

The first scientific geographical flora of South Australia, compiled from the "Flora Australiensis," "Fragmenta," and Mueller's notes.

He proposes geo-botanical divisions of South Australia, which he defines. They are—

(*a*) Central Australian region.
 (1) Desert.
 (2) Central Australia.
(*b*) Murray Desert.
(*c*) South-East.
(*d*) South Australian region.

He enumerates 1,599 species.

"Supplement to a Census of the Indigenous Flowering Plants and Ferns of Extra-tropical South Australia," by R. Tate. (Proc. R.S., S.A., IV, 102-11.)

A large number of species is added to the preceding paper.

This was followed by "Additions to the Flora of South Australia." (Proc. R.S., S.A., 82-93, 1882.) The present paper adds 207 species, which made the enumerated flora then stand at 2,236 species.

Then we come to an address: "On the Influence of Physiographic Changes in the Distribution of Life in Australia," Ralph Tate. (Presidential address, Sec. D., Aust. Assoc. Adv. Science, I., 312-325, 1887). This is an address of special interest to the botanist.

Professor Tate indicated that the flora of Australia consists of the following constituent elements:—

1. "An immigrant portion, derived from at least two separate sources—
   (*a*) "Oriental, which is dominant in the littoral tracts of tropical Australia; but despite the large assemblage of Asiatic species, the Australian character is deeply impressed by numbers, specifically and individually, of *Eucalyptus*, *Grevillea*, Phyllodineous *Acacia*, and others.
   (*b*) "Andean (including also certain species of the cool and temperate regions of the North Hemisphere). For the most part this type of vegetation is restricted to the high mountains of Tasmania, Victoria, and New South Wales. The peculiarity of the Tasmanian flora is only in its Alpine types.
2. "An endemic portion, a localised type of which occupies the extreme south-west of the continent."

He divides the Australian endemic flora into three types, "to which, for convenience of reference, I apply distinctive names." See his plate XVIII.)

"1. Euronotian (lit. south-east wind), dominant in the south and east parts of the continent.

"2. Autochthonian (lit. of the original race), restricted to the south-west corner of Western Australia, and approximately coinciding with the rainfall limit of 20in.

"3. Eremian (lit. desert), dominant in the dry region, which has its centre in the Lake Eyre Basin. It corresponds with the saltbush country, and approximately coincides with the area having less than 10in. of rainfall per annum. It is bounded on the north and north-east by the Indio-Australian vegetation, on the east and south-east by the typical Euronotian flora, and on the extreme south-west by the Autochthonian."

He then proceeds to discuss the Euronotian and Autochthonian floras, but especially discusses the characteristics of the Eremian region.

This botanic region has its centre at Lake Eyre, where the average annual rainfall does not exceed 5in. But despite the high temperature and limited rainfall, the florula of the depressed country around Lake Eyre shows that it contains (at that date, 1887) no less than 368 species.

The total number of species catalogued for that portion of the Eremian region within extra-tropical South Australia is 813 (1887). He then notes the principal genera of endemic or exotic origin. Professor Tate points out that there cannot be a doubt that the Eremian flora occupies an excessively dry region, which is an impassable barrier to the interchange of Autochthonian and Euronotian types. He points out the high state of specific luxuriance in many of the Eremian genera.

The paper summarises the history of the Australian floras, viewed chronologically, and traces it from Cretaceous times.

"A Census of the Indigenous Flowering Plants and Vascular Cryptogams of Extra-tropical South Australia." Tate (Proc. R.S., S.A., XII., 67-128, 1888-9), with a map and definitions of Eremian and Euronotian regions and sub-divisions. The flora to date includes 101 orders, 553 genera, 1,935 species.

In 1890 Tate published his "Handbook of the Flora of Extra-tropical South Australia, containing the flowering plants and ferns" (Education Department, Adelaide. Small 8vo., pp. 303). It contains a key to the system of South Australian plants; a classified list of the native species, with annotations indicating their distribution within the province (with a map); explanation of specific names; index of the orders and genera, with explanation of the generic names. The whole forms an admirable condensed manual, for which South Australian students cannot be too grateful to the author's memory.

He divides the State into the Eremian and the Euronotian regions, and defines them in the following terms:—

1. The Eremian or desert flora, which occupies the arid region of Central Australia, and corresponds with the "saltbush country" of the pastoralist. The region is approximately limited by the rainfall line of 10in.
2. The Euronotian flora, which is dominant in the more humid parts of temperate Australia, excepting the extreme south-west.

He then divides the Eremian region into five districts, and the Euronotian into seven, for particulars of which my audience is referred to the handbook.

5. "Report on the work of the Horn Scientific Expedition to Central Australia."

Part I.: Introduction, narrative, summary of results, supplement to Zoological Report, map; September, 1896. Part III.: (*f*) Geology and botany; March, 1896. Both edited by W. Baldwin Spencer.

This work gives a better and more scientific account of Central Australia than any other I know. The narrative is written in the simplest language, and the whole work is a charming addition to any Australian scientific library.

It is a report of detailed scientific exploration of the country in the vicinity of the Macdonnell Ranges, and it is indispensable to the botanist.

Pages 1-136 of Part I. are taken up with "Through Larapinta Land" (by Professor Spencer); a narrative of the expedition. "The Great Finke Basin, which, adapting the native name of the river, may be spoken of as Larapinta Land."

(*f*) Part II., Zoology, February, 1896; Part IV., Anthropology, September, 1896, do not further concern us on the present occasion.

The journey was over three types of country. They are defined as—

The Australian Steppes, subdivided into—
The Lower Steppes, and
The Higher Steppes, and
The Desert Country.

"It is usual to speak of the whole interior of Australia as a desert or Eremian country, but this name as applied to the whole area is very misleading."

We have the true desert, from the George Gill Range to Ayers Rock and Mount Olga.

Then "there is a vast tract of country comprising the great Lake Eyre basin, stretching from this eastwards and northwards into the interior of New South Wales and Queensland, and up to and beyond the Macdonnell Ranges, across which run such intermittent streams as the Cooper, the Warburton, the Macumba, the Finke, and the Todd, dry for the greater part of the year, but every now and then at varying intervals of time, swollen with heavy floods, which spread out over wide tracts, and for a time transform the whole country into a land covered with a luxuriant growth of vegetation. To this part of the continent the name of the 'Australian Steppes' may be suitably applied.

"Starting from Lake Eyre, and travelling northwards towards the centre of the continent, the traveller passes across a tract some 400 or 500 miles in width, which may again be divided into two districts, which may be called respectively the Lower Steppes and the Higher Steppes.

"The Lower Steppes extend over the area occupied by the great Cretaceous formation, with its alternating stony or gibber plains, loamy flats, and low-lying terraced hills, capped with desert sandstone. At Lake Eyre the land is 39ft. below sea level, and gradually rises to a height of 1,000ft. at its northern limit.

"The Higher Steppes are characterised by high ridges of Ordovician and Pre-Cambrian rocks, which stretch across the centre of the continent from east to west for some 400 miles. The average elevation of these Higher Steppes may be taken as about 2,000ft., and above them the higher peaks of the ridges rise for some 2,500ft. more."

I have quoted Professor Spencer at length, as it is very necessary to realise the topography, or rather the chorography, of the Lower and Higher Steppes and the desert country, in order to form an intelligent idea of the vegetation of Central Australia. We thus take a distinct step in advance of Professor Tate's gross classification of the whole of the northern part of South Australia as Eremian. The photographs are very helpful.

Chapter II. is devoted to the Lower Steppes (from Oodnadatta to Charlotte Waters and the Finke River).

In Chapter III. we have the Lower Steppes—from the Finke River to the James Range.

" The lines of the watercourses are marked by belts of gum trees and acacias: *Eucalyptus rostrata*, the river gum; *Eucalyptus microtheca*, the swamp gum; *Acacia aneura*, the mulga; *Acacia cyperophylla*, the red mulga, a very local tree extending across a narrow belt of country from east to west, a little way to the north of the Old Macumba Station; and the stinking acacia, *A. Cambagei*.

" On the loamy flats, and even gibber plains, the most noticeable plant is *Salsola Kali*, popularly known as the roly-poly. It is, when mature, one of the characteristic prickly plants of the Lower Steppes, and forms great spherical masses perhaps a yard or more in diameter. It is a constant feature of the Cretaceous area, and gradually disappeared as we passed northwards into the Silurian district.

" The thin, poor scrub is made up largely of *Cassias*, *Eremophilas*, *Hakeas*, and *Grevilleas*, all thinly scattered about, and with hard, spiny, or coriaceous leaves. Now and again, especially on the upland stony plains, were patches of saltbush (*Atriplex rhagodioides*), the foliage of which has the characteristic and well-known blue-grey tint, caused by the presence of a 'mealy' secretion on the leaves, which is probably of service in checking too rapid evaporation. The ground is not like that which one is accustomed to in moister parts; tussocks of grass, such as *Spinifex paradoxus*, are scattered about, with little plants of the red-stemmed and poisonous *Euphorbia Drummondii*, or of one or two species of Ptilotus (*P. exaltatus* and *incanus*), but they are not crowded together, and you can count the separate plants. It was not at all unusual to see a small patch of ground occupied entirely by a colony of one species of a plant such as *Ptilotus*. Along by the river flats the clusters of red fruit of the Darling or Murray lily (*g*) were frequently seen, whilst in the wet season its white flowers are a striking feature along the Stevenson Valley."

Valuable notes on the Lower Steppes plants will be found at pp. 15, 16, 28, 29, 33, 38, 46, 47, 49, 57, 59.

Then we take the Higher Steppes, the southern part of the James Range and the George Gill and Levi ranges (Chap. IV.), while Chap. VI. deals with the Macdonnell Ranges portion of the Higher Steppes.

For botanical notes of the Higher Steppes see pp. 67, 74, 75, 77 (Cycads, *Encephalartos MacDonnelli*). For the botany of the Macdonnell Ranges see pages 106 (*Styphelia Mitchelli*, the only Epacrid found on the expedition), 114 (charming scenes of cycads and palms, *Livistona Mariæ*), 119 (*Melaleuca*, *Ficus*, *Capparis*, *Grevillea*, *Loranthus*, *Hibbertia*), 121 (here Hermannsburg, see Rev. H. Kempe, p. 187), with the usual scrub of mallee gum (principally *Eucalyptus oleosa*), mulga, *Cassias* and *Eremophilas*, with occasionally very fine specimens, up to 40ft. or 50ft., of *Acacia salicina*. At page 125, vicinity of Parsley Bluff, *Eucalyptus terminalis*, a species of *Melaleuca* (40ft.), *Cassia glutinosa* and *Grevillea agrifolia*.

Chapter V. is devoted to the desert country. At page 81 we note "a fine sandhill gum, *Eucalyptus eudesmoides*, which reached a height of 50ft. to 80ft." The pituri plant, *Duboisia moyporoides*, grows here.

(*g*) This is an Amaryllid plant, *Crinum flaccidum*.

At page 84 we have the so-called "Spinifex," but more correctly the "Porcupine Grass" (*Triodia*). On the rocks (p. 83), *Ficus*, *Acacias*, and *Gastrolobium* grew. Round the base fine trees of *Acacia salicina*, with kangaroo grass 6ft. in height.

At page 98 is a new grass tree (*Xanthorrhoea Thorntoni*), and notes on *Swainsona canescens*, *Goodenia Horniana*, *Prostanthera*, *Eremophilas*, kurrajong, mallee gum, and *Acacia dictyophleba* are found at page 99.

Then we have a summary of the zoological, botanical, and geological results of the expedition, pp. 139-198, by Professor Spencer. The botanical summary, pp. 159-162, is valuable; see also the general conclusions at page 171.

"The list of plants recorded by Professor Tate numbers 614. Prior to the expedition the number described from the region was 502. The additions consist of eight new species; 16 species new for South Australia, and 112 species new to the region."

Tate's central Eremian district stretches south from about the latitude of Engoordina (Horseshoe Bend), on the Finke, and formed by the Cretaceous tableland. "The latter area is practically the same as that referred to in the narrative as the Lower Steppes, the Larapintine region being comprised within the Higher Steppes." (See also Tate's definitions of the boundaries of the Larapintine region as a botanical area at pp. 117-8).

Part III. includes a report on the botany of the expedition (pp. 117-194), by Professor Tate.

In the summary I have just referred to Professor Tate's work. To show the scope of his report, let me quote the table of contents:—

"Chapter I.—The Larapintine flora.

"1. General physiography and boundaries of the Larapintine region.

"2. Botanical characteristics.

(*a*) Introduction.

(*b*) Salient botanic features of the north Eremian region.

(*c*) The lowland vegetation.

(*d*) The saxatile vegetation.

"3. Origin of the flora.

"4. Previous explorations.

"5. Enumeration of the flowering plants and vascular cryptogams.

"6. Diagnoses of new genus and species.

"Chapter II.—The Central Eremian flora.

"1. Physiographic and botanic characteristics.

"2. List of plants new or rare in the region."

Professor Tate's report will not bear abridgment. It is a valuable record, not only of his own discoveries, but also of previous botanical collectors in the same region.

In fine, the report of the Horn Expedition is the latest and most comprehensive account of the flora of Central Australia. It is a classic, and may be referred to as the standard record of this region. It is useful to South Australians in a special manner, and I make no apology for insisting on its importance.

VI.—FLORULAS (*h*) FROM SPECIFIED LOCALITIES.

(*a*)—Eremian Region.

(*F.—C.—S.—W.—M.*).(*i*)

F. 1. "Plants Indigenous to the Neighborhood of Hermannsburg on the River Finke, Central Australia," by Rev. J. (should be H.) Kempe, missionary. Read October 5th, 1880. (Proc. R.S., S.A., III., 129–137.)

A list of nearly 162 species found in the vicinity of the Mission Station, supplemented with useful notes.

2. In the paper by the same author, with the same title (Proc. R.S., S.A., V. 19–23), 125 species are added, making a total of 287 collected from that district to date (February 7th, 1882).

3. "Descriptions of Two New Species of Plants." Baron von Mueller (Proc. R.S., S.A., IV., 112). *Calotis Kempei* and *Thysanotus exiliflorus*, both from the Macdonnell Ranges.

(The Rev. Hermann Kempe, Evangelical Lutheran minister at Balaklava, South Australia, was born March 26th, 1844, at Deuben, near Dresden, Saxony, Germany. Was theologically educated in the Missions Institute of Hermannsburg, Hanover, Germany, from which he was sent to South Australia to form a mission station on the River Finke, Central Australia. He arrived in Adelaide in 1875, and reached the mission station in 1877. He stayed on the Finke River for 16 years, and left owing to broken health. Mr. Kempe informs me that he sent 600 different plants to Mueller. *Acacia Kempeana*, F. v. M., was named after him.)

C. 1. Tate and Mueller record "List of Plant Species collected by Mr. J. C. Chandler in the neighborhood of Peake, Central Australia." (Proc. R.S., S.A., V., 95.)

2. "Plants of the Lake Eyre Basin." Tate (Proc. R.S., S.A., XI., 85–100).

3. "A list of Plants collected on Mount Lyndhurst Run, South Australia." Max Koch (Proc. R.S., S.A., XXII., 101–18).

A valuable list of plants collected over an area (Farina district) extending over 200 square miles. The plants were named by Professor Tate and myself.

4. At pp. 81–5, vol. XXIV., Mr. Koch publishes a supplementary list.

5. "On some New or Little-known South Australian Plants." Tate (Proc. R.S., S.A., XXII., 119–21). Based on Max Koch's collections. Includes *Corchorus longipes*, n.sp.; *Acacia papyrocarpa*, Benth.; *Helipterum microglossum*, Tate.

(*h*) The works referred to in the previous chapter have not been repeated.

(*i*) The nomenclature given in "Tate's Handbook," 1890, is here adopted. There do not appear to be papers specially dealing with S.

W. 1. "List of some Plants inhabiting the North-eastern Part of the Lake Torrens Basin." Tate (Proc. R.S., S.A., VI., 100–6).

2. "Caroona Hill (Lake Gilles)," by W. L. Cleland. (Proc. R.S., S.A., X., 74–9.)

Pages 78–9 contain a list of plants from the Gawler Ranges.

3. "The Vegetation of the Districts surrounding Lake Torrens, sketched by Dr. Ferdinand Müller, of Adelaide." Translated from the German by R. Kippist. Read at a meeting of the Linnean Society, December 21st, 1852. (Hook., *Journ. Bot.*, V., 105, 1853, sometimes quoted as "Hooker's Kew Miscellany.")

4. "Further Notes on the Botany of the Willochra Valley." Chas. F. Johncock (Proc. R.S., S.A., *ibid*, 31–7).

M. 1. "Notes on the Physical and Geological Features of the Basin of the Lower Murray River." Tate (Proc. R.S., S.A., VII., 24–46). "Leading botanical features," at pp. 44–6.

(*b.*)—Euronotian Region.

(*A.—N.—Y.—L.—K.—T.—G.*) (*j*)

A. 1. "Discovery of Tasmanian Plants near Adelaide, South Australia," J. G. O. Tepper. (*Journ. Linn. Soc.*, 72–82, 1882).

The paper includes a list of plants collected at Square Waterhole, county of Hindmarsh.

2. "Die Flora von Clarendon u. Umgegend (Sud-Australien)," von J. G. O. Tepper, 14 pp. (*Bot. Centralb.*, LXIII., 1895).

Y. 1. "On the Characteristics and Distribution of the Native and Naturalised Plants about Ardrossan, Yorke's Peninsula." Otto Tepper (Proc. R.S., S.A., III., 25).

A useful flora supplemented with geological and other notes.

2. At pages 175–9 Mr. Tepper publishes an important number of additions to his florula.

3. In a note (Proc. R.S., S.A., V., 113) Tepper recorded *Cladium trifidum*, F. v. M.; *Prasophyllum despectans*, J. Hook.; and *Drosera squamosa* (?) as new for South Australia

4. "On the geological and botanical features of southern Yorke Peninsula." Tate (Proc. R. S., S.A., XIII.). Sketch of the botanical features pp. 115–20.

"With the exception of the Warooka Ridge, the botany of which resembles that of the country on the north side, most of south Yorke Peninsula is covered with a dense mallee scrub, here and there with open glades; whilst on the exposed south-east area the country is more heath-like, the shrubs being much dwarfed." The total number of species observed is 235.

5. "Notes on the Characteristic Vegetation about Franklin Harbor" (Spencer's Gulf). Tate (Proc. R.S., S.A., IV., 135).

(*j*) There do not appear to be papers specially dealing with N and T.

L. 1. "The Vegetation of the Great Australian Bight." Mueller (*Journ. Bot.* IV., 120, 1866).

A brief paper giving a list of 26 plants collected by Mr. E. A. Delisser (surveyor), an explorer. See below, p. 199.

2. "The Natural History of the Country around the head of the Great Australian Bight." Tate, Trans. and Proc. Phil, Soc., Adel. (afterwards Roy. Soc. S.A.), 1878–9. Botany pp. 118–24. Includes a list of species of plants of the Bunda Plateau.

In the same volume (III.) of Proc. R.S., S.A., we have (at p. 171) a list of plants collected by Mrs. Richards, at Fowler's Bay.

3. "List of Plants unrecorded for Southern Eyre Peninsula." Tate, Proc. R.S., S.A., VI., 94–5. This is the Port Lincoln country.

4. "Additions to the Flora of the Port Lincoln District, including brief description of two new species." Tate (Proc. R.S., S.A., XI., 82–4).

Fifty-one species new for the district. *Commerconia Tatei*, F. v. M., and *Brachycome cuneifolia*, Tate, are new.

Kangaroo Island.

K. 1. "The Botany of Kangaroo Island." Tate (Proc. R.S., S.A., VI., 116–71) (131–71, Botany).

Botanical explorations.
Artificial influences modifying vegetation.
General botanical features.
  Correlation of the flora—
    Restricted species.
    Species of extra-Australian origin.
    Alien species.
    Inter-provincial relationships.
    Comparison of the flora with that of South Australia.
    Peculiarity of habit of some species.
    Comparative statistics.
    Conclusions respecting relationship of the flora.
    Catalogue of the flowering plants and ferns, with localities.

2. Botanical notes (Additions to the flora of South Australia, including Kangaroo Island) VII., 74–5.

3. "A Revision of the Flora of Kangaroo Island and other Botanical Notes relating thereto." Tate (Proc. R.S., S.A., XII., 62–6).

Criticising some items in Tepper's list (Proc. R.S., S.A., X., 288–92). Offering corrigenda of his own list and adding a number of species, which then stood at 513.

4. "Plants of Kangaroo Island." J. G. O. Tepper (Proc. R.S., S.A., VII., 50–3).

5. "Additions to the Flora of Kangaroo Island." J. G. O. Tepper (Proc. R.S., S.A., IX., 114–5).

6. "Notes on and Additions to the Flora of Kangaroo Island." J. G. O. Tepper (Proc. R.S., S.A., X., 288–92).

Adds 70 species, of which four are new to science. Notes on three of these plants are given at page 301.

(N.B.—Tepper's plants were named by Mueller as a rule).

7. " Plants of Kangaroo Island."

Twenty-eight plants are recorded by Mr. A. G. Campbell which are not recorded by Tate for the island (*Vict. Nat.*, June, 1906, page 54). But F. M. Reader (October, page 120) points out that *Bartlingia sessiliflora* and *Scirpus nodosa* have already been recorded.

G. 1. " A List of Unrecorded Plants and of New Localities for Rare Plants in the South-east part of this Colony." Tate (Proc. R.S., S.A., VI., 95–9).

2. " On the Flora of the Glenelg River." J. P. Eckert (Proc. A.A.A.S., V., 410, 1893). In abstract.

Adds eight species to the flora of South Australia.

VII.—DEFINITE GROUPS OF PLANTS.

In this chapter I arrange papers (not hitherto enumerated) according to the families of plants referred to.

CHENOPODIACEÆ.

" On a New Atriplex from South Australia " (*A. Kochiana* from Mount Lyndhurst). Maiden (Proc. R.S., S.A., XXI., 1897).

COMPOSITÆ.

" Diagnoses of a New Genus and Two Species of Compositæ from South Australia," by F. v. Mueller (Proc. R.S., S.A., VI., 31).

The new genus is *Achnophora*, from Kangaroo Island.

CRUCIFERÆ.

" Dimorphism in Two South Australian Cruciferous Plants." Tate (Proc. R.S., S.A., XXII., 122–4).

A study of *Geococcus pusillus*. I think this was Tate's last paper.

LORANTHACEÆ.

1. " Notes on the Loranthaceæ of the Willochra Valley." Chas. F. Johncock (Proc. R.S., S.A., XXVI., 7).

2. " Notes on *Loranthus Exocarpi*." Chas. F. Johncock (Proc. R.S., S.A., XXVII., 253–5).

MYOPORACEÆ.

" On a New Myoporum from South Australia " (*M. refractum*, from Mount Lyndhurst). J. H. Maiden and E. Betche (Proc. R.S., S.A., XXII., 76, 1898).

OROBANCHACEÆ.

" Note on *Orobanche cernua*, Benth. non Loefl." (Now *O. australiana*, F. v. M.). Tate (Proc. R.S., S.A., VI., 174).

RHAMNACEÆ.

"On a New Rhamnaceous Plant, South Australia" (*Trymalium Wayae*). Mueller and Tate (Proc. R.S., S.A., V., 80).

TILIACEÆ.

"Description of a New *Corchorus* from Central Australia" (*Corchorus Elderi*). Mueller (Proc. R.S., S.A., IX., 58–9).

ARACEÆ.

"An Aroid new for Australia" (*Amorphophallus campanulatus*, Blume., var. *australasica*, from Pine Creek, Northern Territory). Maiden (Proc. R.S., S.A., XXIX., 207, 1905).

AMARYLLIDEÆ.

"On a Winter-flowering State of *Hypoxis pusilla* (J. Hooker) and on the Differential Characters of that Species." Tate (Proc. R.S., S.A., V., 76–8). A useful paper embodying some patient morphological observations.

NAIADACEÆ.

1. "Some Observations on the Propagation of *Cymodocea antarctica*, Endl." J. G. O. Tepper (Proc. R.S., S.A., IV., 1–4, with plate). The paper also contains notes on *Posidonia*.

2. This is supplemented (pp. 47–9 of the same vol.) by "Further observations."

3. In Proc. R.S., S.A., V., 37–9, Professor P. Ascherson, of Berlin, corrects some of Mr. Tepper's explanation, as given in the preceding papers, and usefully supplements his paper.

ORCHIDEÆ.

1. "Notes on the Occurrence of *Eriochilus fimbriatus* in South Australia." Mueller (Proc. R.S., S.A., V., 94).

2. "Diagnosis of a New Species of *Caladenia*" (*C. cardiochila*). Tate (Proc. R.S., S.A., VIII., 60-1).

FUNGI.

1. "Australian Fungi, received principally from Baron F. von Mueller and Dr. R. Schomburgk." M. J. Berkeley (*Journ. Linn. Soc.*, Bot., XIII., p. 155, 1872).

Includes South Australian specimens, chiefly from Adelaide.

2. Tepper (Proc. R.S., S.A., VIII., 159) adds a list of 12 fungi to the list of Clarendon fungi enumerated by him in vol. VI., 68.

3. "Notes on Australian Fungi, collated by J. G. O. Tepper" (Proc. R.S., S.A., XII., 150–3). Named by Saccardo. The paper includes :—

(*a*) List of fungi, new or rare for South Australia.

(*b*) List of Australian Ustilagineæ, with description of and remarks about a new South Australian species.

(*c*) Additional species of Australian fungi.

"A useful list of references and translated extracts referring to South Australian species," in Proc. R.S., S.A., XIII., 238–42. Supplementing the lists in vol. XII., page 150 *et seq.*

4. "Contributions to the Fungal Flora of Australia," by Professor F. Ludwig, Greiz, Germany. Translated by J. G. O. Tepper (Proc. R.S., S.A., XIV., 55–60). Consists of "List of Australian Uredineæ," "List of Australian Ustilagineæ," "Parasitic enemies of Eucalyptus and Acacia," "On the position of Clathrus (*Ileodictyon*) Tepperianus, Ludw."

5. "List of fungi named by Dr. M. C. Cooke, from dried specimens collected near Lake Bonney by Miss Webb, and from colored drawings prepared by her."

Consists of 35 names.

"A list of the charas, mosses, liverworts, lichens, 'fungs,' and algals." Tate (Proc. R.S., S.A., IV., 5–24).

It is extracted from Mueller's *Fragmenta*, the characeæ being enumerated by Alex. Braun, the mosses by E. Hampe, the liverworts by C. M. Gottsche, the lichens by A. von Krempelhuber, the "fungs" by M. C. Cooke, the "algals" by W. O. Sonder. At that date South Australia was credited with seven characeæ, 36 mosses, six hepaticæ, 10 lichens, 86 fungi, and 273 seaweeds.

"Notes on the geographical distribution of Australian characeæ," Mueller, from diagnoses by Nordstedt. Some of the species from South Australia. (Proc. R.S., S.A., XII., 149).

VIII.—MISCELLANEOUS PAPERS.

An enumeration of papers which do not come under the previous headings. Arranged chronologically.

1. The "Miscellaneous Contributions to the Natural History of South Australia." Edited by Professor Tate, "Director of the Natural Science Correspondence Department" of the Roy. Soc. of S.A. (See Proc. R.S., S.A., IV., 135.) Show how desirous Tate was of diffusing a knowledge of the natural history of the province.

Here we have useful notes on *Orobanche cernua*, Loefl., *Aster* (?) *concephalus*, F. v. M., and notes on the characteristic vegetation about Franklin Harbor, as observed May 29th, June 3rd.

2. "Botanical Notes relating to South Australia." J. G. O. Tepper (Proc. R.S., S.A., VI., 65–8).

1. New localities of rare phanerogamous plants.
2. List of algæ and lichens new to South Australia.
3. List of new South Australian fungi.

3. "Diagnoses of some New Plants from South Australia." Mueller and Tate (Proc R.S., S.A., VI., 107).

Dimorphocoma (new genus), *Babbagia pentaptera* and *acroptera*, and *Loranthus Murrayi*.

4. "Additions to the Flora of South Australia." Tate (Proc. R.S., S.A., VI., 110–15).

5. "Descriptions of New Species of South Australian Plants." Tate (*Ibid*, 67–71). The species are :—*Sisymbrium procumbens, Kochia pentatropis, Pultenæa graveolens, viscidula, Hydrocotyle crassiuscula, Hakea Ednieana, Stipa Muelleri.*

6. "Additions to the Flora of Extra-tropical South Australia." Tate (*Ibid*, 72–3).

7. "Remarks on some Indigenous Shrubs of South Australia suitable for cultivation as Fodder," by Samuel Dixon. (Proc. R.S., S.A., VIII., 14–27). A valuable paper, based on accurate botanical observation and practical experience.

8. "Additions to the Flora of Extra-tropical South Australia, including descriptions of two new species." Tate (Proc. R.S., S.A., VIII., 71–2). The new species are *Dysphania simulans* (Mueller and Tate), from Lake Eyre, and *Loranthus gibberulus* (Tate), parasitic on *Grevillea nematophylla*, also from Lake Eyre. The records are in regard to five other species of various genera.

9. "Additions to the Extra-tropical Flora of South Australia." Tate (Proc, R.S., S.A., IX., 57–8).

10. "Additional South Australian Lichens and Fungi." Collected by Tepper, 1880–5. (*Ibid*, IX., 215).

11. "Descriptions of Two New Australian Plants." Mueller and Tate (Proc. R.S., S.A., X., 80–1).

Cheilanthes Clelandi, Caroona Hill, Gawler Ranges; *Newcastlia Dixoni*, Ral-ral on River Murray.

12. "Definitions of Four New Species of Australian Plants." Tate (Proc. R.S., S.A., XII., 129–31).

Cryptandra scabrida and *Schœnus discifer*, from Kangaroo Island; *Caladenia toxochila* and *C. tentaculata*, from Caroona Hill, Gawler Range.

13. In Proc. R.S., S.A., XIII., 236, Mr. H. Sutherland has a note entitled "Poisonous properties of *Euphorbia eremophila*,"

14. And Professor E. H. Rennie (*ibid*, p. 237) announces the presence of Æsculine in an infusion of the leaves of *Bursaria spinosa*, which accounts for the fluorescence noticed in the infusion.

15. "List of Eight New Species of Flowering Plants inhabiting Extra-tropical South Australia." Tate (Proc. R.S., S.A., XIII., 242).

16. "The Effects of Settlement and Pastoral Occupation in Australia upon the Indigenous Vegetation." Samuel Dixon (Proc. R.S., S.A., XV., 195–206).

17. "A supplement to a census of the flora of extra-tropical South Australia." Tate (Proc. R.S., S.A., XIX., 79–83). Valuable lists, both of *addenda* and *corrigenda*.

18. "Diagnoses of Four New Species of Plants from South Australia." Tate (Proc. R.S., S.A., XXIII., 288–92). Includes a valuable conspectus of South Australian *Zygophylla*.

IX.—NORTHERN TERRITORY. (*k*)

We now come to the Northern Territory, a political division of South Australia, which, so far as its botany is concerned, is divided by no sharp line of demarcation from its southern neighbor. At the same time it is convenient, although the division be arbitrary, to take special cognisance of botanical exploration in the Northern Territory.

At Port Darwin we have an interesting Botanical Garden, under the direction of Mr. Nicholas Holtze. It is not as well known as it should be, and I would suggest that here we have the nucleus of a valuable tropical garden, which can be modestly worked on the lines of Buitenzorg in Java, and Peradeniya in Ceylon, where Australian botanical students and visitors from other countries may study tropical Australian vegetation, and also tropical plants grown under Australian conditions. The support of it might well be made a federal matter, if necessary.

ALLAN CUNNINGHAM.—The first botanical exploration of any portion of the Northern Territory (and it was a coastal examination) was by Allan Cunningham, in Captain P. P. King's circumnavigation. The account of the expedition is contained in—

1. "Narrative of a Survey of the Intertropical and Western Coasts of Australia," performed between the years 1818 and 1822, by Captain P. P. King, F.R.S. 2 vols. 8vo. London, 1827.

He surveyed the intertropical and western coasts, and is valuable for Arnhem's Land, Melville Island, and other parts of the Northern Territory.

Since Allan Cunningham was the botanist of the expedition, the botanical results were important. He contributed to vol. II., pp. 497-533, "A few general remarks on the vegetation of certain coasts of Terra Australis, and more especially of its north-western shores."

Cunningham's plants exist in various herbaria, and they, with the above "remarks," should be studied by every botanist investigating the early botanical history of the Northern Territory.

LEICHHARDT.—1. "Journal of an Overland Expedition . . . . from Moreton Bay to Port Essington, during the years 1844-5," by Dr. Ludwig Leichhardt (1847.)

This journal is accompanied with three maps, and the third shows Leichhardt's exploration in the Northern Territory. Chapters XIII.-XV. chiefly refer to the Northern Territory, and contain much botanical information.

2. "Some Observations on Dr. Leichhardt's Overland Journey from Moreton Bay, on the East Coast of Australia, to Port Essington, on the North Coast," by R. Heward. (Hooker's *Lond. Journ. Bot.*, VI., 342, 1847).

(*k*) As already mentioned, the Northern Territory includes all the country north of 26° N. The Macdonnell Ranges, and much of the area already referred to, consequently falls within the Northern Territory. Under the present heading I have confined myself to country at no great distance from Port Darwin, the Victoria River, and the Gulf of Carpentaria.

A useful compendium of this journey, compiled from Leichhardt's lectures in Sydney on the subject. Prominence is given to his botanical explorations. It usefully supplements the previous work. (*l*)

MUELLER.—Then we come to an important series of papers, &c., by Mueller, referring to the botanical exploration accomplished by Gregory's expedition, of which Mueller was botanist.

1. Dr. Ferdinand Mueller and "The North Australian Expedition." (Hooker's *Journ. of Bot.*, VIII., 2, 1856.)

Roughly the design of the expedition was to explore the Northern Territory from the Victoria River, on the northern coast, to the head waters of the rivers flowing into the Gulf of Carpentaria.

This paper is chiefly taken up with two letters from Mueller to Sir William Hooker, in which he refers to his plans and expectations in regard to botanical work.

2. Note on the voyage of the North Australian Exploring Expedition from Sydney to the mouth of the Victoria River, extracted from a letter of Dr. Mueller (botanist to the expedition), dated on board *The Monarch*, September 3rd, 1855. (Hook. *Journ. Bot.*, VIII., 46.)

The portion of the letter referring to Northern Australia refers to a list of plants collected at Quail Island, and another at the entrance to the Victoria River (September 19th).

3. "North Australian Botany, Observations on, by Dr. *Frederick* (*sic*) Mueller, botanist to the North-West Australian Government Expedition, under the command of Mr. Surveyor Gregory." (Hook. *Journ. of Bot.*, VIII., 321.)

This is a letter from the main camp on the Victoria River, June 18th, 1856, addressed to Sir W. J. Hooker.

It is a valuable preliminary report of the botanical results of the expedition, and refers to about 800 species.

4. "*Nova genera et species aliquot rariores in plagis Australiæ intratropicis nuperrime detecta*," *exposuit* Dr. F. Mueller. (Hooker's *Journ. Bot.*, IX., 14, 1857.)

Latin descriptions of a large number of plants.

5. "Notes made during the Recent Expedition across the Northern Portion of Australia, under the command of Mr. Surveyor Gregory, by Dr. F. Mueller, Colonial Botanist of Melbourne, and Botanist to the Expedition." (Hooker's *Journ. Bot.*, IX., 165.)

This is a letter, dated Melbourne, January 14th, 1857: very interesting to every student of the flora of North Australia. Mueller estimated "the number of distinct plants, as collected within the intratropical zone of Australia" at 1,500 species, of which he believed 500 to be nondescript.

(*l*) John Macgillivray's "Narrative of the Voyage of H.M.S. *Rattlesnake*," commanded by . . . Capt. O. Stanley . . . . 1846-50 . . . . to which is added . . . "E. B. Kennedy's Expedition for the Exploration of the Cape York Peninsula," London, 1852, 2 vols., 8vo., may be referred to. Port Essington was visited amongst other places, and his specimens are now at Kew.

6. *Ibid*, page 193, we have a letter dated from the Sydney Botanic Gardens, March 6th, 1857.

A chatty letter on botanical matters, referring in part to the vegetation of the Northern Territory. Certain natural orders are discussed *seriatim*.

7. *Ibid*, page 225, Mueller continues his discussion of certain natural orders.

8. " On some new genera of Australian plants, discovered during the progress of the North Australian Exploring Expedition, by Dr. F. Mueller, Botanist to the Expedition, and Colonial Botanist at Victoria." (Hook. *Journ. Bot.*, IX., 302, 1857.)

Descriptions in Latin of certain new genera, not all from the Northern Territory.

9. " Botanical Report on the North Australian Expedition." (Proc. Linn. Soc., 1858.) I have not seen this work.

10. " North Australian Expedition: Letter from A. C. Gregory, Esq., Commander of the Expedition, dated Victoria River, June 14th, 1856." (Hooker's *Journ. Bot.*, IX., 201, 1857.)

(*b*) Second letter, dated Burnett district, December 2nd, 1856.

(*c*) Third letter, dated Sydney, January 7th, 1857 (*ibid.*, IX.,230).

All ordered by the Legislative Assembly of New South Wales to be printed.(*m*)

Then we come to Landsborough's Expedition of 1861-2.

Henne.—Diedrich Henne, who was born at Hanover, Germany, in 1834, was the botanical collector of Landsborough's expedition in search of Burke and Wills. He is the last survivor of the expedition, and lives in Sydney.

The following two works may be referred to:—

Landsborough (William)—" Journal of Landsborough's Expedition from Carpentaria in search of Burke and Wills." With a map showing the route. 8vo., pp. 128; Melbourne, 1862. At page 8, refers to " Mr. Hennie (Henne) the botanist." There are very few botanical notes. A few are given at page 115.

" Landsborough's Exploration of Australia from Carpentaria to Melbourne, with especial reference to the settlement of available country." Edited by James Stuart Laurie, formerly H.M. Inspector of Schools. With a chart and a systematic arrangement of Carpentarian plants, by F. Mueller, Ph. D., &c., 12mo., Lond., 1867.

The title of Mueller's contribution is " Plants noticed around the Gulf of Carpentaria, from the Roper to the Gilbert River, including those collected during Mr. Landsborough's Expedition." (*n*).

(*m*) A succinct account of the North Australian (A. C. Gregory) Expedition will be found in " An Historical Review of the Explorations of Australia." Mueller (Trans. Phil. Inst. Vic., Vol. II., pp. 160-3).

(*n*) Compare also " A Systematic Arrangement of the Plants Noticed Around the Gulf of Carpentaria from the Roper to the Gilbert River " (Mueller, Melbourne, 1862), which I have not seen.

The author says—

"At Mr. Landsborough's request I have extended this enumeration so far as to include all the plants observed by myself on the south-west, south, and south-east territories of the Gulf. For this purpose the corresponding notes were extracted from the yet unpublished diaries, kept by myself when accompanying Mr. Aug. Gregory in his North Australian Expedition during the years 1855 and 1856."

Mr. Henne has been good enough to give me the following particulars of his movements:—Sailed from Melbourne August 4th, 1861, in the colonial warship *Victoria*, Captain Norman. On September 6th arrived at the Sir Charles Hardy Islands. Landed at Bountiful Island September 27th; this island is merely a sandy patch, with very little vegetation. Established the main depot at Sweers Island, south of the Gulf of Carpentaria. Went in the tender *Firefly* to where the Albert River received a branch of the Norman River. Right up to here the country near the river was swampy and the shores densely overgrown with mangroves. A few miles inland a freshwater lagoon was found, and the vegetation improved. Mr. Henne collected all along the river and up country, not only herbarium specimens, but also fruits and timbers of about 30 kinds of trees. He handed to Mueller six cases of specimens exclusive of the timbers.

One of his excursions was made in a ship's boat to the sources of the Albert River, where he found a tree marked by Gregory in 1856. He collected on Sweers Island. Arrived in Melbourne March 31st, 1862.

Ficus Henneana, Miquel, from Booby Island, Torres Straits, was named after him.

On his return he joined the staff of the Melbourne Herbarium, under Mueller, as assistant, with his friend Wilhelmi, but resigned in 1864 to follow a mercantile career.

Tenison-Woods.—"North Australia: Its Physical Geography and Natural History." Julian E. Tenison-Woods (8vo., pp. 46. Government Printer, Adelaide, 1864).

Chapter VIII., pp. 38–48, is taken up with a sketch of the botany.

The following are comparatively recent botanical papers on the Northern Territory:—

1. At Proc. R.S., S.A., III., pp. 172–3, a list of plants collected by Mr. Chandler, at Barrow's and Tennant's creeks. Barrow's Creek, north of Alice Springs, and Tennant's Creek further north, may be looked upon as intermediate localities as between South Australia and the Northern Territory proper.

2. "Record of hitherto Undescribed Plants from Arnhem's Land." Mueller (Proc. R.S., N.S.W., 1890, pp. 73–9, 128, 174). Abstracted in Proc. R.S., S.A., XIII., 242.

3. "Introduced Plants in the Northern Territory." M. Holtze (Proc. R.S., S.A., XV., 1–4).

"The object of my paper is only to record those plants which in the Northern Territory have, up to date (1891), escaped cultivation, or which have been introduced unintentionally."

He makes a special list of the plants introduced during the last 20 years, amounting to 62 species.

4. "Narrative of an Exploring Tour across Melville Island, North Australia, with Notes on its Botany." M. Holtze (Proc. R.S., S.A., XV., 114-20).

The tour took place in October, 1887. The list of plants enumerated is 170, and the author remarks that no orchids (*o*) were observed, and, with the exception of *Lycopodium cernuum*, no plant which he had not previously observed on the mainland. The author states that his trip was a hurried one, and that he had not much opportunity for collecting.

5. "List of Plants collected by Dr. Stirling in Central Australia between Frew Ponds (lat. 17°) and Mount Stuart (lat. 22°) on the Transcontinental Telegraph Route." Tate (Proc. R.S., S.A., XV., 262). Twenty-two species are enumerated.

6. "Notes on the Fertilisation of some North Australian Plants." N. Holtze (Proc. A.A.A.S., VII., 566–69). The plants are—*Grevillea chrysodendron*, R. Br.; *Scævola Koenigii*, Vahl.; *Goodenia purpurascens*, R. Br.; *Stylidium*, *Mimulus Uvedaliæ*, Benth.; *Dolichandrone filiformis*, Seem.

7. "On a New Dilleniaceous Plant from Arnheim Land, North Australia," by Mueller and Tate (Proc. R.S., S.A., V., 79). (*Pachynema sphenandrum.*)

8. "On a New Acanthaceous Plant from Arnheim Land, North Australia," by Mueller (*ibid*, p. 81). (*Strobilanthes Tatei*).

9. "Description of Two New Species of Eugenia" (from the Northern Territory). Mueller (*Aust. Journ. Pharm.*, June, 1886).

10. "Diagnosis of a New Genus of Verbenaceæ from Arnheim Land." Mueller (Proc. R.S., S.A., VI., 33). The genus is *Tatea*, allied to *Premna*.

A paper entitled "The Sundew and the Rainmakers of North Australia," by F. Antoine (*Oesterr. Bot. Zeitschr.*, May, 1879), may be referred to. I have not seen it.

Biographical Notes.

The Holtzes (father and son) have done good work in the investigation of the flora of the Northern Territory. Maurice was first in charge of the Botanic Garden, Port Darwin, and is now in that of Adelaide. His son Nicholas has succeeded him in the former post. Inspector Foelsche collected eucalypts mainly, and his work is referred to in the "Eucalyptographia." These three and Henne are happily living; the others have passed away.

(*o*) Mr. Nicholas Holtze informs me that he has seen the following orchids on Melville Island:—*Dendrobium dicupum*, F. v. M., and *D. Johannis*, Reichb, var. He concurs in the view that the island is botanically practically a part of the mainland.

ARMSTRONG, J.—"The establishment of Port Essington was founded in the year 1838 by Sir Gordon Bremer. Mr. McGillivray was stationed at it for some time during the expedition of Captain Blackwood, and Mr. J. Armstrong, a collector sent by Kew Gardens, resided there for several years and made important collections, a considerable portion of which are in Sir W. Hooker's Herbarium." (*p*).

He was at Raffles Bay at least as late as August, 1846. See De Vriese's "Goodenovieæ," p. 138.

The following species commemorate him :—

Eugenia Armstrongii, Benth.; *Goodenia Armstrongiana*, De Vr.; *Euphorbia Armstrongii*, Boiss; *Phyllanthus Armstrongii*, Benth.; *Cyperus Armstrongii*, Benth.

SCHULTZ, M, of Port Darwin, made large collections of Northern Territory plants, which were forwarded by Dr. R. Schomburgk to Kew.

The following plants were named in his honor :—

Antidesma Schultzii, Benth.; *Croton Schultzii*, Benth.; *Euphorbia Schultzii*, Benth.; *Arundinella Schultzii*, Benth.; *Ectrosia Schultzii*, Benth.; *Eragrostis Schultzii*, Benth.; *Eriachne Schultziana*, F. v. M.; *E. stipacea*, F. v. M., var. *Schultziana*; *Eriocaulon Schultzii*, Benth.; *Fimbristylis Schultzii*, Boeckel.; *Leptocarpus Schultzii*, Benth.

Schultz's specimens were numbered, and were described in vols. VI. and VII. of the "Flora Australiensis."

ADDENDUM.—See p. 189. Capt. E. A. Delisser made explorations in July, 1861, and June, 1865, from Fowler's Bay to Western Australia. See Fraser's "Western Australian Year Book for 1902-4," p. 76. See also "Report on Great Australian Bight." (S.A. Paper, No. 137 of 1867.)

Eremophila Delisseri, F. v. M. = *Pholidia Delisserii*, F. v. M., was named after him.

(*p*) Hooker, "Introd. Essay to Flora of Tasmania."

Section E.

GEOGRAPHY.

ADDRESS BY THE PRESIDENT,

THOMAS WALKER FOWLER, M.Inst.C.E., M.Am.Soc.C.E., F.R.G.S., &c.,

Hon. Sec. Victoria Branch Royal Geographical Society of Australasia.

Ladies and Gentlemen—Since the last meeting of the Association, held at Dunedin in 1904, the event of greatest interest to geographers of our Southern Hemisphere has been the return of the British National Antarctic Expedition from the scene of its labors in Ross Sea and Victoria Land. The detailed account of the expedition has been available for some time, and attentive readers are compelled to admire the courage and determination with which the work of the expedition was carried out—courage and determination well worthy of the best traditions of our race. Captain Scott's farthest point south was 82° 16′ 33″, or about 534 statute miles from the pole. This is about 50 miles less than the distance by rail from Sydney to Melbourne, or 50 miles more than that from Melbourne to Adelaide. To reach this position Captain Scott and his comrades, Lieut. Shackleton and Dr. Wilson, in 93 days covered 960 miles, an excellent record for a sledge journey, which, however, was surpassed by that of the same leader, accompanied by Evans and Lashley the following season, when, journeying westward, they ascended to the great plateau of Victoria Land and covered 1,098 miles in 81 days, a large part of the journey being at an altitude of 9,000ft. in latitude 78° south. In some respects this journey resembles that of Nansen across Greenland, in 1888, in latitude 64½° N. He reached practically the same altitude and travelled 282 miles in 41 days

Captain Scott gives us a vivid description of the pleasures (or, as most of us would term them, miseries) of sledging in polar regions, and enables us to understand more clearly the hardships experienced by the early polar explorers such as Parry and the Rosses, Franklin, McClure, McClintock, and others, who had not the facilities available to more recent explorers for obtaining warm food. Few of us would relish the comforts of a sledge journey, even with modern luxuries, as described by Captain Scott. Let us picture to ourselves three men in a sleeping-bag, each in turn suffering from intense fits of shivering, which form part of the nightly programme preparatory to a short period of broken sleep; and, again, the misery of putting on each morning boots frozen as hard as iron and far from the shape of the wearer's feet. What agony those men must suffer before those boots get gradually thawed from the warmth of the wearer's feet after he has dragged the sledge for an hour or more.

Commander Peary still maintains his attack on the north pole, and on April 21st, 1906, reached 87° 6′ N. latitude, or about 203 miles from his goal, when he was compelled to retire.

The difference in conditions observed on approaching either pole are remarkable, and so far no satisfactory explanation has been forthcoming. Whilst Scott's great southern journey was approximately parallel to the south-eastern coastline of Victoria Land, it was over the surface of the great ice sheet originally discovered by Sir Jas. Clark Ross. The evidence we have tends to show that this ice sheet is hundreds of feet in thickness and extending uninterruptedly towards the pole. Some authorities have suggested that it is of glacial origin, in which case the surface altitude would increase with increase of latitude; but no such increase was observed, either by Scott during his southern journey nor by those (Royds and Bernacchi, Cross, Plumley, Scott, and Clark) whom he sent to the S.E. nearly 200 miles for the special purpose of observing the conditions of the ice. As far as is known, then, the Great Barrier ice is hundreds of feet in thickness (possibly in places reaching 1,000ft.) and covering a sea surface. The more northern portion is probably afloat, whilst it seems possible that at the more southerly parts reached by Scott's parties the ice extends to the sea bottom. In any case the ice surface is certainly not drifting. On the other hand, Commander Peary, in extreme northern latitudes, met with comparatively thin "floe" ice intersected by open leads and drifting rapidly to the eastward, the more northern ice moving more rapidly than that to the south.

It will be remembered that Nansen, in the *Fram*, found, as he anticipated, a westerly current to the north of Asia, which he hoped would take him across the pole, but which actually carried the *Fram* to lat. 85° 55′ N. in long. 66° 33′ E. The experience of this westerly current in the extreme north beyond Siberia, and the easterly current found by Peary north of Grant Land, seem to imply the existence of one broad current across the high polar seas, and that the north pole itself is covered with water (or more correctly water-borne ice), since should a current sweep, say, from Behring's Strait across the pole to the meridian of Greenwich, the direction followed by the Asiatic side of that current would be described as westerly, and that of the American side as easterly, although the water streams would be running in the same direction and parallel to each other.

During the year we have been advised of the successful accomplishment of the North-West Passage by Captain Amundsen, in the Norwegian ship *Gjoa*, after a voyage of over three years. This is the first occasion on which a navigator has taken his vessel from the Atlantic to the Pacific by the coast of North America and its islands; but McClure, over 50 years ago, brought his crew in the reverse direction during the Franklin search, being thus the first to make the North-West Passage, although he had to abandon his vessel (the *Investigator*) in the ice. The accomplishment of the North-West Passage brings to our minds the names of many gallant navigators and British heroes from the days of Queen Elizabeth. Frobisher and Davis, equally at home in fighting icebergs or the Spanish Armada ; Hudson and Baffin, Jas. Cook, Parry, the Rosses, and Franklin, and many others ; whilst the interview between young Horatio Nelson and the polar bear cannot be forgotten.

Of what advantage is polar exploration ? Why risk human life and treasure in endeavoring to wrest from nature her secrets in these regions of such desolate and inhospitable character ? These questions have been often asked, yet might not similar questions have been asked with reference to Australia, when the gallant Sturt returned from his central Australian expedition ? On Sturt's track there now stands one of Australia's most important mining centres, a city of 30,000 inhabitants, the world-famed Broken Hill. On one memorable occasion Sir John Franklin traversed the ice-bound regions of far north-west America, suffering the greatest possible hardships and having actually to eat his boots to maintain life. What benefit to mankind could such a country be ? In it now the miner is hard at work, and Klondyke, the Yukon, and Cape Nome are household words.

Taught by experience on their western boundary, where, through the carelessness of British statesmen of the past, they now find themselves shut out from access to the seaboard, our Canadian fellow-citizens are steadily extending their dominion and the boundaries of the Empire by including the ice-bound islands to their north ; and it may be asked whether Australia should not take similar action with reference to these southern seas, its scattered islands, and Antarctica. Apparently valueless at present, are they not possibly future Klondykes ? Independently of the possible future value of these polar regions to the human race, their exploration and scientific examination produce data of considerable practical value in solving the problems of meteorology and terrestrial magnetism, whilst the work has been noted for its value in developing the best characteristics of the British seamen.

As geographical students we are deeply indebted to those explorers who have given us a knowledge of the world's great geographical features which govern the development of nations and determine their lines of communication. To the civil engineer, more especially, a thorough grasp of the geography of the country in which his work is located becomes of vital importance, so that he may take advantage of all favorable conditions and guard against or minimise the effect of all unfavorable ones. On the other hand, it falls to the lot of the civil engineer to alter or modify geographical conditions. By piercing the Alps he has brought Southern and Northern Europe into close touch with each other ; with his barrages, canals, and other irrigation works he has enormously increased the prosperity and productiveness of Egypt and of India ; whilst with the Suez Canal he has revolutionised the commercial relations between Europe and the eastern world. We may, therefore, note with satisfaction that our American cousins have actively resumed operations at the Isthmus of Panama, and that there is every prospect of the great scheme originated by Lesseps being carried to a successful termination by people of the Anglo-Saxon race. Whilst, necessarily, this great work will principally benefit American commerce, Australasia cannot fail to profit from it immensely.

Turning to Australia, the prosperity of the South Australian Branch of the Royal Geographical Society of Australasia is a matter for congratulation and pride. Recently that branch has secured the "York Gate Library," a collection of works of the greatest interest to Australia; and South Australians must be gratified to think that these volumes will, for the future, be housed in their capital city. Whilst we rejoice at the prosperity of the branch we sympathise with it in the loss it has sustained through the death of its veteran honorary secretary, the late Mr. A. T. Magarey. The Queensland Branch of the society has also suffered a severe loss through the death of its illustrious president, Sir Augustus C. Gregory, whose name should always, in view of his valuable services in the exploration of the continent, be a household word amongst Australians. Ripe in years and in honors he passed away, beloved by all who knew him. After 23 years of most arduous and valuable work the veteran Mr. A. C. Macdonald has resigned the secretaryship of the Victorian Branch of the society, and I have been elected his successor. I take this opportunity of testifying to the zeal and energy with which Mr. Macdonald has always worked to promote geographical research throughout Australia.

Recently some Victorians have claimed that the country between the Murrumbidgee and the Murray is legally a portion of Victoria, as defined by the Separation Act, under which it was established as a colony. Personally, I cannot agree with this view, as, whilst at one time the Port Phillip district did extend to the Murrumbidgee, the boundaries were then clearly defined and described as, *inter alia*, following that river; so that when the Imperial Parliament, in constituting the colony and describing the boundaries, excluded all reference to the Murrumbidgee and referred to the Murray alone, it deliberately and intentionally fixed the boundary between New South Wales and Victoria as at present accepted. An examination of Australian history in connection with that boundary shows that an injustice has been done to the memory of the first native Australian explorer, Hamilton Hume, who, during his memorable journey from the New South Wales settlements to Port Phillip, discovered and crossed Australia's greatest river, in November, 1824, at Albury, and named it the Hume in honor of his father, the Rev. A. H. Hume. Captain Sturt, in 1829–30, followed the Murrumbidgee down to its junction with Hume's River (which had not in the interval been traced below Albury), entered the latter, and followed it to its mouth, calling it the Murray after Sir George Murray, a distinguished officer who had served with credit in the Peninsula wars, and was at the time presiding over the Colonial Office. By right of priority Hume's name should stand and be applied to the whole course of the river, from its source to its mouth in Encounter Bay. The New South Wales Government gives a partial recognition to the original discoverer, marking the stream as the "Murray River (or Hume River)" on the official maps. Our geographical societies might with propriety unite in asking their respective Governments to restore the original name.

The work of the Australian pioneer explorer is drawing towards a close, and the problem of utilising and settling the interior becomes of increasing importance. The search for gold has been a great stimulant to exploration, and the interior of Western Australia—formerly a *terra incognita*—is now covered with a close network of travellers' tracks.

Conservation and utilisation of the limited water supply and economical means of transport are the great essentials for the development of the interior. Artesian and semi-artesian wells have been most effectual in providing an insurance against drought in parts of Queensland, New South Wales, and South Australia, and the storages of Barossa and Beetaloo, with their reticulations, must be of great value to those supplied.

The Barcoo or Cooper's Creek and the Diamentina provide occasional supplies for the northern portions of South Australia; but, as far as I can gather, these streams are too wide and shallow to permit of useful storage being constructed, in view of the enormous evaporation. The particulars supplied by travellers as to the Macdonnell Ranges, however, would indicate that in that locality sites suitable for the construction of enormous water storages of considerable depth can be found, and no doubt will be utilised when the country becomes more developed. In this connection the journals of Mr. Tietkens and of the Horn Scientific Expedition, and Mr. Arthur Giles's paper, read before the Victorian Branch of the Royal Geographical Society of Australasia in 1902, are most suggestive.

In Victoria extensive works for irrigation and water conservation have been projected, and are in part carried out, and these will provide a fairly satisfactory safeguard against future droughts, and in New South Wales similar works are projected. Whilst these works will necessarily be of immense benefit to the areas supplied, I sympathise strongly with the South Australian view—that the interests of the Murray (or as we may term it, the Hume) navigation should not be completely sacrificed to those of irrigation. For its area, the valley of the Hume and its tributaries is the most fertile region of Australia, and whilst the commerce of its more eastern parts can be more economically dealt with by rail from the adjoining seaboard, the river itself forms the natural outlet for the lower portion. Hence the locking and canalisation of the Hume and its tributaries, the Darling, and possibly also the lower Murrumbidgee, are works in which we as geographers are deeply interested. These works to be successful must be carried out to provide the maximum depth for navigation possible, since to secure economical transport (whether by rail or water) the goods must be handled in large quantities, as otherwise transit expenses increase enormously.

To reap full benefits from the river navigation the entrance must be thrown open to the shipping of the world, so that vessels of the largest size may pass in and out. The importance of such navigation has been recognised elsewhere, as in the cases of the Danube and the Mississippi, where very large sums of money have been expended to secure the desired results. Compared with these instances the conditions at Encounter Bay seem much more favorable, and, in view of experience elsewhere, the problem should be comparatively easy. Sooner or later this important work, which will facilitate the drainage of valuable lands, will be carried out.

In recent years the waters of the Southern Hemisphere south of 40° S. latitude have frequently been called the "Southern Ocean," and Professor Gregory, in his presidential address to this Section at Dunedin, whilst approving of the name, advocates its application to the expanse of waters south of "a line passing from Tierra del Fuego, through South Georgia to Cape Colony, thence approximately along the parallel of 36° S. latitude to the south-western corner of Australia. The Southern Ocean washes the whole southern shore of Australia, and may fairly be extended to include all the Tasman Sea. It runs down the western shores of New Zealand to South Island, and thence runs southward to the Antarctic Continent, near Cape Adair, at the point where the Atlantic coast type of Wilkes Land joins the Pacific coast type of Victoria Land. The whole Pacific is one geographical unit. It is bounded entirely by coasts of the Pacific type, and if we limit the Southern Ocean to the great ocean belt that extends from South America, past South Africa, to New Zealand, that also may be regarded as an independent geographical unit bounded by coasts of the Atlantic type." I confess that I cannot follow Professor Gregory's reasoning. The American coastline of the Pacific Ocean is of a character quite distinct from that of the Asiatic and Australian portions, or even of the Eastern coastline of New Zealand, resembling more the western coastline of that country, which western coast the Professor makes a boundary of his Southern Ocean. Should the term be adhered to, there seems to be some reason for extending the boundary from Stewart Island, New Zealand, to Cape Horn, thus excising an area of a stormy character from the Pacific Ocean. However, the boundaries of the oceans, where not fixed by coastlines, must be of a more or less arbitrary character, and I can see no sound reason for departing from the divisions and nomenclature recommended by the committee appointed by the Royal Geographical Society in 1845, which consisted of Sir Roderick Murchison, Sir Geo. Back, Captain Beaufort, Sir John Franklin, Mr. Greenough, and Captain Smyth. These gentlemen applied the terms Arctic and Antarctic Oceans to the waters within the corresponding circles, and applied the terms Pacific, Atlantic, and Indian Oceans to the rest of the Oceanic waters—adopting the meridians of Cape Horn, Cape L'Agulhas, and South Cape, Tasmania, as the division lines, where not naturally fixed by the continents. Should the waters within the Arctic and Antarctic circles be considered too small to be termed oceans, the former would naturally merge into the Atlantic, and the latter into the three main oceans whose meridianal boundaries would be continued until land is met.

Varying practice exists amongst map-makers as to the limits of Bass Strait, and hence it may be noted that the western boundaries adopted by the Admiralty are from Cape Otway, Victoria, to Cape

Wickham, King Island, and thence from the south point of that island (Stokes' Point) to Cape Grim, Tasmania. As to the eastern boundary, Admiralty charts and practice seem to vary; in some instances Cape Howe being taken as the northern point, and in others Wilson's Promontory. Personally I would adopt the former. Eddystone Point, Tasmania, is taken as the southern boundary, and the division line may be taken as extending through the islands of Furneaux Group.

The celebrated German geographer, Dr. Karl Fricker, has suggested that the channel between Tierra del Fuego and the Falklands, on the north, and the South Shetlands and Graham's Land, on the south, should be termed "Drake Strait," in memory of the great British navigator who first sailed in its waters. The proposal does not seem to have attracted the attention it deserves, and is worthy of support. In view of the width of the channel, however, the term "Drake Sea" seems preferable to that of "Drake Strait."

Whilst the pioneer exploration of Australian lands is rapidly approaching completion, the scientific examination of our southern seas has scarcely been commenced, and the present is a fitting occasion for bringing the subject under notice. Thanks mainly to the work of the British Admiralty, we have reliable surveys and soundings carried out with considerable detail in the vicinity of our principal ports and in such localities as Wilson's Promontory, and with less detail generally along the coasts, whilst the soundings are sufficiently extensive to fix with reasonable accuracy the position of the Australian continental shelf, which we know passes to the south of Tasmania, and is of itself an indication that the island was at one time connected with the main land. Of deep-sea soundings we have but few, and, as a result, our information as to the configuration of our ocean beds is very meagre, being based mainly on observations made in connection with the *Challenger* and *Valdivia* expeditions. In view of the enormous areas to be covered, those observations were necessarily made at considerable distances apart, and, as far as I can gather, not a single deep-sea sounding has been made at Australian expense. And yet a detailed working knowledge of our Australian seas would be of immense money value to Australia.

In 1902, before the Victorian Branch of our Australasian Geographical Society, I discussed the effect of variations in the level of the ocean bottom in diverting the ocean currents, and showed that the southern current of Tasman's Sea was derived in this manner from the south equatorial current of the Pacific Ocean. My predecessor in this chair, Professor Gregory, discussed the subject in his address to the section at Dunedin, pointing out the effect of irregularities in the ocean floor in mixing surface and lower waters, with consequent variations of temperatures and densities. In 1898, and again in 1900, I directed the attention of the section to the effect of such variations of temperature and density of our ocean waters in modifying the nature of our seasons, and this view was subsequently supported very forcibly by Professor Gregory in the address already mentioned and elsewhere. Accurate long-period weather forecasting is a problem of vital importance to Australian graziers, farmers, and others; and its solution would amply justify an expenditure sufficient to defray the cost of the necessary scientific investigation. Both in America and Western Europe it has been proved that an accurate knowledge and continuous observation of the adjoining oceans are essential in such investigations. It is well known that the general track of all weather changes in Southern Australia is from west to east, and hence we are deeply interested in the oceanography of the Indian Ocean to the west and south-west of Australia. With my own limited opportunities I have been able to detect a connection between the variations of the surface temperatures of Bass Strait and the character of the Victorian seasons. Mr. H. C. Russell, then chief of the Sydney Observatory, informed me that he had evidence of an abnormal northing in the westerly winds of the Indian Ocean during the periods over which I had noted high sea temperatures in Bass Strait, causing a drift towards Australia of waters from the warmer parts of that ocean, whilst the low temperatures were coincident with periods in which the southings were more prevalent and the drifts carried greater proportions of the cold Antarctic waters. If such results can be obtained from the comparatively cursory observations made by an individual during his leisure moments, what valuable information may be obtainable from a thoroughly scientific national investigation?

The lines on which such an investigation should be commenced would be as follows:—Soundings sufficiently close to give reliable information as to the general conditions of the ocean floor should be made from 150° E. longitude to 60° E. longitude, and extending from, say, 50° S. latitude to the coastline, or to 20° S. latitude. Preferably the soundings would be carried along meridian lines, say 5° apart, a sounding being taken on each line at each degree of latitude. Whilst at every sounding the temperatures and densities of surface and bottom waters would be observed, at every fifth sounding these should be observed at every 100 fathoms or 200 fathoms. The information thus obtained would give a good base, and positions at which closer sounding might be desirable could then be determined. Such a programme would involve 19 lines of soundings, averaging about 25 in each, and about 30,000 miles of steaming, irrespective of distances travelled for supplies, &c., whilst, under favorable circumstances, probably 18 soundings could be taken per week. Allowing for delays the work would probably take about 18 months, and if carried out with a small steamer might cost about £15,000. In addition arrangements should be made for all vessels trading to Australia *via* the Cape or the Suez Canal to supply a complete meteorological log to the Commonwealth weather office, giving information relative to the Indian Ocean similar to that supplied by many such vessels to the Meteorological Office in London, whilst our weather office staff should be numerically strong enough to promptly analyse and digest the information thus obtained, and before the conditions to which it applied have passed away. Thus attacked, there is a reasonable prospect of the important problem of long-period weather forecasting being solved for Australia.

I am tempted to quote from Professor Gregory's address, already referred to, as follows :—" In meteorology each continent must work out its own salvation. Europe may help us with methods, but we must apply them ourselves to our own waters before we can share in the rewards. Patiently and excellently meteorologists all over Australia are recording the daily changes of our weather ; but far out in the great Southern Ocean the fundamental processes that are determining the rainfall a year or two years ahead are passing unnoticed and unknown. Australia has spent vast sums in irrigation works that have failed through lack of water, and provides for accurate records of present weather ; but for the sake of a few hundred pounds a year we are leaving unstudied the causes that produce and control it. What gift would be of more benefit to the vast agricultural interests of Australia than a warning as to whether they must be prepared next year to face a drought or a deluge ? The apparent fickleness and severity of our climatic changes introduces as large an element of gambling into our farming as there is, alas, in many of our reckless mining ventures. The dragon of uncertainty that now preys on our agriculturists could be defeated by foreknowledge of approaching spells of fair weather and of foul. That knowledge is available, if we but seek it. For, like the seer of old, modern science assures us, ' Cast thy bread on the waters, and thou shalt find it again, though it may be not till after many days.' "

In conclusion, I wish to quote the able remarks of Lieut. Pillsbury, in connection with his report on the Gulf Stream (U.S. Coast and Geodetic Survey Report, 1890, page 471) :—" There is another reason for studying these (oceanic) currents, which will ultimately have the most beneficial influence on mankind. It is now known that the currents vary, through certain forces acting upon them, by periodic changes, entirely according to law, and again through apparently erratic forces. Probably every motion of these vast bodies is absolutely governed by laws which can be ascertained. The moisture and varying temperature of the land depends largely upon the positions of these currents in the ocean, and it is thought that when we know the laws of the latter we will, with the aid of meteorology, be able to say to the farmers hundreds of miles distant from the sea, ' You will have an abnormal amount of rain during next summer,' or ' The winter will be cold and clear ' ; and by these predictions they can plant a crop to suit the circumstances, or provide an unusual amount of food for their stock. We will be able to say to the mariner, ' At such a time the current will be so much an hour in such a direction,' and the percentage of error will be but trifling. From a study of these great forces, then, we derive our greatest benefits ; and any amount of well-directed effort to gain a complete mastery of their laws will revert directly to the good of the human race."

Section F.

ANTHROPOLOGY AND PHILOLOGY.

ADDRESS BY THE PRESIDENT,

R. PARKINSON, Ralum, Bismarck Archipelago.

TOTEMISM IN MELANESIA, AND ITS POSSIBLE ORIGIN.

The word "totem," now well known to ethnologists, was originally connected with certain institutions and customs of the North American Indians; and when similar institutions and customs were subsequently found amongst races of other parts of the world, the word totem was adopted as a general designation.

The highly interesting and important works of Spencer and Gillen, as well as of Dr. Howitt, treating upon the customs of Australian aborigines, give a detailed account of totem as we find it in a highly developed form, not only amongst the tribes of Central Australia, but throughout the continent. Their graphic descriptions have caused an interesting controversy respecting the origin and meaning of the institutions which the ethnologists of to-day signify by the term totem.

I think I will be able to add a few facts to what already has been said in regard to this matter, but before I reach this point it will be necessary to lay before you the results of my observations upon the *distribution* of totem amongst the various more or less mixed races of the Pacific. These observations cover the islands situated between the Philippines and Moluccas in the west to the Hawaiian islands in the east, and from the Carolines in the north to the Polynesian islands in the south. It has fallen to my fortune to make my observations on the spot; and there is not a group of any importance within the limits I have mentioned that I have not visited, and in which I have not had an opportunity to gather reliable information.

Arriving in New Britain nearly 25 years ago, I soon found that the natives of the N.E. Gazelle Peninsula, where I settled, had a peculiar custom. They were, and are still, divided into two great sections, but neither bears a distinctive name. They speak of these sections as belonging to *tawewet* and to *tadiat*, that is, translated, "we" and "they" or "them." *We* are not permitted to marry any woman belonging to *Us*, but *We* can marry women belonging to *Them*. Just so, *They* cannot marry any woman belonging to *Them*, but are permitted to intermarry with *Us*. Children belong to the section of the mother; thus, *We* claim all children as belonging to *Us* if born by a woman belonging to *Our* section, and in the same way do *They*.

In the islands of the Duke of York group, situated between the Gazelle Peninsula and New Ireland, we find a similar dual division;

but here each division has a distinctive name or a distinctive sign by which one is known from the other. The two divisions call themselves Marawe and Pikalaba, which are the names of two different kinds of Mantis. The system is the same as in the Gazelle Peninsula, and children born by a Marawe woman belong to the Marawe division, just as children born by a Pikalaba woman belong to the Pikalaba division.

The father is scarcely considered in the light of a relation; the nearest male relative is the maternal uncle. So strictly is the system regarded that sexual intercourse between members of the same section is looked upon as incest, and in former times was punished with death—a custom still lingering in out-of-the-way places, but gradually losing force through the influence of the authorities and settlers. Intercourse between a male and female who are members of different sections is considered a far less offence, and in certain places, as in the island of Buka, the system is carried to such an extreme that the father is permitted to hold sexual intercourse with his own daughters.

Crossing from the Duke of York group to New Ireland we once more meet with this singular system. In the southern half of the island the inhabitants are closely related to the tribes of the Duke of York group and the N.E. Gazelle Peninsula, the latter being, in fact, immigrants who have crossed the St. George's Channel from southern New Ireland. In consequence, the dual division prevailed, but as they came into closer contact with their northern neighbors, amongst whom the divisions have multiplied, some of the northern customs have been gradually adopted, so that the original dual division has been broken up and augmented by new divisions.

In northern New Ireland the totem system flourishes to its full extent. It is, however, unnecessary to give you a detailed account; it will be sufficient to mention that all totem emblems are selected from amongst the bird tribe. The parrot, hornbill, fowl, pigeon, frigate bird, and various others give their names to, or represent, the different divisions; but the same system prevails in regard to marriage and descent.

In this northern part of New Ireland, and in the outlying smaller islands—Fisher Island and Gardner Island—it is customary to celebrate annual festivities in honor of the dead, and, in connection with these festivities, to manufacture large and elaborate carvings. These wooden carvings have the closest resemblance to the North American totem posts, inasmuch as they represent the totem of the person in whose honor they are erected. In most museums these carvings are well known and, upon closely observing them, no difficulty will be found in recognising the particular totem bird, sometimes executed in a very realistic form, so that the special bird the carver wanted to represent is readily identified, sometimes carved in a highly idealised manner, so that the uninitiated are scarcely able to guess the kind of bird represented. Besides these totem birds the carvings also represent several other forms of life, especially sharks, pigs, lizards, snakes, and so on. These are not totem signs, they represent evil spirits which in his life-time were enemies of the deceased, and in one way or another did him bodily harm or caused his death. Large carvings of this kind at times portray the life-story of the departed, especially the troubles caused him by evil spirits, supposed to be embodied in certain animals. It is not so very long ago that it was believed these carvings were meaningless creations, emanating from the lurid phantasies of the carver. Close investigation among the natives, and especially the carvers, eventually brought me to the discovery of the meaning, and with it to the discovery of the totem system.

From northern New Ireland I shall now go across to New Hanover. Here we again find the same system as in northern New Ireland, with the same bird totems; but underlying this is a wholly different classification, founded on the similarity of the lines of the inner face of the hand. This latter system I consider to be the original one, but gradually it has been influenced by the totem customs of northern New Ireland, so that to-day the bird totem is interlinked with the classification according to the lines of the palm. I have tested this peculiar palmistry at various times, and found that certain bird totems go together with certain lines, and that the natives are able by the latter to ascertain which is the bird totem of the person examined. I shall recur to this palmistry further on.

Leaving New Hanover and going west we reach the Admiralty Islands, and once more the totem system. Here, however, it shows a certain decay, and I attribute this to the fact that the group is inhabited by three distinct tribes: the Usiai, whom I consider the original tribe in the group; the Matankor, who belong to a tribe originating in Micronesia; and the Moamer, who, without doubt, came across from New Guinea. These three tribes have their original customs, but, in intermarrying, the Moamer have impressed on the other tribes the totem customs which they brought with them from their original home, and, up to the present date, observe as rigidly as in the other islands I have mentioned, and from which they draw the same consequence in regard to marriage and descent. The Usiai and Matankor are more lax in respect to the consequence, and the system without doubt has been forced upon them by the warlike Moamer, who always were, and still are, the predominating power in the group.

Having traced the totem system so far to the west, let me now return to the Gazelle Peninsula, and show how far the system is traceable from there to New Guinea and to the Solomon Islands. The Gazelle Peninsula is divided between two entirely different tribes, the one occupying the north-eastern part, of which I have spoken, and the other the western and southern, which is known by the name of Baining. Here we find no trace of totem, or of anything that can possibly be compared to it; in fact, the whole tribe stands on such a low step of culture that it is by far the most primitive native tribe with which I have ever come in contact. But as soon as we pass the narrow neck of land connecting the Gazelle Peninsula with the main island of New Britain we once more meet tribes with a well-developed totem system, closely resembling the system of northern New Ireland. But, although the bird totem is prevalent, plant totems begin to show themselves, thus already bringing us nearer to Australian influence. Going farther along the New Britain seaboard, we observe that the coast tribes are very similar to the tribes living on the opposite shores of New Guinea, from whence they undoubtedly originate. These coast tribes of New Guinea have no totem system, although it is found amongst tribes living easterly, as well as westerly, from them; and the coast tribes of western New Britain also have no knowledge of the system. In the last few years I have had occasion to establish intercourse with the inland tribes, and although up to the present our knowledge of them and of their customs is very limited, so much is certain, that these inland tribes have a well-established totem system, closely resembling the systems of other islands.

That in the great island of New Guinea the totem system prevails has been shown by the investigations of late years. It seems, however, that in this country, through influences emanating from tribes in the west, the system is gradually breaking up. In German New Guinea I have found no trace of totem westerly of Humboldt Bay, and in British New Guinea the system seems to disappear entirely west of the Fly River. Totemism in New Guinea shows a greater similarity to totemism in Australia, in that plant totems seem to be a prominent feature of the system.

I think that, from what I have described to you, a clear track is shown along which totemism has travelled from Australia *via* New Guinea to the Melanesian Islands, or *vice versa.*

But I must still take you across to the Solomon Islands, and to the chain of islands stretching away from thence to Fiji. In the northernmost island of the Solomons, in Buka, we once more find the dual totem system, with two distinct totem signs—the frigate bird and the pigeon. The same system also prevails over the northern half of Bougainville. In some parts of this division, especially in Buka, we find the consequence of the system extended to its utmost. The father does not consider himself to be related to his own daughters, but stands towards them in the same position as to any other women having a different totem. As the daughters inherit the totem of the mother, he considers them as not related to him, and in consequence is permitted to marry them. I may here add, that this excessive consequence is viewed by other neighboring tribes with a certain disgust—as something that ought not to be, although it is not condemned as a crime or punishable as such.

In southern Bougainville the totem system once more branches out in a great many divisions, each having a bird as totem sign; but all these ramifications can be referred back to the dual system of the frigate bird and pigeon, upon which they are based.

The large south-eastern Solomon Islands, Choiseul, Isabel, Malaita, and Guadalcanar, have a certain totem system; but here the system has been mixed up with the customs of various secret societies and obscured by influences coming from the south and south-east. This is still more the case in the Santa Cruz Islands and New Hebrides, as well as in New Caledonia and Fiji, where the system is barely traceable. I attribute this to the influence of Polynesian immigrations, of which we find abundant evidence. The Polynesians, a more highly developed and intellectual race, have broken up the original system and modified it to such an extent that at present it is difficult even to trace the remnants of the original system.

The Polynesians seem originally not to have known anything about totemism. In their wandering towards the east they came, however, across a darker race, who were most likely very closely related to the present tribes of the Bismarck Archipelago. These tribes were conquered and partly exterminated, but we may safely assume that many of the women were spared, and taken as wives or concubines by the conquerors. The Polynesian race of to-day is, therefore, a mixture of the original Asiatic emigrants with a darker race who were very similar to the present Melanesians, with woolly hair, and who had a knowledge of the totem system. We may take it for granted that the women of the conquered race, bringing forth children to husbands of the conquering party, impressed on their offspring some of their old original customs and views, and amongst these the custom of totem, which must have been to them of the greatest importance. In later periods the connection between totem sign and totem system was gradually lost, but still recollections lingered, and the totem signs were, by certain families or certain tribes, considered in the light of an ancestor or ancestral deity. Many chief families in Polynesia, as in Samoa and Tonga, and many Melanesian island tribes up to the present date look upon certain birds or animals as being their forefathers, or in some dim and inexplicable way to be connected with them and their family.

I have tried to show you in brief outline how far the totem system extends at present over the islands of the Pacific, and that in remote ages it in all probability extended to islands where to-day we find only the faintest traces. I shall now try to explain to you the conclusions I have formed concerning the origin of this widespread and singular custom.

We may take it for granted that in past, long-forgotten ages man lived, as tribes or herds of the higher animals live up to the present day. It must have taken a long time before he realised that he belonged to a higher species; but gradually he raised his head, his eye brightened, and his brow expanded, and he began to realise his superiority and to take a greater interest in all that concerned himself and his fellow man. Still he lived in small hordes, without any recognised family ties; the females brought forth children belonging to the tribe; and if any relationship was recognised it must have consisted in the feeling that the offspring belonged individually to the mother that had brought it forth. It must, again, have taken ages before man realised that breeding within a certain limited circle caused a gradual weakness of the offspring, and in consequence a weakness of the tribe; and, arriving at this conclusion, he must have come to believe that the weakness of the offspring was caused by the unfitness of the females to bring forth strong and healthy children capable of upholding the prestige of the tribe. Considering the women of his own tribe thus to be inferior breeders, he would naturally look to the neighboring tribes for a fitter mate. He would most likely take by force or by stratagem what he wanted, and in many marriages customs of different races up to the present day we find survivals of this old original marriage custom. Of a marriage as we understand it to-day these remote ages knew nothing; the abducted woman belonged to the tribe as a whole. The result would be apparent to the tribe; the children born by the abducted females would be strong and healthy; they would be able to defend the tribe against invaders; they would be more successful in the quest for food, and would make the tribe once more to flourish. The welfare of the tribe being the principal aim, the men would soon look on the original tribal females as unfit for sexual intercourse, and a system would spring up by which it was possible to distinguish the offspring of the abducted women from the offspring of the females originally belonging to the tribe. The simplest system, it seems to me, is at present to be found in the north-eastern part of the Gazelle Peninsula, and it is most likely the original system still remaining in force. As stated previously, these tribes speak of themselves as *We* and as *They*, thus in a very simple way distinguishing the members of the original tribe from the members who are the offspring of females belonging to another tribe.

But this dual system would not be sufficient when a number of neighboring tribes mixed with one another; the *We* and *They* would be insufficient to distinguish the different groups of offspring, and man would look for other ways. Maybe a certain outward sign, inherited by the children from the mothers, has brought him to look for such signs in all other cases; and having, in his opinion, found such a sign he would look for it, and class all individuals possessing this characteristic sign as belonging to one group. What these signs in every case have been we do not know, but the system of classing the different groups according to the run of the lines in the palm, as still found in New Hanover, seems to me to be highly instructive, and conclusively to prove that man has tried to solve the question of offspring in this way.

A system like this, based on an outward sign, would soon be found inadequate; errors would come to light and cause trouble and complications, and therefore other systems would have to be looked for. We may, I think, take it for granted that the prehistoric philosopher took as lively an interest in this question as the philosophers of to-day take in the origin of religion or of the belief in God.

Now it would be entirely in conformity with the present native form of thinking and of reasoning to give to women of a certain tribe a general name by which to distinguish them from women of a second or third tribe. In choosing a name the native, up to the present day, selects from his surroundings and prefixes a male or female article to differentiate the sex. As an example you will find in New Britain such names as *Tokalangar* and *Jakalangdar* (*kalangar* = parrot), *to* is the male and *ja* is the female article; or *Tomarup* and *Jamarup* (*marup* = cassowary);

or *Toballu* and *Jaballu* (*ballu* = pigeon). That names of birds should have been selected in preference to other names can, I think, be explained by the fact that the birds attracted more attention than the few quadrupeds living in forests and hiding in trees and amongst rocks. In other parts, the selection of plant totems would seem to be in recognition of the fact that certain plants play a conspicuous role in the life of the tribe as purveyors of food.

Even at the present day new group names will occasionally come to light, and their origin gives us a hint how other names have originated. A few years ago I observed in a New Ireland village a carving in honor of a dead native, representing a bird which I had never before seen represented as totem. The carver, with great realistic truth, had represented a crane, and investigation showed that this bird was a totem of a small group of people having the following origin. Years back a canoe containing several men and women had drifted ashore; the men were killed, but the women were taken by the natives as wives, and as their totem was unknown it was found necessary to create a new totem in order to designate the offspring. The crane was selected for this purpose. At the time I was able to trace about 30 male and female Cranes of all ages, and their foreign descent was plainly perceptible, many having inherited the straight hair and lighter color of their ancestresses, who, without doubt, must have been straight-haired, light-skinned women who had drifted there from a Micronesian or Polynesian island. An old man voluntarily offered the information that the long, straight feathers of the bird were like the straight hair of the castaway women, whom as a young man he had seen and still remembered. It seems to me that certain characteristic features, which were a reminder of some particular bird, originally caused women of certain tribes to be called by the name of this bird.

In Buka I have observed a similar thing. Here a canoe drifted on shore in the beginning of 1880. The men were killed, but three women were spared and taken as wives by the natives. I have known two of these women, who told me they belonged to Asarai, in the Gilbert Islands. These two were married to men of the Pigeon group, and their children were supposed to belong to the Frigate Bird group, the Pigeons, of course, having taken it for granted that the women belonged to the Frigate Bird group, in order that they might be able to take them as their wives.

In explaining native customs and their origin I have always found that it is necessary to go back to the simplest way of explanation, and I think that the explanation of the origin of totem as I have briefly outlined it agrees perfectly with native reasoning. The system of totem in itself would undoubtedly in the course of time lead to further development; it would bring into closer contact tribes who formerly lived in hostility to one another; it would effect an exchange of women, to the mutual benefit of the tribes; it would create family ties where none existed before; it would create the conception of property, both tribal and individual; in short, it would be the basis of social development. But, together with this development, new customs would spring up, modifying older customs and institutions or adding to them, so that at present in many cases it is difficult to discern what is the original custom, and how it has been developed or extended and enlarged by later customs.

This seems to me to be the case in Australia. Totemism has been connected here with other customs, and especially with the secret societies; whereas in Melanesia the totem customs, and all that belonged to them, have kept clear of the secret societies. Of these we find a great number all over Melanesia, some of them being very old, as the Buri of the northern Solomon Island; others being comparatively recent inventions, as the Duk-duk of the Gazelle Peninsula and Duke of York Island, a society not yet a hundred years old. But all these societies, young or old, are based on one foundation, the carrying out of sorcery, the initiating and instructing in it, and the tendency to create for its members a chance of superior living by terrifying the women through all kinds of superstitious fears, causing them to keep away from the meetings of the society members, and to supply them with abundant food in order that the anger of the spirits who are supposed to confer with the men might be avoided.

There can be no doubt that the secret societies are institutions of a much later date than the totem. The latter is unquestionably one of the oldest institutions of man, and it is no wonder that in later ages it was enlarged upon and ornamented with a great deal of by-play, which has in reality little to do with the original institution.

The native of to-day is a very practical being; primitive man unquestionably was very much like him, and his customs and institutions had always, as they have up to the present day, a practical purpose. What higher practical purpose could primitive man have than to keep his tribe strong and vigorous, able to procure abundant food, and able to defend itself against enemies? His thoughts would naturally be centred on these questions, and as a strong and vigorous offspring was of the greatest interest to the welfare of his tribe he would of course devise ways and means to procure such offspring. In Melanesia we see that up to the present day this is the sole object of what we call totem, and I have no doubt that in Australia it was the same in the beginning.

I have been thinking sometimes that the great similarity in customs between Australians and Melanesians might be the result of a common origin. There are certainly many customs that are actually the same in both divisions, and it is remarkable that this similarity occurs, not so much in the leading custom, but in all sorts of small by-play that winds itself round the institution like an ornamental border round a picture. At present, however, we have to leave this an open question. The works of Spencer, Gillen, and Howitt show us the way in which we may be able to solve it; but as yet we know very little about the Pacific races, and especially the Melanesians. It is, therefore, to be hoped that persons living in the Islands, especially missionaries of the various denominations, who come into closer contact with natives than any other settlers, would take up the question and follow the example of the Australian anthropologists who in so able and masterly a manner have shown the way.

Section G (I.)

SOCIAL AND STATISTICAL SCIENCE.

ADDRESS BY THE PRESIDENT,

PROFESSOR FRANCIS ANDERSON, University of Sydney.

LIBERALISM AND SOCIALISM.

It is just 40 years ago since John Bright, in reviewing the political situation in England, said, "We have got household suffrage; we have got the ballot. In a year or two we are pretty certain to have national education; and after that I really do not see what there is that Parliament can usefully do for reform or progress." Many things have happened during those 40 years. Many changes have taken place in political theory and political practice. But the greatest change has been a change in the way of looking at social and political problems, a change of mental attitude. Such changes of attitude on a grand scale are rarely sudden or spasmodic, although their results may be made manifest in what seem sudden, even revolutionary, changes to those who are blind to the signs of the times. Acts of legislation, even when they appear to be leaps in the dark, breaches with an honored past, are themselves effects and symptoms of a change in national temperament and outlook. It is only when we hear voices from the past, speaking words like those I have quoted, that the magnitude of the change is made plain to us. It is a change of sentiment. Our hopes and fears are not the same as those of the generation of English liberals who found in John Bright their most eloquent, if not their most thoughtful, representative. And behind the change of sentiment there is a change of ideas. Words like progress and reform are, in themselves, almost meaningless. As Disraeli said, "They are phrases, and not facts: words to mystify the millions." An Oxford undergraduate luminously defined progress as "advance in the direction in which things happen to be moving." But that definition would apply to progress down a steep place into the sea. Words like progress and reform have meaning only in reference to certain ends or ideals, and it is clear that the ends or ideals which now govern the social and political effort of great bodies of men, transforming and creating political parties, and altering profoundly the character of legislation, have outgrown the formulas which seemed to most of our predecessors to sum up the whole faith and duty of the practical politician.

If we are content for the moment to use the words Liberalism and Socialism as describing general tendencies rather than cut and dried creeds, we may not err in calling the nineteenth century the age of liberalism and in naming, in anticipation, the twentieth century the century of socialism.

Liberalism was the heir of the French Revolution. It stood for the spirit of liberation—freedom from all control which would hamper the individual in his task of developing his own powers, and finding the social place for which those powers fitted him. Its motto was "*Toutes les carrières ouvertes aux talents.*" So far as it uttered any moral imperative to the individual, it called upon him not to abide in the place, but to find the place to which he was called. So far as it offered any practical guide to social and political effort, it called upon society to unite in freeing itself from the restrictions which had been inherited from the misgovernment of the past. And as those inherited restrictions were numerous, and often excessively burdensome, liberalism started with a practical and popular, even although it was in the main a negative, programme of reform. The banners waved, the trumpets sounded, and the liberal party moved from victory to victory, until John Bright seemed to see in the immediate future—that is, in our past—the end of any need for further legislation, the coming of the political millenium, when there would be no work left for liberal hands to do. We need not be disrespectful to our predecessors because changed conditions have led to a change in sentiments and ideas. Without the liberalism of the nineteenth century, the socialism of the twentieth century would not have been possible. It is a superficial view of political evolution which sees in socialism only a reaction, more or less prolonged, against the individualism of the school of *laissez-faire*. The "swing of the pendulum" is a convenient but misleading metaphor, useful as a consolation to the political party for the time out of office, but without scientific value as descriptive of the actual course of social evolution. The movement of liberalism was really a preliminary clearing of the ground for the movement of social and political reconstruction.

Now, whenever a great movement takes place there appears, sooner or later, a theory of the movement, and sooner or later the theory tends to harden into a creed, which, like most creeds, may have only an historical or polemical value. We continue to fight over the meaning of the creed long after it has ceased to apply to the facts of life. Life moves on, and the first postulate of all scientific explanation is that the theory should be adequate to the facts. It is true that no theory —and especially no social theory—ever is adequate to all the facts of the case; but it has always been the curse of theories of social progress to be identified with the rough generalisations of political practice, the results of the analysis of a particular epoch. And this applies to the gospel of collectivism as well as to the gospel of *laissez-faire*. Man cannot do without a working hypothesis, whatever be the sphere of inquiry; but it is harder in politics than in any other department to avoid the fallacy which consists in interpreting the facts by a theory which has ceased to apply to them.

Social science and social practice seem at the present moment to be at the mercy of two conflicting dogmatisms—the dogmatism which denies the State and the dogmatism which deifies the State. Both forms of dogmatism have arisen as partial and opposite interpretations of the same data. Both stand for ideals which, as they are described in theory, never have existed, and, it is safe to say, never will exist, in any society of human beings. And the confusion of present politics is due to the fact that opposing parties are compelled in practice to make illogical concessions to each other, to adopt in turn each other's policy, while reprobating each other's principles, with the result that the non-voting majority of the electors continue in their attitude of indifference, and are more than ever convinced that politics is a game, and a general election a kind of sham fight. I do not urge this as an objection to that spirit of compromise which is a necessity of practical politics and the source of the strength and permanence of our national institutions. We are concerned here with political science rather than with political practice. But I would respectfully ask whether our political practice would not gain if a clearer recognition of the changed conditions of social life brought with it a change in the nature of political controversy. There are so many live issues to be determined that it seems a pity to waste our energies over the discussion of dead ones.

The controversy over the question of Government interference seems to me to be in great measure a fight over a dead issue. The economic theorists of the first half of the nineteenth century were acutely aware of the evils which stupid restrictions on industry and commerce had engendered and fostered, and they set themselves the task of inquiring into what would follow on the entire abolition of such restrictions. The result of their inquiry was the establishment of the traditional political economy which provided a mistaken political gospel to the leaders of the great liberal movement. The mistake was made of treating economic generalisations as moral laws of conduct. The doctrine of non-interference was preached, and was extended from trade relations to almost all the relations which constitute social life. The exponents of the liberal creed did not go so far as the philosophic anarchists of our time, who boldly demand the abolition of all Government interference. Yet they sought, in theory and practice, to reduce the functions of the State to a minimum which could be defined once for all, in set terms, as the defence of the lives and property of the individual members of society. It was thought that at last liberalism had found a final creed, of which it could say, *J'y suis, j'y reste.* But political creeds represent milestones on the road, rather than permanent abodes.

The most effective refutation of a fallacy is to point to its practical disproof in experience. The actual course of liberal legislation was the experimental disproof of the narrow and negative doctrine of non-interference with the economic organisation of society. At the same time almost every new extension of government control, every new successful demand that the business of the State was the organisation of society for certain common purposes and interests, the most important of which was its own economic well-being, was met by the assertion that the new act was only an exception, or a concession, to circumstances, in no wise to be interpreted as a permanent departure from the liberal faith that the best of all social worlds was that in which the State interfered as little as possible. Even of Gladstone it has been written (Paul's "Modern England," vol. V., p. 231): "The special claims of labor did not appeal to him. His service to the working classes was the removal of taxes on food and on the raw material of industry. He had no belief in limiting by law the hours of work for mines or factories." It might be argued—and the course of social and economic history supports the argument—that if the functions of government were reduced to the required minimum what would remain would not be free, self-governing individuals, harmoniously co-operating with each other, but social groups, specialised associations, united for selfish interest and exploitation of society in general. To remove the so-called despotism of the State would not be to set up an individualistic paradise, but to leave the field free for other and worse kinds of despotism—the despotism of the father, the despotism of the employer, the despotism of the priest, not to speak of the tyranny of social and commercial combinations which would have the "outward forms and material advantages of socialism, without its ideal — the general good of the community." Liberalism, as well as socialism, cannot do without Government intervention, whether we call such intervention grandmotherly legislation, or simply the necessary extension of the economic functions of the State. The State is society organised for the common good, for the protection of individuals against groups, associations, unions of masters or unions of men, who, without such common State action, would make freedom of individual development impossible. To reduce State functions to a minimum would be to reduce the possibility of individualism to a minimum. Part of the strength of socialism as a fighting political creed just lies in the recognition of this fact, and on the emphasis that socialistic legislation is a means, and not the final end, of politics. The eminent French socialist and statesman, J. Jaurès, declares socialism to be "the supreme assertion of individual right. Socialists desire to universalise human culture. For us the nature of every institution is relative to the individual. There is nothing above the individual. The individual is the measure of all things—of family, property, humanity, God. *Voila la logique de l' idée revolutionnaire. Voila le socialisme.*"

We may, then, dismiss as a false antithesis the opposition between individual and social interest which has been in the past, and is still, the source of so much futile political controversy. The question of practical politics in this respect is not different from the theoretical question. It is not a question of the maximum or minimum of interference on the part of a Government supposed to stand outside and aloof from the classes to be governed. It is a question of social self-organisation, and a question not so much—except for fanatics and extremists—of the *quantity* as of the *quality* of such social self-organisation, of how far the forms of social and political organisation will help and not hinder the free self-development of the members of the community. In a word, the question is—How shall we help the individual without in so doing tempting him to cease from self-help? It is a matter of indifference whether we describe the social goal as the production of the perfect man or the perfect society. From the point of view of ethics—that is, of the ends or ideals which it seems incumbent on humanity to realise—these two phrases are but different forms of expression for the same fact. But from the point of view of practical politics, the problem cannot be solved by appeal to phrases or by verbal definitions of socialism which satisfy no one but the framer. Nor can social science, so far as it exists at present, do more than analyse—and that very imperfectly—the general conditions of the problem. It cannot adequately diagnose the situation, much less provide an infallible remedy. Social evolution represents the last and most complex phase of the process of cosmic evolution; and the laws and conditions of the final stage of an evolutionary process are dependent on the laws and conditions of the previous stages. In every higher formation the properties of the previous lower formations persist—even when other properties appear as further manifestations of the fundamental cosmic energy, disclosing new and higher ends to be achieved—vital, social, and moral. And, further, every higher formation consisting of a greater number of elements and properties is subject to a greater number of changes and combinations, resulting in specialised forms of action which cannot be determined merely by direct deductive application of the laws of the lower stages of evolution, but only by an examination of the new facts and the new needs. Social science is a new science which has still to master the complexity of the social fact, and social problems can be solved only by that wise adaptation of means to ends which partly follows and partly anticipates the actual course of social evolution. It is, however, the special office of social science to emphasize the fact that the path of social evolution is in great measure determined by events over which the legislature has no control. "What was decided among the historic protozoa cannot be annulled by Act of Parliament."

This position, however, must not be misunderstood. An Australian statesman said some time ago that "Every country must have a political economy to suit its circumstances." It is probable that what the speaker meant was not quite the same as what he said. This sometimes happens in the case of public speakers—even in the case of Australian statesmen! It would be very convenient and very pleasant if every country could produce by legislation a meteorology to suit its circumstances. But since that is impossible, man invents umbrellas and constructs irrigation works. And we may admit, what the economist of abstract theory too often forgets, that every country has, and must have, a politics of its own—a politics to suit its circumstances. A political policy—even a protectionist policy, whether it be for protection of local manufactures or protection of local labor—may be in some ways expensive; but it is not on that account alone, foolish and damnable. Social science is not purely and simply an application of the laws of the abstract science of economics, any more than it is a direct deduction from the laws of biology. At the same time, protection, wherever it exists, implies and is a standing proof of the validity of economic laws, although it may sometimes afford a practical disproof of the false deductions made by short-sighted economists. It may be true, for example, that labor combinations are unable permanently to maintain the remuneration of labor above a point which it would have reached *under favorable circumstances* without such combination. But the laborer himself is more concerned with the unfavorable circumstances, and with the fact that combination has in many cases kept the rate of wages from sinking to a level which it would inevitably have touched without such combination. And this may be granted without admitting the validity of Marx's supposed iron law of wages. A law, in the scientific sense, is nothing more or less than a necessary relation between any event and the conditions in which it takes place, and it has been the misfortune, alike of the old economist and of the new socialist, that they have been too much intent on the hypothetical event, and too little observant of the actual conditions. The old economists were at once too optimistic and too pessimistic. They were too optimistic in their view of the good which would result from a regime of unrestricted competition, from the operation of the "natural economic laws" which were supposed to govern society. They were too pessimistic with regard to the powers of man and society over those natural laws. When the free play of economic forces seemed to produce results which offended the moral sense of the community, the economists for the most part contented themselves with saying that nothing could be done to counteract them. The result, in the field of practical politics, was that when the negative programme of the Liberal Party was accomplished, liberalism found itself without any positive policy for the future. It had maintained itself by attack in the past, and in default of any positive scheme of social reconstruction it is now suggested that liberalism may continue to live and fight under a banner with a negative device—Anti-Socialism.

It is a tendency of human nature—especially of religious and political human nature—when it loses faith in one set of dogmas to take refuge in another set, and to assert them with the same extravagance and disregard of facts. The politician in search of a gospel to take the place of the discredited doctrine of *laissez-faire* is offered the gospel according to Karl Marx as a substitute for the gospel according to Adam Smith. I have hitherto spoken of liberalism and socialism as general tendencies of social and political life, rather than as fixed and stereotyped forms of political creed. To avoid ambiguity, I shall henceforth use the word "collectivism" to denote that definite doctrine which opposes the assertion that the functions of the State should be reduced to a minimum, with the counter assertion, equally sweeping and equally dogmatic, that the functions of the State should be extended until the difference between society and the State is abolished, at any rate in everything that pertains to the economic sphere. If this extravagant state absolutism were to be regarded as identical with the practical state socialism which promises to become the guiding principle of the politics of the future, then anti-socialism might well seem the prudent policy to the bewildered citizen, who is told that his only choice is between two clenched antagonisms, or between the devil and the deep sea. Dr. Johnson advised that we should keep our minds free from cant. Social science bids us avoid the contagion of hysteria.

Socialism has passed through three stages during the last century, and although enthusiasts and extremists may linger in the first or second stage, political theory, and, in an increasing measure, political practice are mainly concerned with the third stage. The Utopian socialism of the early part of the nineteenth century was the work of imaginative dreamers, or of reformers possessed by a single idea. Like the apocalyptic visions of the early Christians, their schemes of social regeneration and reconstruction were valuable mainly as signs of the times. The second stage of socialism is that which is sometimes named scientific socialism, but which ought rather to be called dogmatic socialism—the socialism of abstract theory, the collectivism of Karl Marx and his successors. The third stage is the stage of practical socialism, in which the demands of the ideal theory are subordinated to the necessities of the political situation, and the goal or "objective" of socialism is put more or less in the background, appearing or disappearing according to circumstances.

Collectivism, or the doctrine of state absolutism, is both unhistorical and unscientific. It is one of the most striking examples of a tremendous generalisation, derived from grossly inadequate data. It is based on a narrow and dogmatic reading of history, in accordance with an *a priori* doctrine of value and a fictitious law of wages. What the great protagonist of collectivism, Karl Marx, did was, in the first place, to analyse with great thoroughness a particular period of modern evolution—the transition from domestic production to what he called capitalistic production—and to treat the results of this analysis as if they expressed a universal law or tendency. He next proceeded to make deductions from the supposed universal law, deductions as to what history should be, how industry and capital and labor must develop, in fact to build up a whole philosophy of social and political life. If the facts of history do not fit into that philosophy, then so much the worse for history. The logical collectivist will continue to prophesy. With that consistency which is the essence of fanaticism he demands the system, the whole system, and nothing but the system. In the field of prophecy, as in the realm of fiction, events move smoothly and quickly, once the necessary assumptions are made and inconvenient difficulties ignored. Marxism leaves out half the factors in the social problem, and so succeeds in representing the future course of history as a uniform progress towards the collectivist state, which will in time swallow up every form of economic organisation into its capacious maw.

As for its theory of value, collectivists, generally, seem to be unaware that though it is the corner-stone of their temple, Marx himself practically abandoned it before his death. The supposition was that value is determined by quantity of labor. According to Engels, perhaps the greatest intellectual force among the collectivists, Marx admitted (in the third volume of "Capital," not published until after Marx's death, and not yet translated into English) that the labor theory of value was only a category of the past, roughly descriptive of an obsolete mode of production. It ceases to be valid when applied to the complicated system of modern industry and commerce. This is obvious enough. The value of separate individual labor no longer coincides, granting that it ever did coincide, with price. Quantity of labor is only one of the factors which determine the value of a product. The decisive factor is the capacity of the object to satisfy a given economic need.

Now, the theory of remuneration according to labor cost, as put forward by collectivist theorists, rests upon the following assumptions. It assumes, first, the abolition of the competition which has hitherto been the main instrument in maintaining and extending the supply of commodities. And in the absence of that competition it assumes a stable and permanent equilibrium between supply and demand—that is, between the total national supply and the total national demand. It assumes, further, an average man, who does not exist, and an equality between different kinds of labor, so that they can all be estimated as regards their value—social, æsthetic, political, educational, economic—in terms of labor time. And it assumes, finally, for its successful work--ing—to mention no other assumptions—that the problem would not be complicated by the ever-varying values which would be attached to different objects in demand by different persons at particular times and places.

Some collectivists have simplified the problem of remuneration in the labor state by proposing to distribute the products of labor according to the reasonable needs of the laborer. If one were tempted to follow the example of collectivist writers, and try to shine in the high prophetic line, one might predict that this would lead to a system of exploitation worse than any conceivable under capitalism. It would mean the appropriation by one set of persons of the surplus value created by others. Laborer would exploit laborer. The lazy would exploit the industrious. The impudent would exploit the modest. And the demagogue would become the universal engine of exploitation.

Of course, when a man or a party has a gospel, we cannot object to the preaching of it. The collectivist has his visions of a simplified social state, and I wish to rob no man of his visions of a new heavens and a new earth. It is through visions, through ideals, that man moves on to higher things. Ideals, like poetry, enrich the blood of the world. But it is one thing to preach ideals, another thing to impose them. I have not a word to say against that practical state socialism which seeks with knowledge and careful forethought to secure and maintain the conditions under which it will be possible for every citizen to develop his activities so as to lead a healthy and happy as well as a useful life. But collectivism would try to attain its ideal in the wrong way—by eliminating a necessary condition of human progress, or rather, a necessary condition of human life itself. It is said that in the collectivist state competition will not be abolished, but only competition for profits. Competition will remain, only under another name. People are always ready to allow themselves to be cheated by phrases. The question is—and I do not think that this question has ever been satisfactorily answered—Will not the change produced under the supposed conditions of economic equilibrium be merely a change in the *direction* of the competition ? The stimulus to do the best for oneself and for one's own, the stimulus even to get the better of one's neighbor, will remain. Only, on the basis of equality of reward, the competitive stimulus will work downwards rather than upwards. To suppose that a system of equality of reward will be sufficient for all requirements of the collectivist state is surely one of the most extraordinary delusions which has ever taken possession of the human mind. "The devil take the hindmost" is not a maxim for a moral community or for a moral being ; but there is, if possible, a still more objectionable maxim —"The devil take the foremost."

It is, however, I must confess, almost as idle a task to attempt to disprove the collectivist ideal as to attempt to prove it ; for its realisation, like that of the New Jerusalem, is not open to verification in experience. But socialism, in entering the field of practical politics, has itself become practical. It has been forced to surrender the pure gospel of collectivism, and its visions of an immediate social transformation. The socialist party of the new era declares itself ready to work for practical ends which are immediate and possible. The revolutionary and ideal elements are put in the background, or they are partly concealed and partly revealed in some abstract definition of an objective to be realised in some distant future. John Stuart Mill once said to the working men of London : "You need to be convinced, first, that a revolution is necessary, and, next, that you are able to carry it out." The practical socialist party of to-day seems to be convinced, first, that a revolution in the old sense is neither necessary nor probable, and next, that the way to the desired social reconstruction is by the path of ordinary legislation. I do not think that it is a valid objection to the discussion of the practical programme of the socialist party that the ideal or objective of the party goes far beyond its immediate performance or even promise. Mr. Bryan, the leader of the American democratic party, said the other day, after advocating nationalisation of railways : "I do not know that the country is ready for public ownership. I believe in a great many things that I would not put in a platform." The honesty of the Labor Party in framing its objective is as least as great as that of one of America's representative men. In a free community the best way to treat extravagant ideals is to let them bear the brunt of free discussion. There is a law of natural selection, by which ideals which cannot be adapted to the conditions of actual life perish, or live on only in the hopes of fanatics, or in the fears of fools. But there is one thing to which valid objection can be taken, and that is the tendency to use an abstract theory as a practical principle of legislation in defiance or contempt of the evidence of the facts. It may be a difficult question to determine in a given case what a monopoly is, or when and for what reasons it ought to be taken over by the State. But when a parliamentary commission (as in the case of the recent Tobacco Commission), supposed to be a judicial body, issues a report which is an immediate deduction from an *a priori* theory of the functions of the State, rather than a careful induction from fact, we may reasonably assume that the education of the socialist party has still a long way to go. Yet the important and hopeful thing for Australian political progress is that the socialist party is learning by experience. It is acquiring that sense of responsibility which comes with the consciousness of power and with the consciousness of the limitations before which the fanatical propagandist stands blind and helpless. It is difficult, no doubt, for enthusiasts for co-operation to resign themselves to the slow movements of the processes of social evolution. The kingdom of collectivism, it would seem, must be taken by violence. But no radical system, not absolute individualism, and not absolute collectivism, can do anything but fail when it tries to impose its artificially simplified solution of the social problem on an organism so complex as the society of the present. And the society of the future promises to be more complex still. He that believeth in liberty and the law of liberty will not make haste to abolish those conditions under which poor humanity has reached its present measure of spiritual development, or seek to enslave men in order to unite them.

Section G (II.).

AGRICULTURE.

ADDRESS BY THE PRESIDENT,

THOMAS CHERRY, M.D., M.S.,

Director of Agriculture, Victoria.

THE OUTLOOK FOR AGRICULTURE.

In taking a survey of the agricultural outlook at the present time, I wish first briefly to summarise some of the main facts which will determine the future of Australian agriculture, then to take a glance at the position of our leading products in the world's markets, and, finally, to indicate the chief lines on which I think we can maintain agriculture—the ultimate basis of a nation's prosperity—in a sound and progressive condition.

ALL AGRICULTURAL WEALTH FROM THE SOIL.

I need hardly remind you that the true measure of the fertility of the land is the readiness with which the plant food of the soil can be made available for plants which serve as food for animals or man. It is true that a certain amount of agricultural wealth consists of timber trees and fibre plants, but, on the whole, these form accessory rather than staple products. The plant uses the energy of the sun to build up comparatively simple chemical substances into the much more complex compounds necessary to maintain the life of the animal. The energy of the animal is derived from the breaking down of those complex substances into simpler ones, which ultimately are returned to the earth and atmosphere. Sooner or later they all undergo such changes that they may once more serve as food for the plant. The most far-reaching generalisation which has been made in recent years in connection with agriculture is the discovery of the part played by microscopic plants, or bacteria, in producing and maintaining the fertility of the soil. Not only do they break down the excreta and dead tissues of the animal into forms available for the plant, but we have recently learnt that they cause the free nitrogen of the air to combine with oxygen. This combination is the first step in the wondrous ascent which leads to the transformation of dead into living matter. I am inclined to think that the best measure of the fertility of the soil is the acutal number of micro-organisms which it contains. We regard the soil no longer as dead and inert, but alive and active. No small part of the activity of the soil organisms is seen in the extent to which they form acids and alkalies from the carbon compounds which they use as food. All plant food must be dissolved before it can be taken up by the roots of the plant. The chief solvent is carbonic acid, and probably most of this which is present in soil water is formed by the micro-organisms of the soil. In addition, there is little doubt that much more active acids and alkalies are also formed by the bacteria, and that these not only help to complete the weathering of the rock particles in the soil, but also change the phosphates and potash from insoluble to soluble forms.

THE PLANT FOOD OF THE SOIL.

All plant life is dependent not only on the amount of nitrogen, phosphoric acid, and potash, but also on the water supply of the soil. How the moisture can be best regulated is too wide a question for me to touch at present. I would merely remind you that in order to produce 1 ton of sun-dried vegetation there has been absorbed by the roots and transpired through the leaves of the plants from 300 to 500 tons of water. That is, 1 ton of dried material per acre requires the full utilisation of from 3in. to 5in. of rain.

Considering first the soils of Australia, I presume that, so far as they go, the results obtained from the analysis and experiment with those of Victoria are fairly applicable to the rest of the continent. We have to consider each of the three chief constituents used by the plant—nitrogen, phosphoric acid, and potash. So far as results of analysis are available, it appears that on the average our soils are as rich in nitrogen as those of Europe or America, and nitrifying processes seem to go on with such rapidity that for the most part, especially in dry areas, there is no need to add this element to the soil in the form of artificial fertilisers. On the wheat lands the addition of nitrogen actually diminishes the yield. Where the rainfall is above 25in., the addition of nitrogen increases the yield of grain, and also the total weight of the crop, but the former effect is not so marked as the latter. For the most part the soil appears to be abundantly furnished with nitrifying bacteria; all leguminous crops flourish luxuriantly, and, so far as our experiments have gone, the addition of nitrogen-fixing bacteria to the seed has had no apparent effect in assisting the crop. Considering that all animal excreta and farm-yard manure are proportionately very rich in nitrogen, it appears practicable, by good farm methods, not only to keep up, but also to rapidly increase the amount that exists on virgin land. The nitrogen problem is important, but by scientific methods it may easily be solved, and at present I think there is no indication that it will become as important as it is in Europe and America. While we are not yet able to explain all the phenomena, it appears certain that in this respect we are favored either by the soil or the climate; and the marvellous growth which takes place after a few months dry and hot weather would seem to suggest that nitrification proceeds very rapidly in the soil during the summer. For market garden crops and potatoes, especially on the lighter sandy soils, it is found that a light dressing of nitrogen, in readily available form, ensures a profitable crop; but for cereals, and for ordinary fodder crops, the cost of supplying the necessary amount of nitrogen is not a serious problem to the farmer, and it appears to me that with improved farm practice it will become even less formidable as general farming takes the place of cereals alone. The presence of lime in suitable amount facilitates the process of rendering the nitrogen available, as will be noticed later on.

Turning next to phosphoric acid, we may look upon this constituent as being, in a special sense, the controlling factor in the development of plant life. It is remarkable that the world supply of nitrogen, phosphoric acid, and lime at present available for the use of existing plants and animals has all been combined and rendered available by past generations of living things. Originally, all the phosphoric acid of the soil formed part of the most ancient rocks in the form chiefly of apatite. It has gradually become concentrated on the surface of the soil by the intervention of plants and animals. Comparatively little is leached out of the soil by the rain, only the barest trace being present in sea water. In the case of rock phosphate, the seaweed growing in shallow depths has collected this trace of phosphoric acid from the sea water, just as the coral and other organisms have collected the lime, or the copper sheathing of a ship causes the deposition of silver and gold. From the seaweed the conversion into rock phosphate is accomplished through the medium of the fish and birds. We are at the present time drawing on the accumulations that have been made in past geological ages. In the case of the phosphoric acid of the soil, this has been gradually accumulating in the surface layers through the medium of the plant, but its concentration is brought about through the intervention of the animal. The nearly insoluble phosphate of lime of the bones of vertebrates offers striking analogies to the similarly insoluble carbonate of lime of the shells of invertebrates.

PECULIARITY OF AUSTRALIAN SOILS.

The following table gives the result of analysis of 186 samples of Victorian soil recently made in the laboratory of the Department of Agriculture. For comparison, I append the results the averages of 10 types of English soil, made by Hall, and of a large number of American soils by Hillgard. It will be seen that our soils are well above the recognised limit of efficiency as regards nitrogen (100 parts per 100,000), but very close to the limit of inefficiency as regards phosphoric acid. European and American authorities look on 50 parts per 100,000 as the limit below which it becomes unprofitable to work the soil. It also appears that our subsoil is nearly as rich in phosphoric acid as the surface layers. Potash and lime are so abundant that they call for no comment.

	Soils.					Subsoils.				
	Nitrogen.	Phosphoric Acid.	Potash.	Lime.	Chlorine.	Nitrogen.	Phosphoric Acid.	Potash.	Lime.	Chlorine.
Victoria, clay soils (30)	149	63	205	176	10	100	66	232	155	8
" northern plain (34)	112	61	422	1,072	9	89	60	706	2,487	20
" coastal plain (85)...	178	61	185	903	7	106	46	247	380	13
" volcanic (24)	272	61	277	588	17	103	42	170	1,649	6
" mallee (5)	113	47	380	2,426	7	—	—	—	—	—
" drained swamps (8)	750	76	263	315	40	191	31	154	121	19
England, typical soils (10)...	175	98	463	—	—	—	—	—	—	—
American, arid (466)	—	117	729	1,362	—	—	—	—	—	—
" humid (313)	—	113	216	108	—	—	—	—	—	—
" sand } all samples	—	128	157	115	—	—	124	143	96	—
" clay } all samples	—	207	214	1,761	—	—	159	344	1,481	—

LIVE STOCK ESSENTIAL TO SOIL FERTILITY.

It is often asked if there is not a certainty in the early future that such soils will become exhausted of their supply of plant food, and become unprofitable. So long as live stock are kept in considerable numbers, this is not likely to happen. I take it that Australian soils owe their small phosphoric acid supply to the fact that the continent has never been heavily stocked by large animals of any kind. In Victoria we know that previous to settlement by white men the number of kangaroos and emus was much less than the number of sheep is at present. Periodical droughts reduced them in the north; vast areas were so densely timbered that there was little herbage for them to eat. There were never very many natives in Victoria, but there were quite enough to keep the large animals from becoming numerous on the open plains. Now, the animal is the great factor in concentrating phosphoric acid in the surface layers of the soil. It is true that where no animals are present nearly all the components of the plant are returned to the soil by the process of decay. But the animal stimulates the plant to increased growth. As the flower shoots in particular are browsed off, fresh efforts are made to produce a new crop of seeds. Hence more phosphoric acid is drawn up by the roots from the deeper layers of the soil. The animal concentrates the phosphates chiefly in the bones, and when death occurs the bones are slowly but surely incorporated in the earth. In addition, phosphates are being continually returned to the soil in the excrements. The carcass of one sheep to the acre represents the application of 2lbs. of phosphoric acid, or about 10lbs. of ordinary superphosphates. This quantity does not appear very large, but when the process is repeated year by year for centuries the amount steadily accumulates. As phosphoric acid becomes available in increasing quantities the growth of plants of all kinds is stimulated, and consequently more animals can be carried in a given area. Nature's methods throughout all bygone ages are precisely what every thoughtful farmer aims at imitating at the present day. Just as living plants and animals have slowly accumulated the potash and lime from the sea water till they form vast masses of dry land, so the nitrogen and phosphoric acid have been gradually made available for existing plants and animals by their predecessors throughout all the geological ages. The soils of Victoria are just beginning to be improved by animals. The transformation of the hill country, which is brought about by the introduction of Merino sheep, may be studied about Alexandra or Tallangatta, where a few years have already made great changes. Judging by what has already occurred, I think we may have no misgivings for the fuutre.

The average chemical composition of Victorian soils as taken from the preceding table bears out the inferences drawn from the examination of soils of various localities. Judged by European standards, the amount of fertility is often small. When it is attempted to make an estimate of the amount of plant food in readily available form (soluble in water or citric acid solution), the results are very disappointing. Yet the practical results are precisely the opposite, and it may well be doubted if any soil in the world is more prolific. The total amount of agricultural products consumed locally and exported is valued at over £20,000,000, or an average production of nearly £400 per farm. As only one acre out of every eight of the occupied part of Victoria is at present under cultivation, the above results are achieved to a very large extent simply by grazing the natural pastures. The soils from Mildura, in the Mallee, are much below the average in phosphoric acid and nitrogen, yet under irrigation 10,000 acres support a population of 5,000, or 330 persons to the square mile. Here again development is just beginning, for with the application of more labor the returns from the irrigated land could be vastly increased. From the strictly chemical point of view, much of the wheat land appears to be in danger of early exhaustion, yet after many years of grazing and cropping it is more valuable than ever. Similar instances could be quoted from every part of the State. Another point which must be remembered is the fact that nearly all the cultivation in Victoria is found in districts with a comparatively light rainfall.

Reverting to the total weight of each ingredient present in the surface foot of each acre, it will be seen that rich soils contain in this amount of soil 3¾ tons of nitrogen, 3 tons of phosphoric acid, and 8¼ tons of potash. One of the poorest contains 1 ton of nitrogen, 6cwts. of phosphoric acid, and 9cwts. of potash. As a 20bush. crop of wheat (straw and grain) removes only 35lbs. of nitrogen, 14lbs. of phosphoric acid, and 25lbs. of potash, it will be seen that even poor soil contains materials for generations of cropping if the proper ingredients can only be made available. The phosphoric acid would last about 48 years. There is, however, the subsoil to draw on, and we have seen that phosphoric acid is nearly as abundant in the subsoil as in the surface. With intelligent farming there is no question but that the amount of plant food will steadily increase. The striking results produced by the application of 10lbs. of phosphoric acid in the form of superphosphate has been already referred to. Such a small amount cannot perceptibly increase the total per acre. At the most, it can only give the young plants a good start, because, from what we know of the residual effects of such applications, it is fairly certain that the whole of the added phosphoric acid is not absorbed by the growing crop. There must, therefore, be certain changes going on in the soil during the growth of the crop which rapidly render the latent plant food available. What these are we are not in a position at present to state precisely. The marvellous growth that occurs everywhere when the rain comes after a dry spell shows that there are forces at work during the months of bright sunshine which are very friendly to the husbandman. The fact that applications of nitrogen actually reduce the yield in the northern plains confirms this view. Many acres of the poor sandy soils within 20 miles of Melbourne are bought and sold at from £20 to £40 per acre, after they have been under cultivation for a few years, and where such improvement is daily taking place it is certain that it will follow on the same methods being applied to more remote districts as population increases. The absence of land animals accounts at once for the luxuriance of our primæval forests, and the scarcity of phosphoric acid on the surface of the soil. Had the herbivora been well represented in the past, they would have destroyed the young trees, and at the same time have concentrated the plant food. The existence of dense forests proves that Victoria contains no barren land, for soil that will produce such trees will most assuredly produce a bounteous harvest when its forces are controlled by the intelligence of man.

With regard to the relatively large amounts of potash and lime in the northern soils in Victoria, these substances have been shown to have a very important influence in a number of ways. First of all they favor the growth of micro-organisms in the surface soil, and in this way lead to the rapid oxidisation of organic matter, and the consequent formation of humus. They have, therefore, a direct effect in rendering both the nitrogen and phosphoric acid more readily available for the plants. A soil well supplied with humus is in the best possible condition for maintaining a proper amount of moisture in readily available form in its superficial layers, and hence it follows that soils well supplied with lime and potash are, in proportion to their rainfall, in a good position to have practically the whole of the moisture available for the plants. In the coastal districts, where the rainfall is heavier, and consequently the amount of soluble material which is washed away in the course of each year is considerably greater, we find that the amounts of both phosphoric acid and potash are such that the addition of both these substances gives profitable results. In addition to this the rainfall is sufficiently heavy to allow the plant to make use profitably of a larger percentage of nitrogen in readily available form, and hence it follows that the addition of nitrates or ammonia salts causes a large increase in the yields.

MARKETS AVAILABLE FOR AUSTRALIAN PRODUCE.

Turning next to the question of the disposal of the agricultural products raised in Australia, several points challenge attention. The first is that during the last half-century there has been a steady increase in the consumption per head of food stuffs by the great mass of the population of most civilised countries. A trifling increase each year means an immense expansion in the total amount. While production has been advancing very rapidly, consumption has been advancing at an accelerated rate, and what has happened in the case of European communities will probably also follow in the case of the Eastern nations. It need hardly be pointed out that a slight change in the dietary of these nations, which constitute one-half the population of the earth, must have a profound influence on the demand for any given article of diet. Speaking broadly, I think there is no doubt that wheat and wheat products, animal food and animal products, are steadily displacing less nutritious articles of food all the world over. While the demand for agricultural products, such as those which form the staple industries of Australia, is likely to increase, we have only to turn to the importations into Great Britain over a series of years to see the market—practically unlimited in extent—which is open for us to exploit, and of which up to the present moment we have only touched one or two lines. The following table shows the average value of importations into Great Britain in millions sterling during each of the last six years. The total amounts to £224,000,000. The value of these imports in millions of pounds sterling is as under :—

Live stock for meat	10	millions
Dead meat	38	"
Butter, cheese, milk	31	"
Wheat and flour	38	"
Other grain and meal	25	"
Sugar and farinaceous food	25	"
Wool	24	"
Fruit and vegetables	14	"
Cattle foods	9	"
Hides, horns, tallow	6	"
Rabbits, poultry, eggs	4	"
	£224	"

It may be noted that the only items in this list that Australia supplies to any appreciable extent are wool, rabbits, hides, tallow, and butter. Our contributions to meat and wheat are comparatively insignificant.

I look upon the steady extension of the area of cultivated land as being essential for the continued expansion of our agricultural industries. Wheat is the crop which lends itself most favorably to Australian requirements and conditions. As will be seen from the following table, Australian exports have only on one occasion reached 10 per cent. of the total amount of wheat consumed in Great Britain in any single year, and it is clear from the following tables that every effort must be made to increase the wheat yield of Australia if we are to make a substantial advance in this direction, especially in view of the enormous strides that have been made in recent years by the Argentine Republic, both with regard to the amount of wheat shipped to Great Britain and also with regard to the total area placed under cultivation.

IMPORTS OF WHEAT AND FLOUR INTO GREAT BRITAIN.
(Percentage from each Country.)

	1900	1901	1902	1903	1904	1905
Argentina	19	8.2	4.2	12.2	18.5	21.1
Russia	4.6	2.5	6.1	14.8	20.1	21.8
United States	58.2	66.2	60.2	40	15.7	12.7
Other Foreign Countries	5.9	3.8	5.9	6	6.5	6.7
Total Foreign	87.7	80.7	76.4	73	60.8	62.3
Australia	3	6.9	3.9	—	9.6	10.1
Canada	8.1	8.7	11.3	12.4	7.6	7.3
India	—	3.3	8.2	14.6	21.6	20
Other British States	1.2	1.4	.2	—	.4	.3
Total British Grown	12.3	19.3	23.6	27	39.2	37.7

CULTIVATION OF WHEAT IN MILLIONS OF ACRES.
(Averages for past 25 years.)

	1881–5	1891-5	1901	1905
Argentina	0.6	5	8.3	12.1
United States	37	36.4	49	48
Canada	2.4	2.7	4.2	6
Australasia	3.6	4	5.9	6.5

HOW TO ADVANCE AGRICULTURE.

The main points can be only enumerated, without any attempt to go into details. First, there is the paramount question of conserving all our water supply. It should be the aim of Australian statesmen not to allow a single drop of flood water to flow into the sea. Every storage site on the Murray and its tributaries should be utilised one by one, and wherever possible the flood water from the coastal streams should be turned back towards the interior. The immediate objective we should aim at is to grow lucern and maize under irrigation, and to turn them into lamb, butter, and pork. With regard to dry farming, I hold that wheat should be grown even if it yields no profit over and above the cost of production, simply on account of the indirect profit which becomes possible by enabling the farmer to double the numbers of his flocks and herds. The wheat keeps the sheep and the sheep grow the wheat. They make possible the introduction of the green fallow of rape and leguminous crops; they graze off the young crop, and keep up the supply of phosphoric acid and the moisture-conserving humus of the soil. We have pushed the limit of cultivation, experimentally at least, up to the fringe of the arid region, and farmers are tempted to chance a crop of wheat year after year in spite of the probabilities of failure, simply because the cost of growing and harvesting the crop is so small that a good year means a handsome profit. The average yield of wheat in Australia is very low; but it must be remembered that in no part of the world is the cost of growing it lower per acre, and nowhere is a crop produced on such a low rainfall. Nearly all the wheat grown in Victoria is produced in the driest part of the State, very little of it receives more than 20in. of rain, and there is no doubt that the limit of profitable production throughout Australia will gradually be advanced to the 10in. line of rainfall. Even under these conditions the following results show what can be done towards increasing the yield by selecting the best seed of the best varieties:—

"*Wheat Variety Experiments, Victorian Department of Agriculture.*

"Returns from 22 plots are now to hand, comprising 38 varieties of wheat. Area of each lot is five acres, and the whole was uniformly manured with 56lbs. superphosphate per acre. Ten acres out of the whole area of the plots were cut for hay, on account of the wild oats.

The average of the remaining 100 acres is 16.1bush. per acre. Last year's average was 13.1bush. The following eight varieties are above 18.5bush., and the corresponding yields for last year are also shown.

	1906. Bushels.		1905. Bushels.
Federation	23.9	..	19.0
Dart's Imperial	20.4	..	18.3
Australian Talavera	20.3	..	15.7
Jade	20.1	..	19.2
Sussex	20.0	..	17.4
Silver King	19.8	..	16.7
Tarragon	19.7	..	16.6
White Tuscan	18.7	..	16.8

"The fields showing the best average yield for all varieties are as under :—

Nixon Bros., Eddington	27.8	bushels per acre
Nowatna, C., Jung	26.0	" "
Boyd, A., Minyip	23.8	" "
Hutchings, A., Lubeck	22.8	" "
Sproat, W., Donald	22.8	" "
Carter, J., Marong	18.7	" "

"The worst are those in the Goulburn Valley and North-Eastern District, where the fields were so swamped with continuous rain during the winter that one at Merrigum averaged only 10.7bush. and one near Wahgunyah 7.1bush. per acre. The nine fields in the Mallee averaged 14bush., as against 11bush. last year—an increase of 27 per cent."

THE FUTURE OF AGRICULTURAL PRACTICE.

The future of agricultural practice in all parts of Australia must depend for its success on the judicious combination of animal husbandry with increased areas under cultivation. We have already seen the fundamental principles which are involved in this combination, and also the extent to which both are dependent on the proper use of the available water supply. The details of the ways by which these objects can best be attained vary in every district. It is the skilful use of his opportunities that makes the successful farmer. But a number of points are so important that they each require a few words.

1. *Irrigation.*—The population of Australia is at present too scanty to allow us to do anything more than play at irrigation, because successful irrigation means small holdings and comparatively intense culture. All irrigated land should carry the equivalent of one cow to the acre, and to superintend this amount of production—whatever may be the form it may take—means the utilisation of a far greater amount of labor than is at present available in Australia. The area capable of irrigation is so vast that it must always be one of the chief factors in the agricultural development of Australia. It is estimated that the Murray and its tributaries alone will supply water for 8,000,000 acres of land. In addition, it may be said that in the regions where the rainfall is above 30in. sufficient water now runs uselessly into the sea from each square mile to irrigate another 40 acres. The success which has already been achieved in different parts of Victoria by using this

water to form a small private irrigation scheme indicates the immense possibilities in this direction. The most practical way to promote closer settlement is by establishing irrigation colonies for dairy-farming. Forty acres of land under lucerne and maize on the banks of the Murray would thus easily keep a family in affluence.

2. *Improvement in Dry-farming Methods.*—The best way to carry out the fallowing, and the right amount of superphosphate to use, are points about which we are obtaining more information from year to year. At the same time, the question of the most suitable variety of wheat and the growth of green fodder crops for sheep is engaging the attention of all progressive men. More importance needs to be attached to the growth of deep-rooted and leguminous plants, and to the rotation of crops. It is here that sheep worked in with the wheat is a financial success. Lucerne, rape, peas, clovers, oats, and barley are types of the crops that wherever possible should be grown along with wheat. They are not to be sold in the market, but to be fed to sheep and cattle, and the profit will come from the formation of humus, and the consequent steady increase in the fertility of the land. Lucerne stands unrivalled as a summer crop, the others are brought to maturity by the winter rains alone. Then, again, the sheep conduce to clean farming, grazing off the early wheat, and prevent the wild oats from seeding. The extension of lucerne and rape into the drier areas, and the introduction of allied plants that can be grown with even less rainfall, are two of our most pressing problems. The possibilities of the field pea in this connection need emphasizing.

3. *Conservation of Fodder.*—In all parts of Australia certain months are marked by the luxuriance of the herbage, of which the live stock are unable to consume more than a small fraction. The monsoon rains cause a growth that appears almost incredible in the warmer parts of the continent, while the spring growth is often of the same character in the southern States. Here, again, we want labor to make it practicable, but, given labor as efficient as that which raises our wheat crop, and the possibilities in the direction of hay and silage are immense. The surplus of a good season might then be carried forward to meet a time of drought.

4. *Improvement of Poor Soils.*—The use of superphosphates and the adoption of some such system of rotation as oats, peas, rape, barley or wheat, most of the produce to be fed to live stock on the farm, will at once start a man on the up-grade. Grass land top-dressed with superhposphate or bonedust will rapidly increase in stock-carrying capacity.

CONCLUSION.

But suppose the present bright prospects of profitable markets disappear, then, with our small population, much of the existing industrial buoyancy would disappear also. But the farm as a home would still remain, and, compared with other avenues of employment, it would offer the best field for well-directed energy. Under such conditions there are additional reasons why the most progressive units of our population should turn their attention to agriculture. There is the old saying that the farmer is the most independent of men. The endless modifications of the details of successful farm practice offer ample scope to everyone to develop along his own particular lines. He may change the purpose to which he puts his land, and still be quite as successful as his neighbors. He may become a successful enthusiast. There is the satisfaction of knowing that you are making steady progress from year to year. That next season you will make the poorer part of your land a step nearer in productivity to the best; that you will weed out the worst of your live stock and replace them by something better than the average. In a word, it is the joy of the farmer to know that his future is more in his own hands than is the lot of most other men. If he keeps on sound lines, nature will be true to him, and his upward progress, though it may be slow, is certain to be sure.

Section H.

ENGINEERING AND ARCHITECTURE.

The President-elect of this Section (Mr. W. Thwaites, M.A.) was unavoidably prevented from attendance; there was consequently no Presidential Address.

Section I.

SANITARY SCIENCE AND HYGIENE.

ADDRESS BY THE PRESIDENT,

R. GREIG-SMITH, D.Sc.,

Macleay Bacteriologist to the Linnean Society of New South Wales.

AIR INFECTION.

In the study of the spread of infectious diseases it is of the greatest importance to know the means by which micro-organisms are conveyed from one place to another, together with the effect of the conditions of environment upon their vitality during transportation. Immense advances have been made during the past few years in our knowledge of the etiology and propagation of many diseases, and especially of the insect-borne diseases of men and animals in tropical countries. These have, for the most part, been traced to various protozoa which spend a portion of their life-cycles in the bodies of certain biting insects such as mosquitoes, biting flies, and ticks.(*a*) To discuss these advances would absorb more time than I have at my disposal, and, moreover, the subject is so fascinating that it has been reviewed from time to time by many able writers. I will therefore restrict my address to the consideration of the aerial transportation of bacteria from a source of infection to a susceptible individual.

In considering the conveyance of bacteria in this manner, the first point that we must bear in mind is that these micro-organisms are of extremely small size. They are so minute that a million of ordinary dimensions weigh something like one three-hundred-thousandth part

(*a*) In the case of a disease conveyed from man to man by means of a biting insect, we should consider the matter from two points of view—that of the man and that of the insect. The latter aspect of the case is apt to be forgotten. A healthy insect may bite a healthy man and suffer no ill effects; but should an *Anopheles* mosquito bite a malarial patient, or a man who has the malarial parasite in his blood, the insect will become diseased. A diseased insect is, *per se*, of no importance whatsoever; but if, after a certain period, it should bite one or more persons the infinitely unimportant becomes converted into the infinitely important, for the bite means the conveyance of the malarial parasite, which will multiply enormously in the blood and give rise to the symptoms which we know as the disease. Given a district in which there are healthy *Anopheles*, the coming of even one parasite-containing person may be the lighting of the fuse that fires an explosive epidemic of the disease. Our insects should therefore be guarded from infection. This is carefully attended to in the tropical regions of America, where patients who are suffering from yellow fever are enclosed in mosquito-proof cages in order to protect the "day-mosquito" (*Stegomyia fasciata*), which is the insect-vehicle of the disease-producing parasite. Thus the transference of the disease of a grain. It will, therefore, be easily understood that even the faintest breath of wind or the slightest current of air will convey them from one place to another. They undoubtedly possess weight, and compared with other substances they are of much the same specific gravity (3) as particles of coal or boxwood. For this reason they will settle in a perfectly still atmosphere, but such a condition is exceedingly exceptional. The friction and convectional motion of the air will keep them suspended for long intervals. Furthermore, the smaller the microbe the longer will it float. Some bacteria are so small that they readily pass through the pores of our finest porcelain filters, and on account of their extreme size, which is less than that of a ray of light, they have not hitherto been seen with our most powerful ordinary microscopes. Such are the invisible or ultramicroscopical bacteria, examples of which we have in the micro-organisms of South African horse sickness, of pleuro-pneumonia, and of smallpox.(*b*) Such microbes will probably float about in the air until they perish.

Patients suffering from infectious diseases are capable of giving off virulent bacteria in several ways. They may be avoided along with the waste products from the intestine and kidneys, or be given off with desquamated epithelium. The excreta are but too frequently thrown upon the ground or lightly covered with earth, with the result that the soil becomes infective. But even before this occurs much danger to the community may arise, as anyone can see who notes the persistency with which meat flies and other flies haunt the so-called earth-closets and frequent the rooms in our country townships and our mountain health resorts, whither convalescents resort to recuperate.

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from patient to insect is prevented, and the possibility of the subsequent infection of many healthy persons avoided. The point to be emphasised is that one individual who has the protozoon of a certain disease in his blood may be the means of infecting a number of mosquitoes. In the body of the mosquito the parasite continues and completes an interrupted life cycle. The sporozoites—the terminal products of the cycle—pass with the saliva of the mosquito into the unlucky wight whom it chances to feed upon. Just as the potato is the more vigorous after having been raised from seed, so it is probable that the parasite is more virulent—that is, it can withstand more adverse circumstances or conditions, such as immunity conditions of the individual—after having completed its full life cycle in the tissues of its particular insect host.

The protozoal diseases are in this respect different from the bacterial. Bacteria have no life cycle to complete in the insect, and they die within their bodies in course of time—sometimes a few hours, sometimes a few days. It is true that a bacterial disease may result from the bite of an insect; but in such cases the evidence goes to show that the bacteria have either been adhering to the mouth parts or have been voided with the excreta in the vicinity of the bite and have been scratched into the skin by the individual.

In Australia we have *Anopheles annulipes* (1), the carrier of malaria, and *Culex fatigans*, the intermediate host of filariasis (2), both of which, upon the advent of parasite-containing individuals, will be the means of transferring these diseases to many other persons.

(*b*) The work of Pröscher (4), which bears the impress of probability, shows that the micro-organism of smallpox is retained by the porcelain filter, but is invisible. This may be due to an exceptional neutrophile condition of the cells. He obtained evidence of growth in the alteration of the surface of a special medium. According to other authors, it passes through the Berkefeld filter.

Infective soil is a very dangerous substance in Australia, for it is so easily blown by our high winds upon the roofs of cottages, from which it is washed by the rain into the tanks, which most of our country inhabitants depend upon for their supply of water for domestic use.

It is extraordinary how long some infectious microbes remain in the bodies of patients after convalescence and return to health. For example, convalescents from typhoid fever carry about with them and distribute for months, and even for years, the germs of the malady from which they have recovered.(5) The typhoid bacteria, perhaps in prodigious numbers, leave the body in the urine. Such convalescents have been known to start epidemics in localities where the inhabitants have been unwittingly using a polluted water.(6) Typhoid is one of the cases in which the patient should be taught to understand the danger which he may be to the community. He should be under observation for some time after convalescence, and should never be employed in certain industries—such as dairying—until it has been proved by bacteriological examination that he is no longer capable of giving off virulent bacteria.(7)

But the most dangerous of all methods of aerial infection is the dissemination of microbes with the exhalations from the mouth and nose of infectious individuals, because these emanations are invisible, and the public is not inclined to view them with the same horror that it has for the infectious material discussed in the last two paragraphs. These invisible exhalations are the more dangerous because we can boil our water and cook our food, but we do not filter or sterilise the air that we breathe. As it is by this means that phthisis and many diseases of lesser importance are conveyed from man to man, and as the subject is of much importance, I propose to deal with it at some length.

In ordinary gentle breathing, the air given off by way of the mouth and nose is nearly sterile ; only those bacteria that entered and have not been caught by the mucous membranes of the respiratory tract are present. Even when the saliva and moisture of the passages are teeming with bacteria there is no opportunity given to them to become detached under ordinary circumstances. The case, however, is quite different when air rushes rapidly and suddenly through the channels of communication between the lungs and the atmosphere, as in the acts of coughing, sneezing, or even of loud and energetic speaking. Under these circumstances the exhaled air carries with it minute microbe-holding particles or bubbles of spray of about one two-thousand-five-hundredth of an inch (1-100mm.) diameter.(8) With the healthy individual not exposed to infection the microbes are, to all intents and purposes, harmless. But when the individual is infected with certain diseases—such as pulmonary consumption, whooping-cough, diphtheria, influenza, and even other diseases like typhoid, as authenticated by Jehle (9)—the spray may be deadly.

In proving the emissibility of bacteria in this way, experiments have been made with salivary bacteria, with pathogenic microbes emitted by infected persons, and with *Bac. prodigiosus*, which is absent in ordinary air, but is, on account of the brilliant red color of its colonies, easy to recognise.(c)

Gordon (10) detected characteristic salivary bacteria 40ft. in front of and 12ft. behind a man who had spoken energetically for an hour in a still room. This confirmed the experiments made by Flügge and his pupils with *Bac. prodigiosus*. That the bacteria ejected by a speaker in a quiet room should reach a distance of 40ft. shows the danger to which an audience might be subjected by a consumptive or other infectious person speaking in a small or ordinary room. Even when a handkerchief is held before the mouth to catch the largest particles and deflect the direction of emission, bacteria are still sent outwards, although not to so great a distance. The danger, however, is but little minimised by the interposition of the hand or handkerchief, for a slight air-current may do what the hand was meant to prevent. Experimenting in the open air, Hutchison (11) detected bacteria carried by the wind to places 180yds., and in one case even to 650yds., from the place of origin. Coughing and sneezing send a greater number of spray particles into the air, and although many of them are of comparatively large size, and settle quickly, yet a very large number remain suspended for long intervals. Flügge found that the finest droplets remained floating for from four to six hours, while Hutchison detected them at the end of eight hours in a still atmosphere. They do not appear to rise, but are continually falling, and, according to Heymann (12), the rate of sedimentation is proportional to the size of the micro-organism.

We thus see that the finest spray droplets have the power of remaining suspended in the atmosphere for a comparatively long time, and that air infected by the speaking, coughing, or sneezing of an infectious individual may remain so for from four to eight hours. It is obvious that the only means available for getting rid of the danger in the air is to be found in thorough ventilation. The infected air must be so diluted that there is an infinitely small chance of a microbe being inhaled by a susceptible individual.

But the infectivity of the larger drops does not end when they leave the air and settle upon the ground, for this term includes carpets, floors, clothes, &c. Carpets and floors are swept and clothes are brushed, with the result that a certain amount of infected fibres or dust is again sent into the atmosphere. The larger and heavier particles soon fall, but the smaller, and especially the fibres, float for a considerable time. When carpets are shaken, none of the dust which is created can be found in 10 minutes higher than a yard from the floor. If a handker-

(c) When using *Bac. prodigiosus*, the mouth of the experimenter is rinsed with a suspension of the bacteria before performing the various acts which the experiment demands. As a rule, an empty room, such as a lecture hall, is utilised, and plates of nutritive media are distributed at various distances from the investigator, who either speaks, reads, coughs, or sneezes. In dealing with infectious dust, &c., the experiments are made in specially devised boxes or chambers, with all the necessary fittings for blowing the dust and removing the infected media. The experiments with consumptives are also made in special chambers.

chief is rubbed between the hands, or if clothes are brushed, the finer dust which is created will be found at a height of 3ft. from the ground after an hour in a still atmosphere.

The next point that may be considered is the possibility of air-borne bacteria reaching the lungs. Experimental work has proved that, although the majority of the bacteria inspired with the air are deposited on the mucous membranes of the nose, mouth, windpipe, &c., where certain species give rise to throat and other troubles, yet some reach the lungs, where they can be detected. When animals are subjected to an artificially infected atmosphere, the bacteria are found in the finest bronchi and alveoli of the lungs (13, 14). According to Selter (33) a deep inspiration will carry spray droplets from the mucous membranes of the mouth into the lungs. Experiments such as these have to be quickly done, or the microbes may be bacteriolysed, phagocytosed, or conveyed by the mobile leucocytes to a distant tissue. Even when soot or cinnabar laden air is used the particles can be detected in the bronchial glands, and the inhalation of anthrax spores has resulted in death. (10)

It is, therefore, evident that bacteria in the air, whether contained in fine spray droplets or in dust, are deposited on the membranes leading to the lungs, and, obtaining access to the lungs themselves, may penetrate to the most remote parts, where a disturbance may be set up. (15)

Having seen the possibilities of air-infection, let us look at the other side of the question, and see what may occur while the bacteria are suspended in the air or are resting upon a solid surface. The vitality of the micro-organisms under such conditions has been extensively investigated, chiefly on account of the importance of the matter. The experiments have shown that they are destroyed with greater or less rapidity. Conditions will naturally vary, and a close concordance cannot be expected between the results of the various investigators. Still, if we consider the conclusions generally, we will obtain much useful information. Some bacteria are delicate, and are easily influenced by adverse conditions, compared with other hardier species. Furthermore, the substance upon which they rest, or in which they are contained, has a certain amount of influence. The subject is, therefore, complicated.

When contained in spray and resting upon glass and freely exposed to the air, the existence of the bacterium depends upon its nature. For example, in diffused daylight the comparatively delicate typhoid bacterium perishes in 24 hours, while the hardier pyogenic micrococci live for 18 days; the diphtheria micro-organism dies in two days. In the dark, but under the same conditions, *Bac. diphtheriæ* may live for five days, the staphylococci for 35 days, and the streptococci for 45 days. When the spray droplets fall upon dust the bacteria perish in a much shorter time. *Bact. typhi*, for example, dies in from six to nine hours in dust exposed to diffused daylight and in 18 hours in the dark.(8).

When clothes or dust have been infected, the bacteria either lie upon the surface or in the interior of the cloth fibres and dust particles. In the former we have a condition similar to that which can be obtained by exposing the articles to a fine spray of suspended bacteria, the artificial analogy of the natural cough or sneeze. By soaking up the suspension the articles become thoroughly impregnated, and we have a condition similar to the soaking up of sputum, urine, or other infectious fluid matter. The absorption of the larger spray droplets thrown out in coughing will be intermediate between the two conditions.

It may be taken as a rule that the thinner the layer of infectious matter the sooner will the bacteria be destroyed. When bacterial suspensions are sprayed upon silk threads, the microbes die much more quickly than when they are soaked up and the threads carefully dried. Thus *Bac. prodigiosus* succumbs in eight days when sprayed, and in 72 when soaked up; *Bact. typhi* in 30 hours when sprayed, and in five weeks when soaked up. Bacteria perish more quickly when absorbed in linen than in silk, and much more speedily when in paper. Much, therefore, depends upon the method by which the material has been infected—whether by coughing, or sneezing, or by sputum, &c., and also upon the nature of the absorbent material. By "nature" one includes the kind of material—such as silk, or linen, as well as the texture. The influence of the latter is well illustrated by an experiment which showed that cholera vibrios perished in one hour when soaked up in silk cocoon fibres and in 120 hours when absorbed by silk threads one-twentieth of an inch in diameter. (8) Dust appears to be a most effective material for bringing about a rapid destruction of bacteria. In these experiments the micro-organisms were suspended in water or dilute solutions of salts. In other fluids—with the exception of urine—they have a longer span of life (8). The fluid in which they are contained is of considerable importance, for they are rarely found in water, the usual infectious materials being more often saliva, bronchial mucus, blood, or exudates, all of which are mucinous or albuminous, and are certain to prolong the lives of the bacteria beyond the times that have been quoted.

An investigation relating to this part of the subject was recently made by Heim.(16) Various pathogenic bacteria, contained in pus, blood, serum, &c., were found to be still alive and virulent after periods ranging from three months to two years, the majority of the non-sporulating microbes living for more than a year. But as in these experiments the infected silk threads were dried over calcium chloride, it is evident that one of the conditions was too severe to enable the results to be compared with what might happen under ordinary circumstances. The thorough desiccation preserved the lives of the microbes; they would never reach such a state under natural conditions.

The duration of life of a resting bacterium depends so much upon the kind of bacterium, upon the medium in which they are, upon the substratum upon or in which they rest, upon the conditions of light, temperature, and moisture, that one can only say that they will be alive after 24 hours, and may die sooner or later afterwards. We have a long persistence in Heim's experiments, and as a contrast Kirstein (8) found that *Bac. prodigiosus* when sprayed in dust, disappeared in from six to nine hours in diffused daylight.

One would like to believe that infectious bacteria perish with considerable speed under ordinary conditions. Our comparative freedom from disease points either to that or to our possession of a considerable amount of protection against them. Our immunity probably largely depends upon the fact that we do not seek infection, but rather avoid it as much as possible. It is, however, difficult to avoid being infected by certain throat affections, such as the common cold, which is conveyed from person to person by means of spray particles in the air. Bacteria have been found in localities which clearly indicate this method of distribution. Kinyoun (17) examined the dust and scrapings of railway carriages for pathogenic bacteria, and found positive results in 27 per cent. of the tests. The microbes were chiefly staphylococci and pneumococci, but two of the tests contained *Bac. diphtheriæ.* In a carriage which had been used for conveying consumptives to a sanatorium, *Bac. tuberculosis* was detected. It is one thing, however, to detect injurious microbes in such places and quite another thing to show that they have other than the most remote chance of becoming converted from a potential into an actual danger. It has never been shown that the men who clean railway carriages contract lung affections more frequently than other people. The detection of staphylococci points to nothing, for one has only to introduce a fragment of garden soil under the skin, perhaps accidentally by means of a wound, to bring about a formation of pus teeming with these microbes.

We know that the soil is the ultimate destination of the majority of bacteria, and in it the less injurious forms, which we speak of in a general way as soil bacteria, are able to vegetate and multiply. The noxious kinds find the soil to be an inhospitable medium, and in it they rapidly perish. But if the soil is polluted extensively, and that means the accompanying addition of nutritive material in which the microbes are suspended, the pathogenic forms may gain the upper hand, so to speak, and an infectious or dangerous soil is the result. Dust from such a soil may go far to produce an epidemic, as was painfully experienced in the typhoid outbreaks during the South African campaign. The question of infectious dust is, therefore, closely connected with the viability of pathogenic bacteria in the soil. It appears that if the infection of the soil has not been too great the pathogenic microbes rapidly die out; not, however, on account of the scarcity of food, but from the poisonous action of the products of the putrefactive bacteria which are better adapted to the environment. Sidney Martin (19) was able to detect typhoid bacteria a year and a half after they had been put into sterilised soil, but in ordinary unsterilised garden soil he could not recover them after the second day.

Dust from ordinary soil may, therefore, be accepted as being innocuous so far as the typhoid and probably many other non-sporulating pathogenic bacteria are concerned, unless the infection has been recent, or the pollution has been great.

One might imagine that every particle of dust floating in the air has upon its surface or within its crevices one or more bacteria. Such, however, is not the case ; the great majority of dust particles are sterile. In confirmation of this we have the experiments of Macfadyen and Lunt (20), who found one micro-organism in every 28 million particles of dust in the open air of London, and one mould or microbe in every 184 million motes of an ordinary room. In discussing the comparative poverty of the air as regards bacteria, Flügge calculated that a man during a life-time of 70 years would inspire 25 millions of these micro-organisms—a quantity which is usually found in half a pint of fresh milk, or in an ounce of milk as we receive it from the dairyman. As to the character of the aerial bacteria, Andrews (21) found that those in the air of London were remarkably inert in their chemical and pathological behaviours, and much the same thing has been said of the micro-organisms in the air of other places. On the other hand, Corcornotti (22), in common with other investigators whom he quotes, found pathogenic bacteria in the air of various places in Sardinia, the most numerous being the pyogenic micrococci ; as would be expected, the more dirty the surroundings the more numerous were the microbes.

It appears, then, that comparatively few bacteria are inhaled by the individual, and any that are contained in the air, as Moll (23) has pointed out, are deposited upon the mucous membrane of the anterior portion of the nostril, the posterior part being sterile, or nearly so. That many are entrapped follows from Hasslauer's observations (24) upon the bacterial flora of the air-passages of healthy individuals. He found pyogenic cocci in 35 per cent., and pneumococci in 20 per cent. of the cases examined. Kobe (18) found *Bac. diphtheriæ* in the throats of from 8 per cent. to 18 per cent. of persons associated with affected individuals ; with non-associated persons he detected less than 1 per cent. From the occurrence of so few bacteria in the air, and the rather frequent presence of certain pathogenic microbes in healthy throats, it would appear that once these gain access to the throat they persist there until such time as the vitality of the individual may be lowered, when they assert themselves and produce disease.

In connection with infection generally, we know that some individuals are more prone to contract disease than others. This condition is referred to as one of individual susceptibility, and means the absence or relative paucity of one or more of the many substances which are included under the general term, immunity bodies. It also includes the absence of that faculty of toleration towards microbes such as we find in the case of a typhoid convalescent, who can retain typhoid bacteria in his body for months or even years. Susceptibility and non-susceptibility towards infection in general are only relative conditions. Other things being equal, one man may be able to overcome, say, ten noxious microbes but not an eleventh, while another may be able to withstand a thousand and no more. An individual susceptible to tuberculosis appears to contract phthisis while living amongst his healthy fellow creatures, and a non-susceptible person succumbs to the repeated infection which obtains in the bed-chamber or living-room of a consumptive. There are, however, certain individual peculiarities or habits which will influence the individual susceptibility or non-susceptibility towards aerial infection, and two of these may be noted here. The person who habitually keeps his mouth open must be more liable to this method of infection than the one who filters the air through the nose. Again, a man who uses the handkerchief freely will remove bacteria more frequently from the nasal mucous membranes, and will retard the multiplication in the nasal slime, and subsequent migration to the post-nasal cavities and throat.

The spread of infection by the air has been specially investigated during the past few years in the case of the tuberculosis bacterium, one of the most insidious of all the aerial bacteria, and the data that have been collected with regard to this bacillus is largely applicable to all the others. Tuberculosis may be contracted by way of the intestinal or respiratory tracts. It appears to be by the former channel that the child is generally attacked, and by the latter that the adult is infected. The protection of the child may be easily accomplished by sterilising its food and drink,(*d*) but the sterilisation of the atmosphere is a practical impossibility. The most we can do to overcome this subtle form of infection is to minimise, as much as we can, the pollution of the air. A phthisical patient is not always dangerous; it is only when bacterial matter is coughed up into the air or into the mouth that the pollution of the atmosphere becomes possible. Laschschenko (27) found tuberculosis bacteria in nine tests out of 20 in the saliva and spittle of patients. But, as we cannot tell when the salivary spray is dangerous or when it is not, it is necessary for purposes of prevention to assume that it is always dangerous. Unfortunately the tuberculosis bacterium is rather a resistant microbe, and is not so easily destroyed by exposure to air and by drying as *Bact. typhi* or even *Bac. diphtheriæ.* When in soil dust it persists in the light for from eight to 14 days, in dried

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(*d*) In this connection the views of the International Congress upon Tuberculosis, held in Paris, in October, 1905, may be noted. While recognising the danger of transmission from man to man it also emphasized the possibility of the transference of bovine tuberculosis to man, in spite of the views of Koch regarding the dissimilarity of bacteria of human and bovine origin. In consideration of the recent experimental evidence concerning the rather frequent occurrence of virulent tubercle bacteria in the milk of tuberculous cows, and in consideration of the possibility of infecting the intestinal tract with tuberculosis, which is more frequent than has hitherto been supposed, the Congress decreed that the sanitary inspection of all cow-byres should be performed as speedily as possible, and that in public institutions of every kind—hospitals, schools, &c.—only pasteurised, sterilised, or boiled milk ought to be admitted for use; otherwise, milk should only be accepted from those byres in which the animals had been tested with tuberculin and had been found to be free from tuberculosis.

This advice is excellent; but, failing the compulsory testing of our herds, it behoves us to insist upon all our milk being pasteurised before use. It is fortunate that our climate practically compels the treatment, and that during the long, hot summer months, both vendor and housekeeper find it to their advantage to pasteurise in order to preserve the milk in a drinkable condition. Beyond the question of keeping the milk sweet for a longer time, scientific pasteurisation aims at killing off, or in destroying the virulence of, the more resistant *Bac. tuberculosis* at the lowest temperature and in the shortest time, so that the taste, the solubility of the and powdered sputum from four to seven days (in the dark 22 days), in cloth fibres five to 10 days, and in street dust three to eight days (28). It is strongly influenced by drying and by light, and it is probably these factors rather than exposure to the air that causes its slow decease.(*e*)

The general principles of the dispersal of bacteria by coughing, etc., apply to the bacillus of tuberculosis as to other bacteria. Flügge is rather inclined to belittle the danger of infection, as he says that if a patient coughs into the hand or into a handkerchief, there is little danger of infecting other people if the latter are over a yard away. Then he lays down a general rule that workers in a workroom are quite safe from infection by their confreres if that space is maintained, that is to say, if each worker occupies one square metre of floor space, and if the consumptive coughs into his hand or into a handkerchief. As a rule a worker has both hands occupied while working, and cannot be expected to liberate a hand or find a handkerchief when a sudden fit of coughing seizes him. Laschschenko (27) found that while the coarser particles might be caught in the hand, the finer ones remained suspended, and could be detected at the ceiling of a room, 10 yards from the individual who had emitted them. Heymann (12), after showing that these fine particles can bring about tuberculosis in a guinea-pig, asks if a man has not a far greater chance of contracting the disease than an animal which breathes so feebly as the guinea-pig? The question is pertinent, but let us first consider the matter.

The air which is exhaled during respiration is warm, and rises above the head. The same would happen if the cough or sneeze were directed outwards and forwards. But the sneeze is invariably directed downwards, and so also is the deep cough. The warm air, with the accompanying spray droplets, will, therefore, be sent towards the ground and, being given out with some force, will be mixed with the surround-

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albuminoids, and the physical properties of the milk generally, may be altered as little as possible. The commercial pasteuriser aims at avoiding the formation of a skin or film of dried milk, to kill the bacteria in which an exposure to a higher temperature or at a low temperature for a longer time is necessary. In America, Theobald Smith (29) found an exposure for 15-20 minutes at 60° C. was enough to kill *Bac. tuberculosis* in milk; Russell and Hastings (30) recommended the longer limit. In Theo. Smith's experiments, the bacteria in the "skin" were virulent after an hour's heating at 60°. In Sweden, Barthel and Stenström (31) determined that an exposure of 1·5 to 2 minutes at 80° was ample, provided that a suitable apparatus was employed. This time and temperature appear to be generally employed in Denmark. The exposure which I have quoted gives the limits with the suitable times between which pasteurisation occurs.

(*e*) Not only does it persist under adverse conditions longer than the less robust bacteria, but it is also more slowly affected by disinfectants. In this connection Steinitz (28), from a consideration of his experiments, suggests that sputum-bearing material should be boiled, burnt, or soaked in mercuric chloride solution (1-1000) for five hours. In the cases of rooms or clothes, the parts which have been visibly contaminated should be moistened with mercuric chloride solution (2-1000), and the other parts disinfected by means of formalin vapor, giving an exposure of from three to seven hours with vapor of double concentration, *i.e.*, using 2·5 grams of formaldehyde for every cubic metre of space.

ing air and rapidly cooled, so that it will remain below the head level of other persons. There is, therefore, reason to believe that the risk of infection is less than would at first sight appear. Indeed, the matter resolves itself into a question of the ventilation of the workroom, which, if sufficient, will bring about the dilution and removal of the comparatively small quantity of infectious exhalation. Flügge is probably right when he says that a metre is a safe distance from the worker who may be seated or standing in a workroom, always provided that the room is sufficiently ventilated. One point, however, arises which may influence the safety of workers who are seated even at some distance facing a consumptive. There is the possibility that in coughing, a vortex-ring may be sent out which will carry the spray particles straight across the intervening space to the face of a susceptible fellow-worker who may breathe a portion of the ring. If such vortex-rings are given out, and I think it probable that they are, a known consumptive should be caused to stand or sit behind a network screen of some kind, or facing a wall.

Much has been written about the infectivity of consumptive sputum, but a consideration of the subject shows that the danger has been exaggerated. When thrown upon the ground it falls as a mucinous paste, which dries to a stiff mass. This breaks up after the lapse of a considerable time into comparatively large particles, which are not easily transported. The conditions that obtain with naturally-dried sputum are quite different from those that occur in experimental infections, in which the sputum is dried quickly, broken up by mechanical means, and distributed by strong air currents. This aspect of the case has been noted by Flügge, and more recently by Cadéac (32), who further emphasised the fact that the exposure to light and air, during the time that must elapse before it becomes broken up, weakens the bacilli to such an extent that they are unable to set up tuberculosis in the extremely sensitive guinea-pig otherwise than with the greatest difficulty. And he argues that if the intracorporeal infection of the guinea-pig is so difficult, it will be well-nigh impossible to infect the air-passages of man. There is, therefore, reason to believe that tuberculous sputum, when thrown upon the ground. is not actually dangerous; and such being the case, the chief means of infection, outside of the food supply, is the consumptive cough.

Just as we should rigorously examine the cows which supply milk for the child and the invalid, so should we keep under observation the consumptive, who is a source of danger to the adult population; and, although this is beyond the scope of my address, yet I feel that I ought to express the conviction that drastic measures of any kind will not be tolerated by the community, and that the only means that are open to us in these days of enlightenment is to insist upon compulsory notification, and to have tactful State and municipal officials as public educators who will be advised by the medical attendant as how best to approach the patient, in order to explain the danger to which he or she may expose innocent individuals.

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Section J.

MENTAL SCIENCE AND EDUCATION.

ADDRESS BY THE PRESIDENT,

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MATERIALISM.

There are waves of thought which have recurred again and again in the history of the race. One of these is Materialism. When men began to consider the world as a whole, and to ask if all things could be explained by a single principle, it was inevitable that, among other guesses, matter should suggest itself as such a principle. The material world, with its varied changes, was ever present; might it not be the sole reality, of which our minds are merely parts or manifestations? The same thought repeats itself to-day. We recognise more than ever the universal reign of law; we have learned to regard the world as a systematic unity; and a mechanical theory of the universe, could it be applied all round, would have the merit of simplicity. We distinguish, it is true, between mind and body; but as the bodily organism is built up of physical factors, and depends on a physical environment for its continued existence, may not the mental facts of which we are aware be the effects of changes in the nervous system? We know nothing of a mind, animal or human, save in conjunction with an organism. The mental growth of the child is conditioned by the growth and development of the bodily frame; with the decay of our physical strength the intellectual alertness of youthful vigor passes away; when the body lies pale in death there is no longer any trace of mental activity. A healthy body favors a healthy mind. On the other hand, fatigue and innutrition impair the memory and dull the imagination, and on all sides accident and disease illustrate the mental results of bodily disorder. Our minds as well as our bodies are modified by everything we eat and drink. You may remember that on one occasion the Autocrat of the Breakfast Table asked how much the world would give for the discovery if someone would contrive a lever which would check the wheels of thought or alter their rate of going. And the young fellow whom they called John replied: "From half a dime to a dime, according to the style of the place and the quality of the liquor." "You speak trivially," said the Autocrat, "but not unwisely."

The researches of science strengthen these data of every-day observation. Areas in the brain have been definitely mapped out as connected with certain mental facts, and, though much remains to be accomplished in detail, there are valid grounds for asserting that for every mental change there is a nervous change. The whole study of the pathology of the brain confirms the impression that mental facts are so dependent on cerebral conditions that, when these conditions are changed, there is a change also in the character of the mind. Facts such as these suggest that mental life is simply the result of the working of the bodily machine.

The hypothesis of materialism has been allied also with the theory of evolution. According to this theory man has descended from a lower animal type; the whole of the organic world, including plants and animals alike, has sprung from the same primitive forms; and the organic has, in its turn, been evolved from the inorganic. But evolution, thus widely applied, cannot be denied of mind. With the greater complexity of organic forms, mind has ascended step by step in complexity and efficiency; and the presumption is that every mind, like every organism, must form part of the great natural series. Following the same line of thought, it may be plausibly supposed that matter is prior to mind. The suggestion is that the first dawn of mental life appeared when matter had attained the required development, and that greater and greater complexity in the arrangement of physical and chemical constituents, and of the cells which they compose, led at last to the evolution of the human body, and, as its result, of the human mind. The materialist may thus maintain that matter, as prior in existence, has been the cause of the origin of mind as well as of all its subsequent developments. Or, on a more liberal view of the presence of mental facts throughout the universe, he may represent mind as identical with the energy which is inseparable from matter, or as a special form of that energy. He may ascribe the psychic qualities of sensation and inclination—though in a rudimentary or unconscious form—to the smallest particle of matter, and even to the ether.(*a*) Ascending in the evolutionary scale, he may discover in the psychic life of the higher animals the most elaborate and perfect form of physical energy.(*b*) Thus he may reduce mental phenomena, at this stage, to "elaborate performances of the nervous system."(*c*) Or, varying his phraseology, he may describe the mental life of the higher mammals as depending solely on changes which proceed from moment to moment in the cortex of the brain. On this view consciousness is a cerebral function, and the human soul "merely a collective title for the sum total of man's cerebral functions."(*d*) In any case the mental states or activities of man are either identified with physical energy or regarded as the inevitable effects of physical change. And in whatever form the theory may be expressed it follows from it, as a necessary and avowed consequence, that with the last breath of the body the mind must cease to be.

There are few who have not at some time or another felt the clutch of materialism. Yet it does not present so sturdy a front now as it did 50 years ago. Thus Haeckel notices that such eminent men of

(*a*) Haeckel, "The Riddle of the Universe," pp. 224–5, 229.
(*b*) *Ib.*, p. 226. (*c*) *Ib.*, p. 237. (*d*) *Ib.*, p. 208.

science as Virchow, Du Bois Reymond, and Wundt, who once favored a materialistic view of the world, afterwards abandoned it. And among those who have chosen philosophy as their special sphere of investigation there are few indeed who adopt the tenets of materialism. We may thus rebut the claim, sometimes ignorantly made, that the materialist stands for advanced thought, and that the question has already been decided in his favor by all except conservatives and bigots. Those who do not accept a mechanical philosophy are not necessarily behind the times, whether in science or in philosophy. But let us not meet prejudice by prejudice. A theory which wells up naturally from time to time in the minds of thinking men, and which appeals especially to those who are engaged in physical and physiological studies, is worthy of our respect. And I am here to-day, not to appeal to prejudice or emotion, but to give reasons why I am not a materialist.

In the first place I must call your attention to the striking difference between the facts which we call material and those which we call mental. The distinction is familiar, both in ordinary thought and in science. We distinguish between psychology as a science of mental facts and the sciences of physics, chemistry, and biology. And when, in neuro-psychology, we inquire into the correlation of mind and the nervous organism, we are still acknowledging the difference between them. In such an inquiry we must investigate on the one side the facts of the nervous system, while, on the other, we must consider facts of mind which are made known to us, in the first instance at least, by self-observation. Our task is to ascertain what mental event and what physiological event are connected. Still, they stand apart from each other; their correlation does not mean identity of nature. Thus we may readily admit that, as a fact of observation, mental life is known to us only in connection with bodily life. We may concede that the mental life of man on earth is conditioned in its every phase by the life and efficiency of the body. But the distinction between mental and physical facts remains. Every material object occupies space, and must therefore be of such and such a shape and in a certain position in relation to other objects; it is endowed with motion, and resists pressure. But none of these things can be said of mind. It is invisible and intangible. No one ever saw a mental fact. You cannot touch or handle an emotion; there is no balance in the laboratory where you can weigh conflicting desires; and if you choose to speak of the movement of thought you are using figurative language. If anyone ventures to assert that mind must occupy space because the body or the cells of which it is composed are space-occupying, he is flying in the face of facts, and falling into the obvious error of supposing that things which are connected together by a uniform law are necessarily the same in kind.

Let us see how the distinction between the mental and the material affects the arguments for materialism. It disposes at once of the old idea that mind is itself material, though composed, perhaps, of finer particles of matter. It summarily sets aside the statements that mind is brain and brain is mind. Even if it be true that brain and mind are manifestations of the same reality, they are still, as manifestations, as far as possible from being identical with each other. And this difference is equally fatal to the crude materialism expressed in the saying that the brain secretes thought as the liver secretes bile. There can be no true analogy between thought and the "tangible, ponderable, visible" product of a bodily process. But, setting aside these crudities, is the case for materialism improved when we are told (1) that mental action is a mode of motion; (2) that it is a manifestation of matter; (3) that it is a form of energy—like heat, light, or electricity; (or 4) that it is a function of the brain? These statements are often shuffled about as if they were interchangeable; but it will be worth our while to glance at each of them in turn.

(1) A mental fact cannot be identified with a mode of motion. Mobility is an essential property of material things; apart from motion we could not know them. It is through actual contact of his own moving body and the bodies by which he is surrounded that the child makes their acquaintance. But what is meant by the statement that thought, or any mental process, is a mode of motion? The physiologist might pore till doomsday over the changes of the brain without being made aware, if he were not aware otherwise, of the existence of mind. He might trace, to a fuller extent than anyone has yet succeeded in doing, the manner in which motion is flashed along the nerve fibres, or stored as potential energy in the cell bodies. Could the whole structure, with its ever-varying movements, be laid bare before him, he would expect like movements in the future; but were he strictly confined to the investigation of matter in motion he could never from this assert the presence or predict the advent of mind. Thus Tyndall has justly said that "The passage from the physics of the brain to the corresponding facts of consciousness is inconceivable as a result of mechanics. Were our minds and senses so expanded, strengthened, and illuminated as to enable us to see and feel the very molecules of the brain; were we capable of following all their motions, the chasm between the two classes of phenomena would still remain intellectually impassable."(*e*) And Herbert Spencer, though he has expressed his formula of evolution in terms of matter and motion, has yet, in a well-known passage, decisively rejected the belief that mind may be interpreted in terms of matter, declaring that, were he compelled to choose between materialism and idealism, the latter alternative would seem to him more acceptable.(*f*) Statements such as these emphasize the difference between mental and material facts, and show how impossible it is to reduce mind to motion or matter in motion.

(2) A similar objection applies to the statement that mental action is a manifestation of matter or material substance. A material thing is made manifest to us through its properties, and we know it more fully in proportion as we know them. But mental action is not one of these properties. In attending exclusively to the bodily organism or the brain, the physicist or physiologist abstracts from all knowledge

(*e*) Fragments of Science II., pp. 86–7.

(*f*) Principles of Psychology, vol. I., pp. 158–9.

of mind which he may otherwise possess. Or if the physiologist includes neuro-psychology within his province, as he frequently does, he is a psychologist as well as a physiologist; and the problem is to show the correlation between his material facts and the very different facts of mind. We do not become acquainted with mind by concentrating our attention on matter. It requires for its study special methods, and notably the method of introspection.

(3) When it is said that mental action is a form of energy, like heat, light, or electricity, we are introduced to the doctrine of the conservation of energy. Without energy, actual or potential, matter has no existence; and the theory tells us that, though energy may flow into diverse forms, the sum of energy throughout the material universe is constant. Visible motion may be transformed into heat, and heat again into visible motion, and so on through the whole round of the forms of energy; but in the system of the universe nothing is lost. It is evident that this great generalisation is intended to apply only to a material system. It has been verified by physical experiments, and, since it is held that every form of energy is, at bottom, a mode of motion, it follows from what has been already said that the law cannot be applied to mind. When we try to decipher the connection between mind and matter it is impossible to establish that equivalence which, according to the law of the conservation of energy, prevails between material cause and material effect. A sensation of sound, which is a mental fact, is consequent on a stimulus imparted to the organ of sense. But how is it possible, comparing the sensation with its immediate physical condition or concomitant, to say that these two things are equivalent, in the same way that a given amount of heat and a given amount of visible motion are equivalent and interchangeable? I will to move my arm, and the arm is moved; how can an equivalence be shown between the volition and the changes which take place in neuron or in muscle? How, then, can the conservation of energy be cited in favor of the statement that mind is a form of energy? The procedure of Haeckel on this point is simplicity itself. He shows that matter and energy are inseparable. He then takes the liberty of substituting mind, spirit, or thought for energy.(*g*) And, in so doing, he assumes that mental process is either identical with, or a special form of, physical energy. The assumption is unwarrantable. The transition from energy as a fact which characterises the material world to the quite incomparable fact of mental change is no better than a verbal juggle, and the only marvel is that anyone has succeeded in deluding himself by so transparent an artifice.

(4) What, again, is meant by the statement that mind is a function of the brain? The idea is that every bodily organ has its office or function, and that it is the office of the brain to grind out mental facts. To this it must be objected that, in describing any organic function, we are describing the organ itself at work, and that we are going far beyond any function of this kind when, instead of confining ourselves to the working of the brain, we ascribe to it the power of generating

(*g*) See "The Riddle of the Universe," pp. 21, 220.

consciousness. Here the materialist may turn upon us. It is absurd, he argues, to assert the contractility of muscle apart from muscle, or digestion apart from its appropriate organ; and we are entitled, in a similar way, to regard mental action as a cerebral function, inseparable from the brain-workings by which it is conditioned. It is doubtless true that contractility is a mere name apart from that which contracts, and that digestion is impossible apart from the organ which digests. But the point is that while the investigation of muscle discloses its contractility, and a knowledge of the stomach discloses its power of digestion, no investigation of the brain as such will ever disclose a single mental fact. Cerebral changes do not of themselves reveal mind; and, conversely, a child may be aware of his own thought and feeling even though he knows nothing of the hemispheres or grey matter of the brain. The analogy, therefore, breaks down, and is seen to be only another of the ingenious but unsuccessful attempts which have been so often made to confuse the boundaries of psychology and physiology.

Yet, it may be said, admitting the difference between mind and matter, may it not be true that mind is the effect of matter? May not material changes be the causes of mental facts, even though they be not equivalent? This, I take it, is really the problem which troubles the ordinary man. I have already admitted that nervous changes condition mental facts. This, however, does not exclude the possibility that mind may have something to do with our motor activities, and especially with those that are deliberately willed. Most men are ready to believe that, if anyone strikes against an obstacle, the sensation which he feels is the result of a physical stimulus imparted to the nervous system, and, on the other hand, that the removal of the obstacle may be conditioned by the will to remove it. But the thorough-going materialist believes in a one-sided activity, in which causation proceeds wholly from matter. Consciousness in its varied forms is on this view determined by bodily change; but consciousness does not exert the slightest influence on our bodily activities. How, he asks, can mind alter the direction of motion, or change the position of molecules in the brain? Perhape we may be unable to answer this question. But if we cannot explain *how* mind influences matter, neither can the materialist tell us *how* matter can originate or influence any mental change. Yet he has no doubt of the causal action of the body in producing mental facts, while he scorns the supposition that mind can influence nervous change even to the slightest extent. He appeals again to the doctrine of the conservation of energy, which, as we have seen, is applicable only to the material world. The energy of the material universe is believed to be constant in its amount. If so, the mind is powerless either to create or to annihilate energy. And if it be suggested that, in some unknown way, the mind may to some extent alter the direction of energy without increasing or diminishing its amount, this is emphatically denied. The material world is thus represented as a closed circle, impervious to psychical guidance or control. But the argument cuts both ways. If, from moment to moment, each physical cause is fulfilled in its physical effect, where is there room for the strange by-product of consciousness ? The physical cause empties itself, so to speak, into its effect, is equivalent to its effect ; how can it produce, over and above this, the collateral effect of mind ? If the physical circle is so closed and self-contained that it cannot be influenced by mind, then it cannot influence mind in its turn, or call any mental fact into being. Matter, it would appear, has enough to do with itself and its forces ; beyond these limits it cannot move a step in its causal process ; all its effects are within itself ; and mind remains solitary, apart, and unexplained. Materialism thus finds itself in a blind alley.

On the theory that material agency is the sole cause, and mind simply an effect, a human being is only a conscious automaton. If this be true, mind is at best a spectator of what it cannot influence. We move from place to place, intent on ends to be accomplished, apparently guided by desire and volition, but we are asked to believe that our movements are never directed by foresight or ordered by will. The savage or the schoolboy is struck, and the blow arouses feeling. He strikes back again, but the return blow, we are assured, is not the result of feeling or will ; it is a reaction which is due wholly and solely to physiological factors. The song of the poet, the manuscript of the philosopher, the book published by the man of science, owe nothing to imagination or thought ; they are the products of cerebral changes. The mental facts which have been caused by these movements in the brain are supposed to have exerted no real influence on the song, the manuscript, or the treatise. Civilisations have been founded, cities have been built, nations have grown up, without the active aid of any living mind. All the bodily activities of the race might have been carried on equally well by mindless organisms.(*h*) And if mental facts are only inert consequents of successive changes in the brain, it follows that mind has no efficiency within itself. We do not direct our thoughts or imaginations ; our conclusions are not the result of reasoning ; we are not drawn by pleasure or repelled by pain ; we are not swayed by motives. Every mental change, as it is unfolded, is the immediate offspring of a cerebral change ; even our will is but the passive slave of molecular currents in the brain. The logical consequence of this theory, as Dr. Stout has said, is that man as a conscious being never does anything at all.(*i*). Is not this a sufficient *reductio ad absurdum ?*

The human mind is thus degraded into a remarkable, but irrelevant, appendage of bodily activities. Mind, it would seem, is the one thing in the world which is thoroughly useless. We have learned from Darwin that when a variation is found to be of no service to an organism it dies

(*h*) " An author writes a book ; a builder has a house built by the help of a hundred workmen ; a general fights a battle with a hundred thousand soldiers. The omniscient physiologist would explain all these processes, as physically conditioned, by the organisation of the respective bodies, their nervous and muscular systems, and, on the other hand, by the nature of the external stimuli. He would explain the author of the *Critique of Pure Reason* just as he would explain a clockwork." Paulsen, Introduction to Philosophy, p. 88.

(*i*) Manual of Psychology, p. 50.

away. If, then, mind is powerless to effect anything, why does it not vanish incontinently? On the contrary, it persists and flourishes, growing more complex with the increasing complexity of the organism, as if, instead of being an idle pretender, it really had some service to perform. It would appear, indeed, that consciousness varies greatly in its relations to the organism. There are many organic functions which, in their normal working, arouse no consciousness, and over which the mind exerts no voluntary control. There are habits, such as walking, which after being consciously acquired become semi-automatic, and are attended to only at intervals. Some organic movements—such as breathing, coughing, winking,—are apparently subject to voluntary modification, though they cannot be entirely controlled. And again, there are movements which are performed with clear consciousness and deliberation, with the full consent of the performer and apparently in obedience to will. Recent experiments have been held to show that the energy expended in various ways by the body can be measured, and that it bears an exact equivalence to the food supplied. This mechanical equivalence is only what might have been expected. But it will scarcely be maintained that, in a free country, the voluntary consent of the subject who submits to be experimented upon is not essential to such an experiment. It certainly does appear, in the case of our voluntary movements, that the mind may, to some limited extent, direct the activities of the organism, even though it may add no jot or tittle to the sum total of physical energy. And the general rule may be laid down, in accordance with the Darwinian theory, that this control is possible only in so far as it may be serviceable to the organism.(j) From day to day we regulate our lives on the assumptions that organic stimuli may excite sensations in our minds, and, further, that the mind is active in the control of conduct and of its manifestations in bodily movements.

A typical illustration of the position which must be taken by the consistent materialist is given in Lange's "History of Materialism." A merchant is sitting comfortably in his easy chair, when a servant enters with a telegram announcing that a big firm has failed. The merchant orders his carriage, springs to his feet, gives instructions, dictates letters, sends telegrams, then visits the bank, the exchange, his business friends, and before the hour is over throws himself again into his easy chair with a sigh, "Thank heaven, I have provided against the worst." Now, the problem for the materialist is, as Lange says, to trace back the physical series of causes through the brain to the first occasion of the whole sudden movement, without any regard to the so-called consciousness. He must treat the feelings, ideas, and volitions that have passed through the merchant's mind as inactive accompaniments of physical phenomena. He must limit his consideration to the nervous message sent from the retina to the brain, and the nervous impulses which have produced, in response, words of command and all

(j) "No activity that leaves some trace of its performance behind it is strictly and wholly removed from the possible control of the will."—Professor J. Jastrow—"The Subconscious," p. 36.

the other bodily activities. He demands that physical action shall be explained by physical causes, and by physical causes alone. But is it possible thus to dismiss the mental facts as in no way influencing the merchant's movements ? In the mere appeal to the visual centres of the brain, the telegram is of no more significance than any other series of upstrokes and downstrokes of the same height and in a similar script, conveying, let us say, an invitation to lunch or to a game at billiards. The real message lies in the meaning, conveyed in so many signs, and mentally grasped. It is this which makes the merchant start up agitated, and which forms a motive of his subsequent activity. We may not know how the mind influences the nervous system, any more than we know how nervous changes influence mind ; but to deny the mental influence while alleging the other, and to treat mind as of no account in the transaction of human affairs, is an ingenious folly.

Let us suppose that the whole of our bodily movements could be explained in a purely mechanical way. An unbroken chain of physical causes and effects would satisfy the demands of physical science. But, over and above these, there are still the mental facts. What are we to make of the sensations, the percepts, the ideas, the emotions, the purposes and volitions which form the truly significant side of human conduct ? If the chain of physical events be complete within itself, permitting no interference by mind, these events must be equally powerless to produce any mental change. From this point of view co-existence in time is affirmed between the physical and the psychical, while interaction is denied. We are thus led, not to materialism, but to parallelism, which is powerfully represented in the thought of the present day. It is seen by the supporters of this theory that between mind and matter there can be no mechanical causation ; physical influx or efflux is impossible. Yet concomitance at least between facts of brain and mind has been established by observation and experiment. Can we be satisfied, however, with a statement of *mere* concomitance ? The world is not to be cleft in twain, as by a hatchet, into unconnected orders of phenomena. Mind and matter alike belong to the one great system of the universe. We cannot regard them as entirely isolated, running, as it were, in parallel lines, with no real connection between them. Parallelists, from Spinoza downward, have sought for some ground or bridge of communication connecting the two great orders. Some of the supporters of parallelism have sought to base their theory on an idealistic view of the universe. They have thus been able to maintain the efficiency of mind, holding it to be the only thing of real value and significance, the material world interesting us only as it ministers to the needs of mind.(*k*) In any case, parallelism in its varied forms regards the mechanical theory of materialism as inadequate.

The materialist approaches his subject from the point of view of physics and physiology. But as soon as we step across the boundary that separates mind from matter, and look at the mental facts for our-

(*k*) Reference may be made to Professor Stout's "Manual of Psychology," Introduction, c. III. ; Professor C. A. Strong's "Why the Mind has a Body" ; and Professor Paulsen's "Introduction to Philosophy," B. I., c. I.

selves, a new scene lies before us. So far from being confronted by inert states of consciousness, we are in a region of activity and life. Our experiences are emphatically ours; they are linked to each other as they occur in the unity of consciousness, and form part of a continuous series. The mind, as Locke used to say, compares and compounds. Even the comparison of two sensations or ideas, and the knowledge of their likeness or difference, implies a discriminating intelligence. It has become a commonplace of mental science that the simplest perception of a material object is a mental construction. Even here, the mind is not a mirror or camera obscura, passively receiving what is impressed upon it. When we look at any object we add the results of past experience to the sensations of the moment, and it is only thus that the object of perception stands out before us. The activity of memory and of the combining imagination is incessant; and each of us, attracted by some things, while indifferent and inattentive to others, builds up for himself out of the material of his experiences a world of his own. But, as truth-seekers, we desire a knowledge of facts and laws which shall truly represent reality, and shall be valid for every intelligence. How do we set about this task? Not, certainly, by laying ourselves open passively to impressions which may be excited by the outer world; that would give us a chaos, not a cosmos. We fasten our attention on certain aspects of things to the exclusion of others. The man of science is active in his observations and experiments, forming conjecture after conjecture, and compelling nature to answer his questions; and it is through this glorious activity of thought that his triumphs have been achieved. Further, we speculate on the nature and meaning of the world as a whole. This mind of ours, which some would resolve into so many states passively accompanying cerebral changes, inquires into the nature of mind and matter and their relations; and in its quest for a principle which will explain the universe it dares to constitute itself, in the great phrase of Plato, the spectator of all time and of all existence. And when we turn from the theoretical to the practical side of life, is it not true that every human being is engaged, for good or evil, in moulding his own character? The facts of purpose and choice cannot be omitted from our estimate of human life. We are drawn by ends which we place before ourselves and which we strive to attain; and the attraction of ideals which hover before us, and which some among us would follow to the death, is very different from the forward push of a mechanical cause.

On the theory of materialism our purposes and ideals are of no real value, since, after all, our actions, good or bad, are the necessary results of molecular motions in the brain. As a consequence moral precepts, as statements of what we ought to do, are useless; morality expires; and the problem of evil ceases to have any meaning, since all actions are on the same level in the series of inevitable events. A theory which leads to such conclusions cannot be a true representation of human nature. The life of man has its deepest meaning in ethical endeavor, not as the expression of mechanical forces over which we have no control.

As soon as we realise that the mind is active in building up its knowledge, in speculating on the nature of the universe, and in striving to achieve its ideals, we have left behind us the fiction of mind as consisting of so many inert states, the products of physical movements. I have no desire to minimise unduly the tremendous influence of physical or physiological conditions. I do not doubt, for instance, the existence of rare and abnormal cases of double or multiplex personality, conditioned by strange and subtle changes in the brain. But, even so, the unifying power of mind is illustrated in each of these so-called personalities, where a limited or dissociated, or it may even be a brighter and larger, consciousness is built up in a new synthesis. The unity of consciousness does, indeed, arise in conjunction with the developing organism which conditions our earthly being; but under these conditions a new and wonderful life appears, with activities peculiar to itself. The awakened soul, with its hopes and fears, its purposes and ideals, its desires and volitions, cannot be construed into a passive accompaniment of bodily movement. When the human mind is a centre of activity in the midst of its varied changes; when by its combining and selecting power it constructs its own world; when it is conscious of its own operations, and can criticise its imperfect knowledge; when it transcends itself so far as to affirm laws that are valid for all intelligence; when it addresses itself to the great question of the principle of the universe; when it is drawn by the attractions of love and hope, and reaches forward towards an end which stretches ever on before, it is a miserably deficient account which resolves it into so many passive phenomena, the effects of so many mechanical changes.

Materialism, as we have seen, is protean in its modes of expression. But, in its most prevalent form, it is based on two assumptions: the first, that matter, or the ether from which it may have sprung, is original and fundamental as compared with mind; the second, that the principle of mechanical causation is adequate to the explanation of all changes, mental as well as material. But when we look at matter from the point of view of the physicist, or in abstraction from the mind which knows it, we find that this supposed matter, *per se*, affords no hint of the existence of mind. And thus, when matter is vaunted as the source of all things, it sometimes turns out that what is thought of is not the matter of the physicist or of ordinary thought, but a glorified matter which has been invented to suit the occasion, and which ought to have been called by some other name. The retreat from materialism may be cloaked, as an army may conceal its retreat by leaving its watch-fires burning, but it is none the less real. Thus, in a well-known passage of his Belfast address, Tyndall asserts the control of mind by matter, and discerns in matter "the promise and potency of all terrestrial life." This is apparently, when taken by itself, a profession of materialism. But in the same passage he speaks of matter as possessing "latent powers."(*l*) And in another address he asks if human thought and feeling, differing so widely as they do from any material fact, can be referred back for their origin to the nebulous haze from which the

(*l*) "Fragments of Science," II., p. 193.

worlds are supposed to have been formed. "If so," he asks, "had we not better recast our definitions of matter and force; for if life and thought be the very flower of both, any definition which omits life and thought must be inadequate, if not untrue."(*m*) What is this but a confession that the derivation of mind from matter, as commonly understood, is untenable? Or, if all that is alleged be that matter and mind have alike originated from one and the same source, we are forsaking the idea that mind is the product, in the last resort, of the primary constituents of matter. We are asserting the existence of a primeval power from which all riches of the universe, mental and material, have been poured forth in the course of evolution. And, granting such a power, the question arises whether this source of all things is unknowable, or Divine and knowable in part. With such questions before us, we have risen above the level of materialism.

If matter be understood in the usual sense, as consisting of things like those which we see and touch and handle, it may be asked if we have any right to assert its existence, save in relation to mind. So far I have followed the customary usage in speaking of mind and matter as different orders of facts; and undoubtedly there must be a difference between such facts as perception or memory and any material changes within or without the bodily organism. But a deeper analysis, drawn from the theory of knowledge, may convince us that the material world is meaningless apart from mind, and can be known only in relation to sentience and thought. We speak of the sensible qualities of material things—as color, taste, odor, or resistance; but it is the mind which is sentient, and to ascribe such qualities to material things is devoid of meaning, unless with reference to the truth that the mind can and does experience such sensations. Again, it is through the combining activity of intelligence, in accordance with the principle of uniformity, that we build up our percepts, blending presentative and representative elements and becoming aware of material objects in space. Without this mental construction we should be conscious only of fleeting sensations, and the distinction between mental and material facts would be impossible. And further, in the very fact of perception, material things become objects for a subject or knowing mind. We may indeed speak of matter in abstraction from mind; but it is a common fallacy to suppose that things which may be spoken and thought of separately have therefore a separate existence. For us, at least, matter has no existence except as related to mind, and we have no right to represent matter as an independent reality of which our minds are merely the effects.

The assumption that mechanical causation is a universal solvent is easily understood. It has done yeoman's service in scientific investigation—both in the sphere of the inorganic and of the organic; for it is thoroughly legitimate to regard even a living organism as a machine, and to endeavor to explain all its parts and functions on the principle of mechanical change. It is only a step to the assumption that mechanical causation is adequate to all our investigations, and that the introduction of any other principle involves the sacrifice of

(*m*) *Ib.*, II., p. 90.

a unifying basis for knowledge. We must not, however, allow ourselves to be led by our craving for simplicity to disregard the facts. The application of a law of continuity depends on the point from which we start. If we begin with a supposed matter *per se*, allowing no breach of continuity, we shall never be able to take the fatal leap from matter to mind. And this result is an absurdity, since we are already safely on the further side in our knowledge of our own minds. If, again, we begin with the indubitable facts of mind, the argument from unity and continuity may be used in favor of idealism.

We may at least assume that the world is an intelligible system. This assumption of intelligibility is made implicitly, if not explicitly, by all science and all philosophy. It is impossible, within the physical sphere, to dispense with the principle of mechanical causation. But it is equally impossible, when we consider the mental life of man, to ignore the presence of purposes or ends, with the choice of means for their attainment. May we not, from this higher standpoint, regard the mechanical system of the material world as subservient to an end ? While each of us is a centre to himself, he is allied to all the world beside. The animal and vegetable kingdoms are full of subtle and far-reaching adaptations, which the inquiries of evolutionists have brought more fully to the light. Every organism, with its end of self-conservation, is allied to the environment in which it lives and from which it draws its nourishment. And so the idea of purpose may be extended throughout the whole region which is covered by mechanical laws, backward to the nebulous mists from which our solar system and myriads of other systems have evolved. If this be so, the reign of purpose does not conflict with the reign of mechanical law within its proper sphere, but works in and through it. We can form no adequate idea of a tree unless we take into consideration its flowers and fruit ; and so, in the scheme of evolution, we must dwell not only on the humblest steps in the process, but still more on the highest development which within our knowledge has been attained. It is folly to restrict our attention to mechanical causation, setting aside mind and its purposes as secondary or irrelevant. If we are true to ourselves we must endeavor to read the meaning of the universe in the light of the highest things we know, and to which the course of evolution has been tending. Thus regarded it is no longer a succession of aimless changes ; it is instinct with purpose, shot through and through with thought. It is impossible for us, beings with thought and purpose, to find an adequate explanation of ourselves or of the world around us in mechanical laws.

Reports of Committees.

COMMITTEE FOR INVESTIGATION OF GLACIAL PHENOMENA IN AUSTRALASIA.

Members of Committee.

Mr. E. G. Hogg
Mr. A. Gibb Maitland
Mr. B. Dunstan
Mr. R. M. Johnston
Mr. G. Sweet
Mr. W. H. Twelvetrees
Mr. W. Howchin
Mr. G. A. Waller
Mr. R. Speight
Mr. A. E. Kitson
Dr. Marshall
Professor David (Secretary).

1.—INTRODUCTION.

Note by the Secretary (T. W. Edgeworth David) on the Reports of the Glacial Committees.

The secretary desires to call special attention to the important report and map by Dr. P. Marshall, relating to the Pleistocene, or possibly in part late Tertiary, glaciation of New Zealand. This map is a great advance on any of its predecessors.

In regard to glacial evidences in Australia, the secretary, while directing special attention to the important paper by Mr. Walter Howchin, F.G.S., on Lower Cambrian glaciation, desires to state that Mr. A. Gibb Maitland, F.G.S., Government Geologist of Western Australia, wishes that a record may be here made of the view that the conglomeratic beds between the Sturt Gorge and Blackwood, in the spurs of the Mount Lofty Ranges, near Adelaide, are not of glacial origin. He concurs with Mr. H. Y. L. Brown, the Government Geologist of South Australia, and Messrs. Basedow and Iliffe, in interpreting them as being something of the nature of crush conglomerates. The secretary wishes to point out that whether the above beds are of glacial origin or not (and he firmly believes them to be glacial) they are stratigraphically continuous with the beds at Petersburg to the north, and with those at Pekina and Jamestown, &c. That the beds are of glacial origin at the last three localities is, in the opinion of the secretary, an absolute certainty.

He exhibited at the British Association at York last year, and also at the International Geological Congress at Mexico last September, a large boulder obtained *in situ* from the Lower Cambrian boulder beds at Petersburg, and some smaller boulders. These specimens were seen by many scores of expert glacialists at the above meetings, and not a single doubt was expressed as to the glacial origin of their grooves and striæ.

The secretary would strongly advocate, in any further investigations on this subject, those who may question the glacial origin of the Sturt beds—go first to Petersburg, to that less disturbed and less crushed area, where the glacial evidences are clear and undoubted, and then work down southwards towards the more disturbed area of the Sturt Gorge. The continuity of the beds must then become apparent.

Readers interested in this question are advised to compare with Mr. Howchin's evidences of the Great Lower Cambrian Ice Age in South Australia the description of the more recently discovered Cambrian glacial beds near Ichang, just above the head of navigation of the Yangtse River in China.

See Chamberlin & Salisbury's Geology, vol. II., Earth History, p. 273; also Year Book, No. 3, Carnegie Inst., p. 282.

SOUTH AUSTRALIA.

2.—CAMBRIAN AND (?) PERMO-CARBONIFEROUS GLACIATION.

By WALTER HOWCHIN, F.G.S.

There are two extensively developed series of glacial deposits in South Australia, widely separated in relation to geological time. These have been respectively made the subjects of reports by this committee at different times. Since the last report was presented (in 1902) some additional data have been obtained in relation to each of these periods, which will be briefly summarised.

I.—Glacial Beds of Cambrian Age. [a]

1. *Age of the Beds.*—The stratigraphical relationships of the glacial beds are now sufficiently defined to fix their geological age as definitely Lower Cambrian. A general description of the Cambrian series of South Australia is reserved for another paper to be read before this Section; but the position of the beds in question may be briefly explained as follows:—The Cambrian rocks form a very thick series, which may be divided, lithologically, into two parts—(*a*) an upper (which is much the thicker portion), consisting mostly of red-colored rocks; (*b*) and a lower, chiefly characterised by siliceous quartzites and phyllites. Near the top of the upper set of beds are some fossiliferous limestones, with *Archæocyathinæ* reefs, Cambrian trilobites,

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[a] See Howchin on the Geology of the Mount Lofty Ranges, Part II., Trans. Roy. Soc., S. Aus., 1906, p. 228.

Hyolites, *Obolella*, &c. The glacial beds occur in the lower set of beds, many thousands of feet below the limestones which carry characteristic Cambrian types, and within a few thousands of feet of the basal beds of the series, which rest, unconformably, on a Pre-Cambrian complex. There is no apparent break in the order of succession throughout the entire series. The geological horizon of the glacial beds is inferior to the *Archæocythinæ*, and not much above the base of the Cambrian series ; they can, therefore, be definitely classed as Lower Cambrian.

2. *Geographical Extent of the Beds.*—Extended observations have shown the enormous area affected by the glacial conditions in these latitudes in Cambrian times. In the Mount Lofty Ranges near Adelaide the glacial beds only come to the surface in one great fold, with a north and south strike. To the south the beds are lost sight of after passing the Onkaparinga River—20 miles south of Adelaide—beyond which they are obscured by newer deposits, and are, moreover, cut off by a great downthrow fault along the Willunga and Sellick's Hill ranges, which brings in the *Archæocyathinæ* limestones of the Upper Cambrian.

In the northern areas and throughout the Flinders Ranges the glacial beds recur at intervals in great anticlinal and synclinal folds, which take in the full width of the country from Mundallio Creek, near Port Augusta, to the New South Wales border. On the eastern side observations have been recently made by my colleague, Mr. Douglas Mawson, B.Sc., which prove that the beds in question cross the borders and are developed in the Barrier Ranges of New South Wales.

In the northern Flinders they have been proved to outcrop in the Mount Nor-West [b] and Willouran ranges [c], on the north-west of Hergott, as well as at the extreme north-eastern portion of the Flinders Ranges to the north of Lake Frome.[d] The limits of their occurrence have not been fixed either on the eastern or northern sides. The known area of the Cambrian glacial beds, at present, is about 450 miles north and south and 300 miles east and west. Their most northerly known occurrence is in 29° 40′ south latitude, which is within about 6° of the Tropics. The glacial bed noted by Tate (Horn expedition), and subsequently by Spencer, at Yellow Cliff, on the River Finke, will probably be found to be referable either directly to the Cambrian series or the re-arrangement of the Cambrian glacial erratics in a deposit of later date. The last-named supposition would explain the presence of desert sandstone pebbles in the debris, as determined by Professor Tate, [e] as well as the large granite boulders in Cunningham Gap, also in the Finke

b Brown.—Report on Country East and West of Farina, Parl. Paper, No. 102 of 1884.

c Howchin.—Trans. Roy. Soc., vol. XXX., 1906, p. 330.

d Woodward.—Report on Range to the East of Farina, Parl., Paper, No. 40 of 1884. The present writer traced these beds for 50 miles through the north-east Flinders as far as the Daly and Stanley mines, near the Freeling Heights, where several well-marked glaciated stones were picked out of the till.

e Trans. Roy. Soc., S. Aus., vol .XXI., 1897, p. 68.

(a mile above Crown Point Cattle Station), described by Mr. J. J. East. *f* The present writer has called attention to a similar distribution and re-arrangement of the glacial erratics in deposits of recent age in the Hergott and Stuarts Creek districts. *g* The supposition that the erratics of Yellow Cliff and Cunningham Gap are of Cambrian derivation, if confirmed, places the northerly occurrence of the glacial beds in about 25° 30′ south latitude, or within about 2° of the Tropic of Capricorn. As elevation above sea-level cannot in this instance be predicated to explain the occurrence of ice in these low latitudes, the climatic conditions must have been exceptional and extraordinary to admit of floating ice carrying its burden of morainic debris almost into the equatorial belt.

3. *Thickness of the Beds.*—The determination of the thickness of the glacial beds is often rendered difficult by stratigraphical disturbances, which, at times, duplicate the outcrops, and at others more or less cut them off. The absence of bedding planes through great thicknesses of unstratified till introduces another element of uncertainty in this particular. In the gorge of the Appila Creek, near Appila-Yarrowie, there is a very clear exposure of the beds with their upper and lower boundaries sharply defined. The measurement in this case is rendered the more easy in that the beds are tilted to within a degree or two of the vertical, so that the width of the outcrop may be taken, practically, as the thickness of the beds. In this instance the thickness amounts in the aggregate to 1,500ft., including 860ft. of characteristic till with boulders. The till proper occurs in two main horizons; the lower occupies the basal position of the beds and is 750ft. thick; and the other makes the topmost bed, and is 110ft. in thickness. Between the two beds of till there is a series of gritty quartzites, slates, and a thin limestone, aggregating 640ft. Throughout this middle zone erratics are either absent or rare. In other sections of these beds, as at the Sturt Valley and the Onkaparinga, for example, the barren zone is of much less extent, and more divided up in its relationship to the till.

4. *Form of Glaciation.*—All the evidences available point to floating ice as the agent immediately concerned in producing the deposits under consideration. In no case has a glaciated floor or underlying unconformable series been observed, which might be expected to occur in the case of land ice. The upper and lower limits of the ice deposits are sharply defined, as no erratic occurs either above or below those limits; but, on the other hand, there is a stratigraphical continuity in the sedimentation which has taken place. It was a soft sandy bottom which received the first contributions of the ice-borne material, a fact which is inconsistent with glacier ice, except in a very limited way. Indeed, the extent of the area affected limits the agency either to a continental ice-cap or an oceanic basin, and the evidences favor the latter. At the same time the ice must have floated from an area undergoing intense glaciation, which is evident from the enormous amount

f Trans. Roy. Soc., S. Aus., vol. XII., 1889, p. 44.
g Trans. Roy. Soc., S. Aus., vol. XXX., 1906, p. 330.

of material transported, the great size of many of the erratics, and the great number of ice-scratched stones which have been obtained from almost every outcrop of the beds when opportunity presented itself to search for them.

II. THE NEWER ((?) PERMO-CARBONIFEROUS) GLACIATION.

Whilst making geological observations on the older rocks of the Inman Valley, a few additional notes were incidentally made of the glacial phenomena in the neighborhood. These are now presented in the form of a progress report, and are supplementary to those already given of this highly glaciated district.[h]

The Hindmarsh River valley, the Inman River valley, and the Back Creek are valleys of erosion cut through the glacial deposits of a once much greater valley, that had its boundaries in the Hindmarsh Tiers on the north-east and the Waitpinga highlands on the south-west. This older valley had a width varying from three to seven miles. At the time of intense cold in these latitudes the valley was filled from side to side by the great Inman glacier, which, in its course northwards, surmounted obstacles in its path 800ft. in height.

Several well-marked *roches-moutonnees* occur as inliers of the glacial sands and clays. Granite Island was probably one such, but has been subsequently much weathered and broken by sea action during Tertiary and Recent times. At the entrance to the Hindmarsh Valley two rounded hills exhibit characteristic *roche-moutonnee* features. One of these forms the rounded knoll on which "Adare," the residence of Mr. D. H. Cudmore, is situated. The rock consists of micaceous quartzite, and on its westward side numerous large granite boulders line the face, some of which show 9ft. of surface near the level of the ground in which they are almost concealed. In the paddock adjoining the house are two granite erratics each 5ft. in length, and are associated with a group of six smaller boulders. Another, but smaller, *roche-moutonnee* hill is seen in a line with the one just described, composed of similar rock, with a granite boulder, 3ft. 6in. long, perched near the top. On the west side of the hill are two others, measuring respectively 3½ft. and 2½ft. In the south-east paddock there is a group of 20, measuring up to 5ft. in length. Morainic material is seen on the saddle connecting the two *roche-moutonnee* hills.

About eight miles north-west from Victor Harbor an important spur of the ranges penetrates the Inman Valley on its northern side, and includes Strangway's Hill and the Inman Hill. Whether the glacier passed over these highest points of the spur or not is uncertain; but there is definite evidence that it passed over a saddle near the head of the Duck's Nest Creek, on the northern side of the spur (which is only a few feet below its highest point) and filled up the Duck's Nest Creek and the Deep Creek, which occur on its western side. The height of this saddle, as given by the aneroid, is 790ft. That the ice should

[h] See Roy. Soc., S. Aus., vol. XXI., 1897, p. 61. *Ibid.* vol. XXII., 1898 p. 12. Report Aus. Asso. Ad. Science, Sydney, 1898, p. 114. *Ibid.* Melbourne, 1901, p. 172.

have passed over so high a watershed is a very important fact, especially as at present there are no high lands to the south equal to supplying the gravitative force for surmounting such a barrier.

Before describing the glacial features of this spur and its associated valleys, we must refer to some remarkable features on its south-eastern flanks. What must be regarded as one of the most important discoveries of glaciation in Australia was pointed out to me by Mr. Crossman, in the way of a glacial pavement of great extent and in perfect condition. In approaching this spot from the east, in section 196, hundred of Encounter Bay, a deep wash-out creek occurs, exposing banks of morainic material, 20ft. deep. At a bend in a tributary of this creek, a little above the junction (section 194), a granite boulder, measuring 14ft. by 12ft. by 8ft. high, is set in the creek bottom, with an expanding base covered with silt. A little lower down the creek, hard glacial sandstone, very irregularly bedded, forms the bed of the watercourse, and on the right bank of this creek are the exposures of the glacial pavement referred to above.

The *Glacial Pavement* is evidently of great extent, as three wash-outs, parallel to each other, and making a united breadth of 100yds., show the polished floor to be at least of that extent.

The most northerly of these washouts is the most extensive, and exposes several faces which are separated from each other by intervals in which the pavement is replaced by broken rock or obscured by creek material. The highest up face, in this line of washouts, is 4yds. long; 60yds. lower down a second polished face occurs, 5yds. long; and 12yds. farther is the main polished face, 30yds. long. Nothing in the way of glacial polish, striæ, and groovings could be more perfect and striking. The markings (whether of striæ of microscopic size or fluted grooves a foot wide) all have the same direction, at 280°. That the ice was travelling westerly is proved by the frequent deep digs into the pavement in that direction—like a chisel, cutting and jumping as it is pushed along. The slope of the pavement varies up to 10° in the south-east direction. By the scour of this small creek several large granite boulders up to 6ft. have been freed from the finer morainic material.

The second washaway, parallel with the preceding, at a few yards distance, has a polished face exposed for 12yds., and shows some very fine shallow and wide grooves, giving the same direction as the preceding reading.

The third washaway is smaller than the above, and carries the same features.

One of the most interesting features of these extensive exposures of the polished glacial floor is the evidence of crust movements and slight faulting which have occurred since the ice withdrew from South Australia. In the cases of the large face, in the first washout described, there are six successive and parallel drops of the floor, from 2in. to 3in. in depth, producing a series of small step faults. In the third wash-away there is a normal fault of 15in., the fault plane being from 3in. to 4in. wide, and filled with a ferruginous breccia. In all cases the faulting shows a downthrow to the south-east.

As these polished faces occur within a quarter of a mile of the polished pavement in the Inman River, it is reasonable to conclude that the glacial floor is continuous between the several exposures, and gives the strongest evidence that the glaciating agent was land ice on a very large scale.

Strangway's Hill Spur.

In taking the rise to Strangway's Hill, in section 122, morainic material and large erratics are plentiful. Near Mr. Crossman's hut, in the above section, are many granite boulders up to 8ft. in diameter. One of these, 3½ft. long, is strongly glaciated ; and another, 6ft. by 6ft. by 4ft. high, is a fine-grained granite with segregations of tourmaline in globular masses, 2in. to 6in. in diameter.

On the saddle of the range, near the head of the Duck's Nest Creek, (referred to above), and slightly on the western side of the crest, are two large boulders of granite resting on each other, the dividing plane probably being a joint, which give a combined measurement of 7½ft. by 6ft. by 5ft. high, resting on glacial sandy clay. The presence of these unmistakable erratics in such a position is of great importance, proving that the actual path of the glacial was over this high ridge.

The summit of the range at the place where these evidences occur is covered with a remarkable clay-sand deposit, which is disposed in innumerable small hills and hollows, like graves in an extensive graveyard. The mounds are from 6in. to 12in. above the hollows. The local residents have no knowledge of the origin of these mounds, and the piece of country is known to them as "the Bay of Biscay." That the material is of glacial origin cannot be doubted, but it seems extremely unlikely that superficial features of so perishable a nature could have remained unaltered during the immense interval which separates this glacial period from the present.

Duck's Nest Creek.

The Duck's Nest Creek, which is a deep gully on the western side of the Strangway's Hill and Inman Hill, has been excavated in glacial sands and clays which formerly must have almost filled the older valley. Sections of these beds, in the form of finely laminated sandstones in horizontal position, can be seen exposed in several places (Section 86). Going up the creek, just over the fence (in passing from Section 87 to 120), a prominent rock arrests attention from its peculiar shape, suggesting a *roche-moutonnee.* An examination shows that the rock is a rounded mass of very hard quartzite, 60yds. in extent, with nearly vertical walls, 20ft. high on the side next the valley. The rock face, although mostly covered with lichens, still preserves faint indications of striæ that run east and west in the direction of the curve of the valley at this spot, and still more distinctly, both polish and striæ can be seen on the top of this bared rock. A very large granite boulder is perched on this rounded mass, measuring 7½ft. by 5ft., with several large blocks of similar stone at the base of the wall face, which have evidently been broken from the main mass.

Along the same hill face, rising towards the head of the creek, numerous very large boulders are seen. One granite mass, with metamorphic rock inclusions (similar to what occurs in the granite of Granite Island), measures 8ft. by 6½ft. by 7ft. high; another, 8ft., in a group of eight, which almost equal this one in size. A sand ridge, produced by the breaking down of the glacial sandstones of the creek, is marked with several very large stones; one of these, 10ft. in length, is almost sunk in the sand; another, 16ft. by 10ft., has undergone much exfoliation, and is nearly covered by drift.

Ridge on West Side of Duck's Nest Creek and Deep Creek Valley.

The Deep Creek (or Fresh-water Creek) lies to the north-west of the Duck's Nest Creek, and is the channel of drainage for a large area, giving a perennial supply of fresh water. The valley has been largely choked with glacial drift, which has been subsequently removed, and now presents the features of extensive sandy flats, richly timbered, with occasional boggy places. More interest attaches to the ridge which separates this valley from the Inman Valley than to the Deep Creek Valley itself.

Near the eighth mile-post from Victor Harbor, a bridge crosses the Inman, and the road, going north, takes the rise with the Duck's Nest Creek on the right hand. Glacial sands and clays are seen on the hill side, and on the top of the ridge, to the left hand, a small rounded hill of broken quartzite suggests a disintegrating *roche-moutonnee.* There are one or two other less prominent rounded spurs to the right hand, on the sides of the gully, but these are also much broken.

Whilst some of the ice-sheet passed over the saddle of the Strangways Hill spur, it is evident that the main flow passed up the Inman Valley and, rounding Inman Hill, formed a rather sharp curve in the direction of the Deep Creek Valley. The ice left an enormous number of large erratics on the convex side of this curve—the greatest field of erratics that I know in any part of South Australia, and included the largest examples of these travelled stones. By far the greater number are granites, and mostly the large-grained, Granite Island type, of which there are many hundreds.

Three of these lie beside the road, near the top of the ridge, and measure respectively—No. 1, partially buried, 17ft. by 5½ft.; No. 2 almost round, 16½ft.; No. 3, 15ft. by 12ft. A quartzite, in scrub, not far from road, is well polished and striated.

In the scrub, on west side of road, can be seen many similar ones. A group of 16 large erratics are crowded together; the largest of the group measures 16ft. by 15ft. by 8ft. high, and must have been much larger, as it is surrounded by large pieces which have exfoliated from the mass. Another, more on the slope towards the valley (Section 48), is 9ft. by 8ft. by 9ft. high. Another, deeply sunk in morainic matter, has an exposed surface of 9ft. by 8ft., with 3½ft. out of the ground. The largest erratic I have seen in the Inman Valley is on this slope, and measures 19ft. by 16ft. by 10ft. high, which has also been much reduced by exfoliation. The white sand and clay, which form the finer part of the morainic material, pass over the saddle of this ridge into the valley of the Deep Creek on its northern side, where the ploughed land on the slopes is very light and of a white sandy nature.

The Deep Creek Valley is bounded on the north side by lofty hills of lower Cambrian and Pre-Cambrian rocks, which appear to have formed the limits of the ice flow on that side. On the south side is the much lower ridge, known as Martin's Hill (Section 145). The creek is responsible for the removal of much of the morainic material from the sides and bottom of the valley, and has obscured the deposits by alluvial laid down from flood waters.

A small tributary, in Section 87, exposes the glacial beds at its bottom, with numerous boulders in the creek and on the slopes; and on the dividing ridge between this creek and the Duck's Nest Creek are several granites, measuring respectively 5½ft., 4½ft., and 4ft. One hundred yards south of these there is a large erratic fractured in two, 12½ft. x 9ft., covered up, apparently, to a considerable depth. A spur of the older rocks here projects into the valley, having a rounded contour, though much fractured at the surface.

Lower down the valley from the point just indicated there is a long, rounded ridge of sand, 50ft. high, which runs up from Mr. J. Crossman's, in Section 404, to a high level on the road which crosses the ridge from Inman Valley. One large erratic is seen on this sand ridge, not far from Crossman's, 7ft. by 2½ft., and contains inclusions of schist like those at Granite Island. This is the only large erratic I saw in Deep Creek Valley.

The Deep Creek, as a rule, runs through alluvial flats of its own formation, but at a point (in Section 361) where the creek makes a sharp horseshoe bend to the south it has cut deeply into the morainic material. The bottom of the creek is in yellow, grey, and white clays, with sands, in which the water has cut deep ruts and potholes, and cut back into a cliff of glacial beds 20ft. high. The clays are irregularly deposited in heaps and vertical bands. A few erratics are present, but I saw none at this spot of any considerable size. The Deep Creek Valley curves round to the south-west and unites with the main Inman Valley.

The localities described in these notes formed part of the northern edge of the great Inman Glacier, and the number and great size of the erratics which occur along this line may in a great measure be explained by this fact.

The morainic ground-mass of the district described, as of most of the Inman Valley glacial beds, consists principally of a yellowish sandy clay, or argillaceous sands, with coarse granitic grits in places. This is what might be expected. From the dominant part which granite rocks make in the erratics carried it may be assumed that the snow-fields and upper glacial valleys were largely in granitic country, and one that had already been rendered, to a great extent, rotten and friable through weathering. Such a surface would readily yield to frosts, water, and ice; and much of the granitic debris would be carried with the erratics on the surface of the glacier, or ground into "rock flour" beneath its weight. A whitish, imperfectly cemented sandstone forms the most characteristic feature of the moraines of that age in South Australia, and was carried in such quantity that the older valleys of the districts concerned were choked with material up to 1,500ft. in thickness, which has had the effect of splitting up the main lines of drainage into numerous smaller outlets. The absence of superincumbent mass and rock strains, in the interval which separates that period from the present, has left the morainic matter almost unaltered. Where the ground moraine exists in hollows of the glacial pavement, it is very hard from the compression it has undergone; but, as a rule, the clay constituent is easily washed out, and a fine incoherent white sand is left behind and forms the principal surface feature.

VICTORIA.

The following notes were sent by Mr. A. E. Kitson, from Colombo (whilst on voyage to Europe), addressed to Professor David, the Gen. Sec. of Glacial Research Committees.

Since the last meeting of the Association (Dunedin, 1904) the only published paper on the glacial geology of Victoria that I have seen is one by Mr. W. H. Ferguson, of the Geological Survey of Victoria, entitled "Report on Glacial Conglomerate of supposed Jurassic Age, in Parish of Wonga Wonga, near Foster, Southern Gippsland," published in the records of the Geological Survey, Vict., Vol. I., Part 4.

The author records his discovery, in August, 1902, of a glacial deposit consisting of pebbles of indurated mudstones, shales, sandstones, grits, quartzites, jasper, cherts, lydianite, felsites, granite, &c. (some showing polish, striation, and facetting; others none), in a road cutting at Chitt Creek, in the hillsides adjacent to and some distance to the west of that place.

Although he is apparently inclined to regard them as belonging to the Jurassic period, he concludes his report by leaving the question of age open. He suggests three periods, viz.:—(1) Permo-Carboniferous; (2) Jurassic; (3) Post Permo-Carboniferous to Pre-Jurassic. He gives the sequence of the beds at Chitt Creek as follows—commencing at the youngest beds:—

(1) Jurassic sandstones of moderate texture.
(2) Glacial conglomerate, a few feet thick at most.
(3) Loose angular, sub-angular, and waterworn boulders and pebbles of the underlying rocks.
(4) Altered Silurian rocks (shales, sandstones, and quartzites).

Mr. Ferguson was not able to determine, from the field evidence, the relation of the glacial deposit to the underlying and overlying deposits, though he is apparently inclined to regard the glacials and the Jurassic sandstones as quite conformable with each other. He records these glacial deposits as extending altogether for about one and a quarter miles, but not in a continuous mass—the two deposits being about one mile apart.

I recently examined the locality about the road cutting at Chitt Creek, and have no hesitation in giving my opinion that the material is of glacial origin. Pebbles up to the size of a man's head, and showing polish, grooving, and striation are not uncommon; while smaller pebbles, similarly marked, are present in considerable numbers in a gravelly clay. On the hillside, however, I was not able to see the outcrops of Silurian rocks nor the glacial deposits, for a recent landslip from the overlying Jurassics had covered the hillside with soil and Jurassic rocks.

The material in the road cutting is, in my opinion, not *in situ*, but part of an old landslip from probably 50ft. higher up the slope. The Silurian strata occurring here form the eastern extension of the Foster goldfield belt of Silurian (?) rocks, and the Jurassics occur at about 100ft. up the slope, and comprise the mass of the country extending northward for a great many miles.

From such evidence as I saw, and long acquaintance with the Jurassic rocks of South Gippsland, I am rather inclined to the belief—though I do not definitely advance it—that these glacial deposits are more of the nature of large lenticular masses in Jurassic sandstones than consisting of one continuous bed. During my survey of the South Gippsland coalfields and adjacent country I frequently found, occurring as small lenticular beds of conglomerate or scattered pebbles, among Jurassic sandstones, rocks such as usually occur in glacial deposits and others as well, and in a paper, "Volcanic Rocks at Anderson's Inlet, South Gippsland," published in Proceedings of Royal Society, Victoria, in 1903, have cursorily described them, suggesting a direct or indirect glacial origin for them.

Mr. Ferguson, in his paper above referred to, states he also came to the conclusion prior to the discovery of the glacials at Chitt Creek that blocks of sandstone, granite, &c., among the Jurassic sandstones were due to shore ice.

WESTERN AUSTRALIA.

Remarks on the Permo-Carboniferous glacial deposits of Western Australia, by Mr. A. Gibb-Maitland. will be found in his Presidential Address (Section C), at page 145, *et seq.*, of this volume.

TASMANIA.

1.—THE PERMO-CARBONIFEROUS GLACIAL BEDS AT WYNYARD, NEAR TABLE CAPE, TASMANIA.

By Professor T. W. EDGEWORTH DAVID (Gen. Sec. of Glacial Committees).

[WITH PLATE.]

Through the kindness of Mr. W. H. Twelvetrees, F.G.S., Government Geologist of Tasmania, the author was furnished with copies of the official reports by Mr. Twelvetrees and his late assistant, Mr. G. A. Waller, together with a series of local maps relating to the remarkable glacial beds of the above locality. These strata were termed by the late Government Geologist, Mr. A. Montgomery, the Wynyard formation. Later they were referred to specially in a report by Mr. G. A. Waller "On the Coal of the Inglis and Arthur River District, near Table Cape." A very interesting section is also furnished in this report, which makes it clear that the Wynyard beds are at the base of the Permo-Carboniferous system in that locality.

On the occasion of the meeting of the Australasian Association for the Advancement of Science, at Hobart, in 1902, Mr. A. E. Kitson, late of the Geological Survey of Victoria, now Geologist to Nigeria, made the important discovery of undoubted ice-scratched boulders in these Wynyard beds at a point about three miles E.S.E. of the town of Wynyard. At the close of the Association meeting a geological excursion was led to the spot by Messrs. Waller, Kitson, and others, and a number of excellent striated boulders were obtained. Since then Mr. Twelvetrees has visited the area, and made a special report on the occurrence of coal and kerosine shale at Preolenna. His report entirely confirms that of Mr. Waller in the stratigraphical horizon assigned to the Wynyard formation. It is clear that its position is at the base of the Permo-Carboniferous system, and below the fresh-water Coal Measures of Preolenna. These Coal Measures, which are interstratified between two marine Permo-Carboniferous series, are almost certainly the equivalents of the Greta Coal Measures of New South Wales. The result of the author's visit to the locality last April, together with notes kindly supplied by Mr. Twelvetrees, are given in the accompanying short report.

Immediately to the south of the entrance to the Inglis River at Wynyard, and for three miles towards Burnie, there are magnificent flat sections in the coast platform of marine erosion showing the glacial beds. These beds, called by Mr. A. Montgomery (the late Government Geologist of Tasmania) the Wynyard Formation, extend also N.N.W. from the Inglis River for a distance of about two miles towards Table Cape.

At Freestone Cove, near Table Cape, the top of the glacial beds is about the level of half-tide, or mean sea-level. It is there capped by the *Crassatella* and *Turritella* beds of Eocene age. The junction line is a slightly eroded one, and there must be also a slight unconformity, as whereas the Eocene beds are almost horizontal, the Permo-Carboniferous glacial beds dip in a general W.N.W. to N.W. direction, at an angle of about from 5° to 10°.

At a point about three miles to the E.S.E. of the mouth of the Inglis River the glacial beds disappear under a flow of Tertiary basalt, which descends to below the level of low tide. The flow just here is only about 200 metres in width, where it has filled up an old Tertiary river valley. On the E.S.E. side of the flow no trace is seen of the glacial beds, but in their place, occupying the foreshore of the coast platform, are dark grey to black schistose slaty rocks, and felspathic quartzites. (The latter strike from N. to N. 5° E., dipping E. at 60° to 70°.)

It is evident [from this section] that the old Tertiary river valley, now filled with drift and basalt, was eroded just along the junction line of the older Palæozoic rocks with the glacial beds of the Permo-Carboniferous system.

The Permo-Carboniferous basal glacial beds are extremely hard, and have a gentle angle of dip on the whole, whereas the strata of the Ordovician series are much softer, and being steeply inclined, as above stated, at angles of 60° to 70°, are very readily eroded.

The existence here of this basalt-filled Tertiary valley extending to below sea-level makes it impossible to see just here the actual pavement on which the glacial beds rest. There can be no doubt whatever, in view of the evidence in Victoria and South Australia, that such a pavement when found further inland will prove to be strongly striated and grooved. As will be shown presently, fortunately, striated pavements are to be seen occasionally in the glacial beds themselves, which pavements show the direction of movement of the glacier ice.

It will be seen from the accompanying section, taken through the glacial beds between the Inglis River and the base of the formation, three miles to the E.S.E., that the glacial beds consist of at least four distinct types of rock, viz. :—

(1) The glacial till, resembling the boulder clays of late Cainozoic age of the Northern Hemisphere.

(2) Conglomerates, frequently containing erratics and striated boulders.

(3) Sandstones, with occasional—but rare—striated boulders.

(4) Thin-bedded, often minutely lamellated, clay shales with intercalated thin flaggy sandstones, and occasionally thin bands, 1in. to 2in. only, of boulder clay. The flaggy sandstones and mudstones are in many cases beautifully ripple-marked.

The following is a general description of the boulder clay proper, which is very well developed immediately to the south of the entrance to the Inglis River.

The base of the boulder clay is a dark grey mudstone ; no very definite stratification is visible, but there is a faint indication there of a general W.N.W. dip. The matrix is seen under the microscope to be made up of comminuted fragments of the Ordovician shales and quartzites.

The boulders in the gritty hard boulder clay are mostly rounded or subangular; occasional angular fragments may be seen of black jasperoid slate, and quartz or quartzite. The boulders are mostly from 1in. to 2in. up to about 8in. in length. More rarely large blocks up to 5ft. in diameter are met with, the latter being mostly well worn. Here and there are lumps or masses in the boulder clay, resembling at first sight large erratics; these are of rounded or irregularly oval shape, and often exhibit a slight concentric structure. They merge insensibly in some cases into the boulder clay of the base at their margins. The diameter of these masses varies from 1ft. to 27ft.

In the one shown in the photograph [exhibited] the thin beds of conglomerate, locally developed in the till, are nearly vertical as regards their bedding planes where they abut against the block. The block itself is formed of very fine sandstone, showing extremely minute diagonal bedding. It would seem from the shape of some of these fine-grained masses of hard fine-grained sandstone that they were bent out of shape slightly subsequent to the time of their deposition.

As regards the shape of the typical boulders, they are either flattened oval, or somewhat blunt-pointed at one end, and more squared off at the other end, like a short boot. Frequently one of the two larger surfaces is flat, while the other is more convex. In such cases the flat side is usually uppermost when the block is *in situ* in the boulder clay. For the most part the lie of the longest axes of the boulders is irregular, as is also that of their principal planes, which are inclined at all angles with regard to the horizon at the time of their deposition, being frequently vertical. Some of the included fragments in the boulder clay appear to be true water-worn pebbles derived from older rocks and subsequently glaciated.

As regards glacial markings, a large proportion of the boulders are intensely glaciated, being deeply grooved and strongly striated. In many cases faulting may be observed, as might be expected. The hardest rocks, such as the quartzites, quartz, and jaspers, have resisted the glaciating forces.

As regards the nature of the rock in these blocks, some of the most angular, from 3in. to 6in. in diameter, are blackish jasperoid or cherty argillite, passing into a black slate. The latter contain numerous impressions of Graptolites (*a*).

A common rock, occurring in blocks from 6in. to about 15in. in diameter, is an ocherous brown soft sandstone, with numerous hollow

(*a*) There can be little doubt that the rock pavement underlying the boulder beds in the vicinity is formed chiefly of these blackish graptolite rocks of the Ordovician series. Mr. T. S. Hall, M.A., Lecturer in Biology, University of Melbourne, the well-known authority on Australian Graptolites, has identified *Phyllograptus* and *Diplograptus* among these specimens, as well as examples of the Phyllocaridæ and shells of Brachiopods allied to *Obolella*.

casts of *Pentamerus*, Crinoids, and *Rhynchonella*. Rarely blocks of reddish limestone are met with exhibiting similar fossils. Mr. W. H. Twelvetrees informs me that similar rocks of Upper Silurian age occur at Heazlewood and Zeehan.

The above are the only fossiliferous rocks observed by me in the boulder beds. A greenish-brown felspathic quartzite is extremely common, and is almost invariably intensely glaciated. A fine-grained, reddish-brown quartzite exhibits striæ well, but is less often grooved. Hard, dark-grey quartzites and whitish quartzites weathering ocherous are not uncommon. White marble occurs sparingly; one block, shown on the longitudinal section and in the photograph, measures about 5ft. x 4ft. x 4ft. Occasional boulders may be noticed of a tough quartz-grit, as well as of a curious quartzite (?) with red orthoclase, and of a dark greenish conglomerate, which Mr. Twelvetrees compares with the conglomerates of the Dial Range.

Ancient crystalline schists and gneiss—a red orthoclase gneiss—are met with here and there, but the metamorphic crystallines are not so much in evidence as the sedimentary rocks just described, and the eruptives about to be described. The latter are represented by conspicuous blocks of red granite, often rendered porphyritic by orthoclase; these are frequently in blocks from 6in. to 2ft., or even 3ft. long.

Granite-porphyry and orthoclase-porphyry, with veins of tourmaline and pseudomorphs in tourmaline after orthoclase, are less frequent but fairly numerous. A few boulders of serpentine, usually in small fragments, but in some cases 18in. long, are to be seen at wide intervals. Mr. Twelvetrees considers that this serpentine resembles some of those which occur *in situ* near the township of Forth and at the Bald Hill, Heazlewood.

With regard to the probable parentage of these rocks, Mr. Twelvetrees has kindly supplied me with the information contained in the note at the end of this report.

As a rule striated pavements were not observed in the boulder clay, where it was of considerable thickness; such striated pavements as were noticed appeared to be restricted to thin patches of boulder clay interbedded with conglomerate. As shown in the Section, three such striated pavements were observed by me.

1. As shown in the Section, the trend of the grooves and striæ on these pavements in the boulder clay varies from N. 30° to 35° E. to about N. 20° E. In most cases the grooving and striation is about N. 30° E., that direction being the lee side, so that the ice in this locality evidently moved from about S. 30° W. towards N. 30° E. The lie of the longest axes of the large boulders agrees fairly well with the same direction.

2. As regards the evidence of the locale of the parent rocks of the boulders in the clay, Mr. Twelvetrees considers that their parent rocks may be to the S., the S.S.W., or the S.S.E. At all events there is nothing in this part of the evidence inconsistent with the view that the ice which caused the glaciation moved from a general S.S.W. or S. 30° W. direction.

3. If, as now seems probable, the glaciations of Wynyard, Bacchus Marsh, and Hallett's Cove were synchronous there is now evidence of a radiation of the ice, the angle enclosed between the striæ of Wynard and those of Hallett's Cove being from 30° up to 40°.

4. The intercalation of bands of sandstone, conglomerate, and ripple-marked flagstones and mudstones amongst beds of true till perhaps indicates either contemporary recession of the ice sheets or definite interglacial epochs.

5. The fact that the most angular boulders in the till are formed of black claystones and clayslates, often containing Graptolites, and that there is a large amount of similar but finer material in the matrix of the till, and that this particular rock closely resembles that seen outcropping in the immediate neighborhood, leads to the conclusion that here, as at Bacchus Marsh and at Hallett's Cove, the till, as regards its matrix, at all events, is chiefly of local origin, and was formed by the action of land ice in the form of a piedmont, or of an ice-sheet.

6. The proximity of the top of the glacial beds of Wynyard to the marine strata of the Permo-Carboniferous shows that even near the latitude of Wynyard the ice probably came down very close to—if not actually to—sea-level.

Under existing meterorological and geographical conditions it would probably need a reduction of temperature of about 10° C. in order to admit of glacier ice coming down to sea-level in this region.

In conclusion the author would emphasize the need for further research in this district on the following points :—

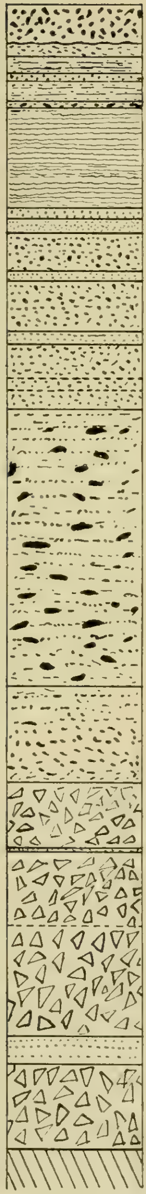
1. As to the existence inland of striated rock pavements.
2. As to the exact thickness of strata intervening between the topmost of the glacial beds at Wynyard and the lowest of the overlying marine strata.

Another feature of special interest in the Wynyard glacial beds, and one which the author has not hitherto observed anywhere else, is the occurrence at the point shown on the plan of a large mass of laminated sandstone in the apparent form of an erratic in the glacial beds. The mass measures 27ft. in length, 6ft. in width, and the part protruding from the denuded surface of the glacial beds about 5ft. in height, while there is evidently a considerable portion of the mass still buried from view. The locality is about 10 chains to the south-east of the entrance to the Wynyard River.

At first sight the mass presented the appearance of a true erratic. It is a very fine-grained sandstone, showing thinly-bedded structure, together with very minute cross-bedding or current-bedding. The bed planes of the mass are now almost vertical, but their upper portions are slightly bent over from the W.S.W. towards the E.N.E. At the south-west side of the mass are some contemporaneous gravel beds in the mudstones, which are now nearly vertical as regards their bedding planes. The mudstone of the till in which the mass is embedded dips in a general westerly direction on the east side of the mass at an angle of about 30°.

PERMO-CARBONIFEROUS GLACIAL BEDS, WYNYARD, TASMANIA.

BY PROFESSOR T. W. E. DAVID, F.R.S.



40 feet	Hard Glacial Till.
15 "	
18 "	Bedded Mudstones and Shales, with Erratics
10 "	Boulder Beds
20 "	Bedded Mudstones, with small Erratics.
5 "	Conglomerate, with large Striated Erratics in places.
108 "	Thin-bedded Flagstones and Shales, with minute Boulder Beds and lens-shaped Concretions of Ironstone. Ripplemarks.
10 "	Boulder Beds.
15 "	Sandstone.
42 "	Conglomerate, with Glaciated Boulders.
10 "	Sandstone.
55 "	Glacial Conglomerates, numerous Striated Blocks.
12 "	Sandstone.
70 "	Boulder Beds, without Clay. Striated Pavements, 2 and 3
300 "	Conglomerates with numerous patches of Striated Boulders.
100 "	Conglomerates.
70 "	Till.
	Sandstone.
	Till.
	First Striated Pavement, N., 27° E.
200 "	Till.
30 "	Sandstone
90 "	Till (?), with patches of Conglomerate and Sandstone Bedding contorted contemporaneously; vertical in places
1,220 "	Ordovician Slates: dip E. to E. 5° S. at 70°

A close examination of this pseudo-erratic shows—

1. That it exactly resembles the minute current-bedded sandstones interstratified with the glacial beds themselves.
2. That at its edges it rarely merges into the matrix of the till.
3. It is clear that the bending of the top part of the mass from W.S.W. to E.N.E. was effected while the mass was still in a plastic state.

It is not easy to account exactly for its mode of origin. Possibly it represents material laid down by some sub-glacial, or possibly en-glacial stream, which by a forward carrying movement of the ice became driven over the top of the ground moraine, and was eventually forced into it, possibly when the mass was in a semi-frozen condition. An alternative explanation is that it may represent material deposited at the bottom of a glacial moulin, in which case it would represent the infilling of a structure analogous to a "giant's kettle."

The lie of the longest axes of this remarkable mass is N.N.W. and S.S.E. On the whole, the author is inclined to the former of the two theories as to its mode of origin.

Summary.

The author wishes to emphasize the following facts :—

1. The section at Wynyard may be taken as a type for the rest of Australasia. It shows in the most clear and unmistakable manner that the chief horizon for the Permo-Carboniferous glacial beds is at the very base of the Permo-Carboniferous system, and considerably below—stratigraphically—the horizon of the Greta Coal Measures. The same conclusion has already been formed by the author in regard to the Permo-Carboniferous glacial boulder horizon at Lochinvar in New South Wales. This section is, therefore, of great importance in the light which it throws on the exact stratigraphical horizons of the Bacchus Marsh glacial beds of Victoria, of Permo-Carboniferous age ; the glacial beds of Hallett's Cove, near Adelaide, in South Australia, of the same age ; and those of the Irwin, the Gascoyne, and the Wooramel rivers in Western Australia.

In the opinion of the author all these horizons may now be referred to the basal beds of that series in the Permo-Carboniferous system known as the Lower Marine.

2. The Wynyard evidence shows that even as far south as that latitude the ice was still moving from some gathering ground still further south, probably considerably further south, if one can judge of its distance at all by the thickness of the glacial beds themselves. For example, in the case of the Pleistocene glacial beds of Europe and North America, as well as in the case of the Permo-Carboniferous glacial beds of South Africa, it is found that they are thickest in those areas which were at the margins of the great ice sheets ; whereas they thin out or completely disappear towards the centres of radiation of such ice sheets.

2.—NOTE ON GLACIATION IN TASMANIA.

By W. H. TWELVETREES.

Permo-Carboniferous Glaciation.—At Easter last year the Permo-Carboniferous boulder-till near Wynyard was visited by Professor T. W. E. David, who, besides establishing the existence of an ice pavement, made a collection of many of the stones embedded in the clay matrix, with the idea that by their means the locality of their parent rocks might possibly be recognised.

An examination of the specimens gathered, however, has not disclosed any very distinctive criteria.

Some indurated dark shale or slate was submitted to Mr. T. S. Hall, M.A., by Professor David for the determination of some impressions of graptolites which were visible, and that observer has identified some of them as belonging to *Phyllograptus typus* (J. Hall), *Tetragraptus serra* (Brong.), both of Lower Ordovician age. Mr. Hall says the rest are indeterminate, though there appears to be a *Diplograptus* among them.

The same stone contained a Brachiopod and some Phyllocarids which have been determined by Mr. F. Chapman, F.L.S., &c., of the National Museum, Melbourne, as *Siphonotreta Maccoyi* (Chapman), and *Caryocaris Wrightii* (Salter) respectively. Mr. Chapman's paper describing these fossils accompanies this note. He fixes the age as Lower Ordovician.

Fossils found previously in the blocks of stone or boulders of this Wynyard bed were submitted to Mr. R. Etheridge by Mr. T. Stephens, M.A., and described by the former in a paper published in the proceedings of the Royal Society of Tasmania for 1882. These were *Pentamerus Tasmaniensis* (R. Etheridge, jun.); *Spirifer* sp.; *Spirifer* resembling *S. plicatella* (Linn.); *Spirifer* not unlike *S. crispa* (Hisinger) or *S. elevata* (Dalman); *Orthis*, resembling *Orthis biforata* (Schlotheim); fragment resembling a *Strophomena*; *Ophileta* (probably); *Tentaculites*. Mr. Etheridge concluded that it might be said that at least some of the Table Cape boulders are of Upper Silurian age, the Upper Llandovery beds, or May Hill sandstone, putting in a very strong claim for recognition.

Upper Silurian calcareous and sandstone beds, fossiliferous, occur upwards of 30 miles south-west of Wynyard, and slates and schists of undetermined age occupy the valley bottoms not far to the south; but the exact parent rocks of these fragments have not been identified. The pink granite occurring as stones and boulders in the conglomerate is not now seen nearer than the Upper Blythe and the Dial Range. The slate is not quite like any that I have seen in that part of the island, while the evidence obtainable from the numerous specimens of quartzite in the till is too vague for use.

3.—ON A BRACHIOPOD AND SOME PHYLLOCARIDS OF LOWER ORDOVICIAN AGE FROM A GLACIAL ERRATIC AT WYNYARD, TASMANIA.

By F. CHAPMAN, A.L.S., etc., National Museum, Melbourne.

[WITH PLATE.]

The fossils referred to in the following notes occur on a rough cleavage face of a slab of black indurated shale broken from an erratic found in the Carbo-permian glacial beds of Wynyard, near Table Cape, Tasmania. For the opportunity of examining these fossils I am indebted to Mr. T. S. Hall, M.A., to whom the rock specimen was sent by its discoverer, Prof. T. W. Edgeworth David, F.R.S.

DESCRIPTION OF THE FOSSILS.

Class BRACHIOPODA. Order NEOTREMATA.

Genus SIPHONOTRETA, DeVerneuil.

SIPHONOTRETA MACCOYI, Chapman. *See* plate, fig 1.

S. maccoyi, Chapman, 1903, Proc. Roy. Soc., Vict., vol. xv. (N.S.), pt. II., p. 118, pl. XVIII., figs. 12–14.

Remarks.—The structure of the specimens referred to the above species is, in places, remarkably well preserved, so that further diagnostic characters of the species are afforded beyond those originally given in the description of the Victorian specimens. The valves in the present example are somewhat crushed, and in the figured specimen the dorsal has partially slipped aside from the pedicle valve. The umbonal or apical part of the dorsal valve is rather prominent. The hollow conical beak of the ventral valve is strongly compressed, and the tubular canal is clearly seen through the thin shell, together with the striated areas of the muscle attachments on either side. The surface of the valves, especially near the apex, is marked with fine radii. By the discovery of this specimen the distinctness of *S. maccoyi* from *S. micula*, to which species McCoy originally referred it, is even more evident. In the original description of this species I remarked on the variation between the Lower Ordovician and Upper Ordovician examples from Victoria, the former being smaller than the latter. The present specimens also agree in this feature with the Lower Ordovician forms.

Measurements of the present figured example:—Length of dorsal valve, 5·7mm.; width of dorsal valve, 4·9mm.; depth from apex of ventral valve to outer margin of false cardinal area, 1·2mm.

Class CRUSTACEA. Order PHYLLOCARIDA.

Genus CARYOCARIS, Salter.

CARYOCARIS WRIGHTII, Salter. *See* plate, figs. 2, 3, 5.

C. wrightii, Salter, 1863, Quart. Journ. Geol. Soc., vol. XIX., pp. 137, 135, fig. 15, p. 139. Jones and Woodward, 1892, Pal. Soc. Mon., Brit. Pal. Phyllopoda, pt. II., p. 89, pl. XIV., figs. 11–15, figs. 5 and 6 (woodcuts).

Remarks.—The majority of the examples seen on the slab of indurated shale from Wynyard may be referred without hesitation to *C. wrightii.* One of the specimens (figs. 2, 2*a*) exhibits an interesting structural feature at the attenuated and blunt extremity (anterior, auct.), which there is good reason to regard as the rostrum, and beneath this occurs a slender appendage partly hidden below the former, which may be homologous with the antenna. The same wrinkled aspect of the carapace is seen in our specimen, which is common also to those of the Skiddaw slates, indicative of a filmy membranous structure. That this wrinkling is not entirely due to the dynamical folding or rippling of the slate seems to be shown by the fact that the surrounding matrix breaks with a fairly even surface. Further, if we assume that the membranous valves of *Caryocaris* were strongly inflated in the median area and rigidly strengthened on the dorsal and ventral borders, it is easy to conceive how a flattening of the valve would produce an extremely wrinkled film.

C. angusta (*a*) from the Victorian Lower Ordovician rocks approaches this form very closely, but is distinguished by its rounded anterior. *C. wrightii* occurs in the Arenig Group in England and Wales (Salter, Jones, Woodward, and Marr), and in the Calciferous (Tremadoc) Group of North America (Gurley).

CARYOCARIS MARRII, Hicks. *See* plate, figs. 4, 6.

C. marrii, Hicks, 1876. Quart. Journ. Geol. Soc., vol. XXXII., p. 138. Jones and Woodward, 1892, Brit. Pal. Phyll., pt. II., p. 92, pl. XIV., figs. 16–18.

Remarks.—One of our specimens, smaller and narrower than the preceding species, is probably referable to the above form. The carapace in this, like those of the accompanying species, is thin, glossy, and wrinkled. The wrinkling here, however, is as strong longitudinally as transversely. The reproduced outline of one of Jones and Woodward's drawings of this form (fig. 6) exhibits the same general shape, but is probably slightly distorted through pressure. It is interesting to note that, similarly with ours, the two species occur together on the same slabs of the Skiddaw slates, and in regard to which Messrs. Jones and Woodward remark that these forms may represent sexual differences.

EXPLANATION OF PLATE.

Fig. 1.—*Siphonotreta maccoyi*, Chapman. Example with two valves slightly separated. From glacial erratic, Tasmania. x 5.

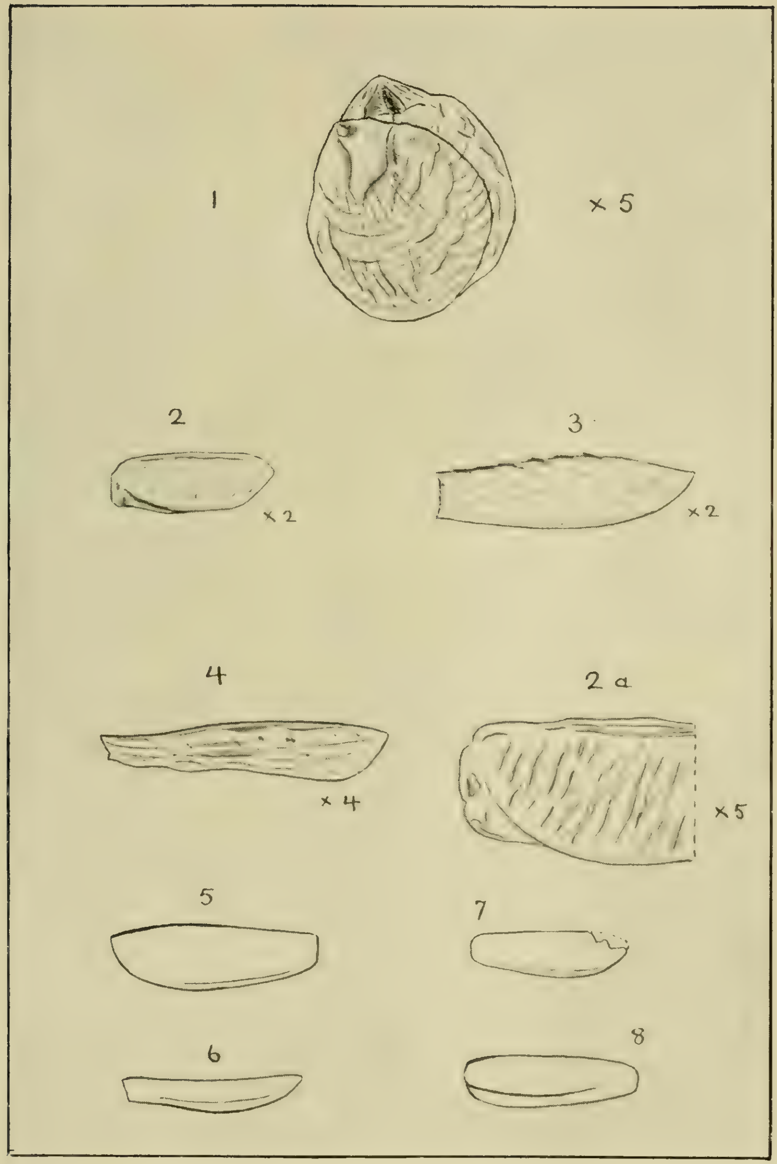
Fig. 2.—*Caryocaris wrightii*, Salter. Valve showing (?) rostrum, x 2; 2*a*. magnified portion of same showing rostrum and (?) antenna, x 5. From glacial erratic, Tasmania.

Fig. 3.—*C. wrightii*, Salter. An example of a longer valve with prow-shaped posterior. From glacial erratic, Tasmania. x 2.

Fig. 4.—*C. marrii*, Hicks. From glacial erratic, Tasmania. x 4.

Fig. 5.—*C. wrightii*, Salter. Outline of Skiddaw specimen, after Jones and Woodward.

(*a*) Proc. Roy. Soc. Vict., vol. XV. (N.S.), pt. II. 1903, p. 113, pl. XVIII., fig. 10.



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SIPHONOTRETA AND CARYOCARIS, TASMANIA ETC

By F. Chapman.

Fig. 6.—*C. marrii*, Hicks. Outline of Skiddaw specimen, after Jones and Woodward.

Fig. 7.—*C. angusta*, Chapman. Outline of Victorian specimen.

Fig. 8.—*C. oblonga*, Gurley. Outline of Canadian specimen (Calciferous group).

NEW ZEALAND.

1.—NOTES ON GLACIATION IN NEW ZEALAND.

By P. MARSHALL, M.A., D.Sc.

(WITH MAP.)

The great Taieri moraine is the only evidence that glacial conditions extended to the present east coast in any part of New Zealand. The main features of the moraine were described by Hutton, in his "Geology of Otago and Southland." The geological survey referred to the moraine as the Henley Breccias. The moraine is 10 miles long and three miles wide. In places it rises to an altitude of 1,000ft., but its base is beneath sea-level. On the north-west it is bounded by the Lake Waihola depression, and on the south-east a range of mica schist 1,000ft. high, against which it abuts, separates it from the ocean.

The material of the moraine consists almost solely of fragments of mica schist. In many places it has been rudely stratified by the streams that flowed from the ice face. In all places where the stratification can be seen there is a constant N.W. dip of 15°. The surface is greatly disfigured by stream action, and its loose incoherent matter allows of slips forming in large numbers in winter ; in fact there are few portions of the hillsides that have not recently moved. The Taieri gorge strikes straight across the moraine and the schist hills that separate it from the sea. The gorge is tidal throughout its whole length, and was evidently corroded when the land was at a higher level. At the same time it is a recent feature, for it is extremely precipitous to the water's edge, where it traverses the solid schist ; but where the moraine is crossed the banks are far less steep. No marine shells or other fossils have yet been found in the morainic matter.

The moraine requires special explanation, both because of its singular position, and of the peculiarity of the Waihola basin and the Taieri gorge. Hutton stated that the ice filled the Waihola basin, and that at first the stream to which it gave rise flowed down the Tokomairiro Valley, the broad bottom of which is at least 600ft. below the summit of the hills that rise precipitously from the gorge. During the glacial recession he supposed that the valley was blocked by an ice dam, and an overflow over the coastal hills resulted, and thus the gorge was formed.

It is rather more probable that earth movements have in this case produced these remarkable features. The north-west side of the

Waihola basin is a steep escarpment rising to a level surface 1,500ft. above the floor of the basin. This surface is nearly on a level with the summit of the schistose hills beyond the moraine. This suggests the idea that the Waihola basin is situated on the site of an infallen block. The constant north-westerly dip of the moraine on the south-east side of the basin also supports this idea.

If this explanation is correct it follows that the Taieri moraine does not owe its present position to severer climatic conditions nor to regional depression, but to a local earth movement, of which the steep N.W. scarp of the Waihola basin and the N.W. dip of the moraine are the visible signs.

Little attention has hitherto been called to the fact that the large glaciers of the past in New Zealand gave rise to several streams at the terminal face. The lakes that now occupy the lower portion of many of the glacial beds have, of course, a single outlet, and it is too often assumed that this was the course of the only stream that flowed from the glacial front. The road to Lake Te Anau follows a valley that was evidently a second outflow, and several others can be found when the moraine is inspected.

At the present day the Mueller glacier has a second outlet. The main stream flows from its terminal face; but a mile above this there is an outlet through the southern lateral moraine. Down this channel torrents of water flow in continuous wet weather, after the glacier has "filled up."

An exploration expedition was conducted in December, 1905, and January, 1906, up the north branch of the Clinton Valley, which had never before been visited. The valley is 14 miles in length, and ends in a precipitous unscalable cirque, rising, apparently, 2,500ft. from the valley bottom, which is itself 2,700ft. above sea-level at its termination.

Nine miles from the cirque it was found possible to scale the fall of a hanging valley, whose termination was 1,100ft. above the floor of the main valley. A little way along the hanging valley there is a further abrupt step of 500ft., beyond which is a perfect rock basin one mile long and half a mile wide. Icebergs were floating on the lake. The outlet is over solid diorite gneiss. The lake is bounded on three sides by steep mountain slopes, and on two sides by relatively low cols. One of these leads over to the Neale Valley, but is apparently too precipitous for use. The other, on the north side, leads to the head waters of Joe's River, which Mr. W. G. Grave, of our party, followed to Lake Ada, in the Arthur Valley. This is the second practicable route that has been explored between Milford Sound and Lake Te Anau.

There is one feature in the north branch of the Clinton that seems to me to have escaped notice in similar regions. I refer to avalanche tarns. The first avalanches of spring do not affect the rock walls of the valley, but consist of pure snow that forms a cone at the foot of the avalanche precipice. Later avalanches bring down much rock, which rolls down the previous cone, and forms a ring of debris round it.

SOUTH ISLAND OF NEW ZEALAND
Shewing extent of
PLEISTOCENE GLACIATIONS

SURVEYOR GENERAL'S OFFICE ADELAIDE A. Vaughan Photo lithographer

When the avalanche melts in late summer, a tarn forms at the foot of the precipice. These tarns were very numerous, and sometimes 300yds. in diameter.

I append a map showing what I believe to have been the area covered by ice during the greatest glacial extension in New Zealand. The map shows the South Island only, for no glacial extension has yet been noted in the North Island. In this connection it is worthy of note that there are small glaciers on Mount Ruapehu 9,175ft. now. The largest of these is on the south-west face of the mountain. Including *névé*, it is one and a half miles long and half a mile wide. It shows all the features of an ordinary glacier in moraines, crevasses, &c.

The terminal faces of the large glaciers were retraversed in 1905. The Mueller has slightly advanced, but the Tasman is stationary. The rates of movement have also been observed. The information is contained in the Lands and Survey Report.

On December 25th, 1902, Rev. H. Newton lost an ice axe two miles from the face of the Franz Joseph glacier. It was found by Batson on January 15th, 1905, sticking in the ice of the terminal face.

2.—NOTES ON SOME OF THE NEW ZEALAND GLACIERS IN THE DISTRICT OF CANTERBURY.

By R. SPEIGHT.

The following notes were collected as the result of three journeys into the country at the head of the Rakaia, Rangitata, and Waimakariri Rivers, all of which flow from the eastern side of the Southern Alps through the provincial district of Canterbury. All these rivers rise in glaciers which are the shrunken remnants of great glaciers which formerly extended out of the present mountain valleys into the coastal plain on the east, as is recorded in various papers by Haast, Hutton, and others.

The first portion of this note deals with the rapid recent retreat of some of the present glaciers. With regard to the Rangitata glaciers, my notes relate to those up the east branch of the River Clyde, the principal feeder of the Rangitata River. The glaciers here occupy a small part of the head of the valley, so that they may be called valley glaciers. The front of this glacier, perhaps, shows signs of recent small advance, judging from the overhanging character of its terminal face, but the evidence is unsatisfactory. Observations of the river valley immediately below show that rapid retreat has taken place at a very recent date. Lateral moraines occur at places along the side of the valley and at but slight elevation above its floor, and at a spot about five miles below the present terminal face, a well-defined terminal moraine stretches more than half way across the floor of the valley. As this is exposed to the erosive and transporting action of a large river, subject to heavy floods, and flowing on a mean slope for this part of its course of about 100ft. per mile, it is difficult to believe that it has been in existence for a long space of time. This moraine is in an ideally perfect condition, and but sparsely covered with the vegetation that soon covers undisturbed rock material in the locality.

In the valley of the Cameron River, a tributary of the Upper Rakaia, the signs of recent retreat are still more marked. The glacier at the head of this river is larger than those in the Rangitata, and it has recently occupied about a mile of the floor of the valley. The valley opens out at its head into a wide amphitheatre, which has been formed by the united action of two glaciers, only one of which now exists, and this one is rapidly shrinking. The evidence for this is as follows:—The lateral moraines are now left perched high above the present level of the ice, sometimes as much as 150ft. (determinations made with the aneroid); the terminal face has thinned out till it cannot be readily distinguished under the covering of debris from the frontal fluvio-glacial deposits; the morainic heaps, which mark the last great halt in the recession of the ice, are separated from the end of the glacier by about 600yds. of ground covered by material which has but recently been surface moraine, and is almost free from plant covering. The glacier shows signs of extremely rapid collapse over the whole of its lower portion. I have noted a similar phenomenon in connection with the Muller Glacier in the Mount Cook district. A glacier may thus disappear over large areas at nearly the same time, and not by a slow recession of the terminal face. This fact may have some bearing on the rapid retreat and disappearance of an ice sheet.

In the two localities above mentioned, observations were made for use on future occasions. It is a very long time since these glaciers were visited by anyone who intended to observe them carefully, so that there are no reliable data by means of which their actual rate of recession can be determined at present. The fact that they are retreating is confirmed by station managers in the neighborhood, one of whom assured me that from his own observation the Ashburton Glacier has retreated about three-quarters of a mile during the last 30 years.

These notes concerning the retreat of the glaciers show that from causes not adequately determined there has been a rapid recent retreat, and that we are probably approaching a period of minimum glaciation. No doubt the whole period of recession since Pleistocene times has been marked by a series of such minima, with intervening maxima.

The next observations that I have to record relate to the truncation of spurs by glaciers in the above-mentioned localities, and also at the head waters of the Waimakariri. Here the valley floors are not hidden under water, as is the case with the West Coast sounds, although they are buried to a certain extent by the waste brought down by the rivers, which in this portion of their course are not degrading their beds. The details of the erosive action of the glaciers are therefore more easily studied. In this area the valley systems had been thoroughly developed previous to glaciation, and the following observations were made on the corrosive action of glaciers on such a country, the point specially noticed being the method by which spurs were truncated.

The following conclusions were come to as the result of detailed observations :—

(1) The truncation of spurs to a greater or less extent is apparent in nearly all cases where lateral valleys join a main one.

(2) This appears to be greatest where the tributary valley meets the main valley nearly at right angles, or at an angle greater than a right angle.

(3) The cutting back is almost wholly on the down stream side of the tributary.

(4) When a portion of the spur still remains stretching out into the valley (like a reef running out from a point), a deep notch sometimes occurs close to the steep end of the truncated spur. Further out in the valley the rocks rise higher.

(5) There are sometimes a series of terraces produced by erosion above the principal face produced by cutting back.

(6) All the rocks standing up above the floor of the valley show striæ and flutings, thus showing that the truncation was the work of ice.

This striation is becoming much more apparent in the Waimakariri Valley, as the clearing of forest has shown that what were previously considered moraines are in most cases the remnants of truncated spurs. An excellent instance of rock striation is thus disclosed within a few yards of the Bealey Hotel, on the Christchurch-Hokitika road. Other good illustrations of spur truncation are seen in the valley of the Waimakariri at the junction of the Crow River, the Bealey, the Hawdon River, and Dr. Cockayne, who accompanied one expedition, tells me that the same phenomena are repeatedly seen up the Poulter River—another tributary of the same river. Similar phenomena were observed in the Rangitata Valley.

I think it will be apparent that the truncation of the spurs is due to great pressure, which must occur on the down-stream side of a tributary glacier when it joins the main stream. Owing to the imperfect fluidity of the ice and its slow motion, the tributary glacier is forced over the shoulder of the spur on its lower side. Its corrasive power is very great, and the spur is being continually cut back, either by sapping of the walls or by their being overriden by the ice. In the second case a series of shelves may be cut out. As the spur is becoming reduced to the level of the valley it is natural that erosive action will be more intense near the end of the spur, and thus the notch will be formed.

It seems probable that the obscure terraces or zones of tolerably even slope, which occur above the steep walled sides of valleys heavily eroded by glacier action, may be put down at times to an action similar to that which produces the terraces above truncated spurs. These shelves are frequently seen where the glacier has moved round the shoulder of a hill, or in the narrower parts of the valley. Where the valley widens out the slopes become more even, and such shelves are absent.

REPORT OF COMMITTEE FOR BIOLOGICAL AND HYDROGRAPHICAL STUDY OF THE NEW ZEALAND COAST.

Members of Committee.

CAPTAIN HUTTON	DR. BENHAM
PROFESSOR THOMAS	DR. CHILTON (Secretary and Convener).
MR. HAMILTON	

In presenting a progress report of the work done in connection with the Biological and Hydrographical Study of the New Zealand Coast, the Committee has, in the first place, to record with very great regret the death of one of its members, Captain F. W. Hutton, F.R.S., an ex-president of the Association, who had taken a keen and active part in the work of the Association from its commencement.

Immediately after the Dunedin meeting of the Association an attempt was made by some members of the Committee, assisted by Messrs. C. Hedley and G. M. Thomson, to dredge, on the Continental Shelf, off Port Chalmers, but owing to unfavorable weather the attempt was unsuccessful, and considerable gear was lost. The thanks of the Committee are due to the Union Steamship Company of New Zealand for the loan of deep-sea sounding apparatus and the services of two of the officers to operate it.

A second expedition was afterwards organised at Auckland, with considerably better success. The spot chosen for operations was in the vicinity of Cuvier Island, east of Great Barrier Island, in lat. 36° S. and long. 175° 55′ E., and two successful hauls were made by the bucket dredge from about the 100-fathoms zone. Mr. C. Cooper kindly granted the party the use of his premises, and Mr. H. Suter took charge of the collections and distributed the different groups to various specialists for investigation, and it was decided that types of any new species should be placed in the Colonial Museum, Wellington. The results of these investigations are contained in the following papers, published in the Transactions of the New Zealand Institute, vol. XXXVIII. :—

1. "Results of Dredging on the Continental Shelf of New Zealand," by Charles Hedley, l.c., pp. 68 to 76.
2. "On the Foraminifera and Ostracoda obtained off Great Barrier Island, New Zealand," by Frederic Chapman, l.c., pp. 77 to 112.
3. "Report of some Crustacea dredged off the Coast of Auckland," by Dr. Charles Chilton, l.c., pp. 269 to 273.

4. " Results of Dredging on the Continental Shelf of New Zealand," by R. Murdock and H. Suter, l.c., pp. 278 to 305.
5. " Results of Dredging on the Continental Shelf of New Zealand," by W. H. Webster, l.c., pp. 305 to 308.

A study of these papers shows that the greater part of the collections consisted of mollusca, and that of these a number are new species, while many are interesting additions to the New Zealand fauna.

The Committee regrets that although several other attempts have been made to organise further dredging expeditions it has up to the present been found impossible to do so. This has been mainly due to the fact that the various members live in different parts of New Zealand, and seldom find it possible to meet at any one centre. Another attempt is now being made to make dredgings off Port Chalmers, and it is hoped that this may be successfully accomplished before the end of the year.

A sum of £10 9s. 3d. out of the grant of £50 has been expended in the purchase of several hundred fathoms of wire rope and other appliances, and the balance (£39 10s. 9d.) is in the hands of the secretary. A balance-sheet is attached.

In view of the importance of the results already obtained, the Committee begs to recommend that its members be reappointed to continue the work, and that Mr. Edgar R. Waite be appointed to the Committee in the place of the late Captain Hutton, and that the unexpended balance of the grant be placed at the disposal of the Committee to meet further expenses.

CHAS. CHILTON, Hon. Secretary and Convener.

REPORT OF COMMITTEE ON NEW ZEALAND FOOD FISHES.

The Committee, consisting of Messrs. C. W. Chamberlain, D. Barron, and Geo. M. Thomson, was appointed at the last meeting of the Association "to investigate the local conditions affecting the food supply of food fishes of New Zealand seas at the fish hatchery at Portobello."

The station was formally opened on January 13th, 1904, by Professor T. W. Edgeworth David, President of the Association, but work was not begun till later in the year. The Marine Hatchery Board was very fortunate in the selection of Mr. T. Anderton as curator, as he has entered into the spirit of research with great zeal.

The methods adopted to carry out the work of the Committee have been (1) to collect and record, as far as possible, the contents of the stomachs of various species of fish taken; (2) to note the occurrence, distribution, and life histories of the living organisms which compose the food of fishes; and (3) to keep daily records of the temperatures of the air, of the ponds, and of the water of the harbor. From the limited means at the disposal of the Board and Committee it was only possible to carry out these methods very imperfectly; still, a good beginning has been made. Very considerable assistance has been afforded by Mr. F. J. Sullivan, owner of the steam trawler *Express*, who afforded Mr. Anderton the opportunity of going out with the steamer at any time she was at work, and also placed facilities in his way for securing the ova of fish, any rare or unknown specimens which were taken in the trawl nets, and of examining the stomachs of the fishes caught. The engineer of the trawler also assisted by keeping, for a time, a record of the temperatures of the surface water of the harbor and of the ocean six miles off Otago Heads. At such times as the work at the station permitted and the weather was favorable, Mr. Anderton was out about once a week with the trawler, and made good use of his time.

One of the most interesting facts ascertained in connection with these observations is that while the temperature of the ocean—even in midwinter—does not fall below 9° C. (= 48° F.), that of the shallower waters in enclosed bays, such as that of Otago Harbor, frequently falls as low as 3° C. (37°·4 F.). Of course, this chilling of the tidal waters is greatly intensified in the shallow ponds at the hatchery, where at times during the winter of 1905 the temperature fell to 0° C. It was ascertained that certain species—such as the blue cod (*Parapercis colias*, Forster)—could not survive exposure to this temperature. Such chilling of the shallower coastal waters evidently causes this and probably many other species to move out into deeper waters at the commencement of winter. In cold weather also it was noticed that this species does not take food.

Observations were made on the contents of the stomachs of nearly a score of different species of fish—some of them not food fishes, however—from November, 1904, to May, 1905, and from February to November of the present year (1906). The reason of the interrupted observations is that the work of collecting ova, rearing the fry, and attending to the stock of fish in the ponds, frequently interfered with the trips on the trawlers or with records of the stomach contents of the fishes taken on these occasions. Some fishes also—such as the moki (*Latris ciliaris*)—are never opened by the fishermen on board the trawlers, so that it was difficult to obtain any record of them.

The commonest food material in the New Zealand seas in the neighborhood of the south-west coast is the pelagic crustacean, known as "whale feed," which is almost certainly a free swimming stage of *Munida sub-rugosa*. Attempts have been made in the hatchery aquarium to rear this crustacean from the egg, but without success hitherto; so that while there seems little doubt of the accuracy of the identification, actual proof is still wanting, and the species is usually registered as *Grimothea gregaria*. This crustacean is taken through a great part of the year, but is particularly abundant in the summer months, when it is met with in shoals numbering often many hundreds of thousands of individuals. The bright red color of the animal, which is about an inch or more in length, makes it extremely conspicuous, and it appears to furnish food for most kinds of fishes which swim near the surface, as well as for some shallow-water ground feeders.

Next to this free swimming form, many species of crustacea which live on or near the bottom of the sea are more frequently recorded as furnishing food for fishes than perhaps any other group of organisms. But one reason for this certainly is that their exo-skeleton is not so readily digested as the bodies of other animals, fishes, worms, &c., and consequently they are more readily identified. The migrations of these crustacea are not at all known or studied yet, but there seems little doubt that the migrations of the fish themselves is probably more often due to their following their food than to any other cause.

An interesting example of this was noted by Mr. Anderton in the end of May and beginning of June of this present year. For over a fortnight the trawlers worked over a small area about four miles square in Blueskin Bay, to the north of Otago Harbor, fishing in from four to seven fathoms of water. They were getting great numbers of large soles (*Peltorhamphus novæ-zealandiæ*), flounders (*Rhombosolea plebeia*), and red cod (*Physiculus bacchus*). The fishermen attributed the abundance of the fish to their coming in to spawn, and the remark is characteristic of the utter ignorance prevailing among fishermen as to the habits of the fish which they are continually catching, for the fish were not within two months of their spawning time, and, further, they do not come inshore to deposit their ova, but appear rather to keep away from shallow water. Mr. Anderton found the explanation to be due to their following their food. The sea-bottom was covered with a vast number of cumaceans (*Diastylis novæ-zealandiæ*), a species hitherto only known from two or three small specimens taken in a dredge in the Bay of Islands over 20 years ago, which came up among the weed and in the trawl nets. All the fish, also, were found to be gorged with these crustacea.

No record is possible at present of the enormous numbers of copepoda, zoœas, and other minute free-swimming forms, which certainly are a great source of food, especially for larval and very young fish, for no observations have been taken of them.

The following fishes were examined during the months named as to the contents of their stomachs. The information thus gained is manifestly only a very small contribution towards a knowledge of the subject.(*a*)

1. Hapuka or groper (*Polyprion prognathus*). February, March, April and November. Nearly always contained other species of fish, mostly red cod or soles. One contained a quantity of *Nyctiphanes*.
2. Tarakihi (*Chilodactylus macropterus*). This fish was only examined in April, when specimens were found to contain *Grimothea* and opossum shrimps (apparently *Nyctiphanes*).
3. Moki (*Latris ciliaris*). Opportunities of examining this fish seldom occurred, because when taken on the trawlers they were never cleaned. On the occasions when the contents of the stomach were examined they were found to consist of some other species of fish—apparently red cod.
4. Maori Chief (*Nothothenia maoriensis*). November to February. With the single exception of a common shore crab (*Cyclograpsus lavauxi*), the stomachs of all examined contained *Grimothea*.
5. Blue cod (*Parapercis colias*). Those in confinement fed readily on fish and *Grimothea*. The only captured fish examined (in February) had no food in their stomachs.
6. Barracouta (*Thyrsites atun*). The adult fish, examined in May and June, contained red cod—often large specimens. The young of this species are very abundant in the summer and autumn months in tidal waters. They themselves furnish food to larger species. Specimens examined in May were found to be feeding on the common rock-pool species—the cocka-bulli or kokoporu (*Tripterygion sp.*)
7. Kingfish (*Promethichthys prometheus*). February to May, and November. This fine fish, which seldom appeared in the Dunedin markets before the advent of the trawlers, is now commonly sold. Most of those taken contained red cod. Some taken on March 5th had eaten young of their own species; others on April 26th had young mullet (*Agonostomus*) and young barracouta; while some taken on November 14th contained young barracouta and garfish (*Hemiramphus intermedius*).

(*a*) Some further information, but not of a very accurate character, is to be found in a paper "Notes on Sea Fishes" in Trans. N.Z. Inst., vol. XXIV., p. 202, by G. M. Thomson.

8. Trevalli (*Caranx Georgianus*). November to February. This is a shallow-water fish, and those examined contained *Grimothea*, shrimps (*Pontophilus australis*), and species of *Tripterygion*.
9. Butterfish or spotty (*Pseudolabrus bothryocosmus*). November to February. *Grimothea* and seaweed.
10. Flounder (*Rhombosolea plebeia*). March to June. This is a ground feeder, and the stomach chiefly contains minute shells and small crabs, mixed with mud and sand. Reference has already been made to the abundance of *Diastylis* found in the stomachs of this and the two following species in June of this year.
11. Sole (*Peltorhamphus novæ-zealandiæ*). A ground feeder, like the last.
12. Red cod (*Physiculus bacchus*). This is one of the most abundant fishes on the coast, and is itself an extremely common article of food to larger and more powerful species. Those opened from November to May contained chiefly *Grimothea* and young barracouta, also various species of crustacea (*Gonodactylus*, *Platyonichus*, *Cyclograpsus*, &c.)
13. Lemon sole (*Ammetretis rostratus*). April, May, and November. Minute mollusca, chiefly bivalves, worms, unrecognisable crustacea, sand and mud.
14. Ling (*Genypterus blacodes*). February to May and November. Nearly always contained various species of fish—often large red cod.
15. Elephant fish (*Callorhynchus antarcticus*). April. Nothing but shellfish, apparently all Brachiopoda, but always broken up by the hard palate.
16. Skate (*Raia nasuta*). November. All the specimens examined had the stomach empty.
17. Dogfish (*Cephaloscyllium laticeps*). February to April and November. Contained *Grimothea*, various species of crabs (*Leptomithrax*, *Cancer*, *Ommatocarcinus*, &c.), and worms.
18. Spined dogfish (*Squalus acanthias*). March and April. Crabs, worms, and kingfish.

Geo. M. Thomson, Convener.

N.B.—A report on the Portobello Marine Fish Hatchery is printed in the last volume (xxxviii.) of the N.Z. Institute Transactions.

COMMITTEE FOR INVESTIGATION OF TERRESTRIAL MAGNETISM IN AUSTRALASIA.

Members of Committee.

Dr. C. C. Farr	Mr. E. F. J. Love, M.A.
Professor E. G. Hogg	Mr. P. Baracchi (Secretary).

1.—REPORT OF THE MAGNETIC COMMITTEE OF VICTORIA.

The work of the Melbourne Observatory consisted, as usual, in the photographic registration of the magnetic elements, on the ordinary absolute measurement; also the continuation of the measurement and reduction of the curves of all past years of record, and the completion of the programme in connection with the Antarctic Expedition of 1903.

The Melbourne series of photographic curves, extending as far back as 1868—a series which is unique in the Southern Hemisphere—is now complete, so far as the measurement of the hourly ordinates and their preliminary reduction and arrangement in tabular form.

A catalogue and classification of magnetic disturbances for the same period are now in course of preparation. It should be gratifying to the Australasian Association to see that through its instrumentality the magnetic work of New Zealand and that of Melbourne has been so satisfactorily advanced. With the exception of the two observatories mentioned above, no other institution in Australasia undertakes systematic magnetic work.

The set of magnetic instruments of the Sydney Observatory for the determination of absolute values of magnetic declination, dip, and horizontal component, with which some occasional observations were made in past years, is now again in good working order, after having been in disuse and in a bad state for several years, and it is intended to utilise it; but it is difficult to see what good purpose could be served by these instruments if used at the Sydney Observatory without a complete set of variation instruments.

The council of this Association should urge the Government of New South Wales, or the future administrative authorities of the Sydney Observatory, to install a complete set of magnetographs for the continuous registration of the variation of the magnetic elements, so that the Sydney Observatory may be able to undertake systematic magnetic work. The same remarks apply also in the case of the Perth Observatory.

It is of great importance, in view of the necessity of undertaking extensive magnetic surveys in Australia in the near future, not only for scientific but also for very practical purposes, that the observatories of Sydney and Perth should be brought into line with Melbourne and Christchurch in regard to terrestrial magnetism.

The Association would render a signal service to science if this object could be achieved.

2.—REPORT OF THE COMMITTEE ON THE MAGNETIC SURVEY OF NEW ZEALAND.

Since the last meeting of the Association the magnetic survey of New Zealand has progressed. Mr. H. F. Skey, who is now in charge of the magnetic observatory in Christchurch, has made observations at about 40 stations in the Middle Island, selected with a view to filling in the gaps in the previous work.

The work just done practically completes the survey of the main islands of New Zealand. In view, however, of the investigations of the Carnegie Institution at Washington, in the Pacific Ocean, and of the general activity in terrestrial magnetism, it is most desirable that the magnetic survey of New Zealand should be extended so as to embrace the outlying islands of New Zealand.

Representations have been made to this effect to the New Zealand Government by the Philosophical Institute of Canterbury, associated with the affiliated institutes. To these representations Dr. Bauer, of the Carnegie Institute, and Mr. Baracchi, of the Melbourne Observatory, have lent the weight of their support, and it is hoped that a favorable reply will soon be received.

COMMITTEE FOR INVESTIGATION OF SEISMOLOGICAL PHENOMENA IN AUSTRALASIA.

Members of Committee.

Sir Charles Todd	Mr. Tarlton Phillipps
Professor T. W. E. David	Mr. A. Macaulay
Professor J. W. Gregory	Mr. P. Baracchi and
Dr. C. C. Farr	Mr. G. Hogben
Mr. W. E. Cook	(Secretaries).

REPORT OF THE SEISMOLOGICAL COMMITTEE, COVERING THE PERIOD JANUARY, 1905—JANUARY, 1907.

Since the last report of this Committee the seismological work carried out in Australia has consisted as follows, viz. :—The continuous registration of seismic disturbances by the Milne horizontal-pendulum seismograph, installed at the observatories of Perth (Western Australia) and Melbourne (Victoria).

Last year a similar instrument was installed at the Sydney Observatory, which has since been kept in continuous action.

The Australian, as well as the New Zealand, results of the work in question have been or are being published in the annual reports of the Seismological Committee of the British Association, and in separate works of some of the observers themselves.

It is very desirable that seismographs—preferably of the same pattern as those now in use at Sydney, Perth, Melbourne, Wellington, and Christchurch—should be installed at Brisbane, Port Darwin, Hobart, or Launceston, and the council of this Association should be asked to take the necessary steps to induce the authorities of the respective States to assist in this purpose.

COMMITTEE TO RECOMMEND A UNIFORM SYSTEM FOR THE NOMENCLATURE OF THE IGNEOUS ROCKS OF AUSTRALASIA.

Members.

Professor David	Mr. W. H. Twelvetrees
Professor Gregory	Mr. G. W. Card, and
Mr. A. W. Howitt	Mr. S. Jevons (Joint
Mr. W. G. Woolnough	Secretaries).
Dr. Marshall	

The Committee did not meet in the interval, and no report was furnished.

Proceedings of Sections.

Section A.

ASTRONOMY, MATHEMATICS, AND PHYSICS.

1.—ON THE GEOMETRY OF AN AXIS OF HOMOLOGY.

Part III.

By EVELYN G. HOGG, M.A., Christ's College, Christchurch, New Zealand.

This paper is a continuation of two previous ones read before the A.A.A.S. at its Hobart (1902) *and Dunedin* (1904) *meetings.*

§ 1. *On related triads of points*—

Let the trilinear co-ordinates of a point O referred to a triangle of reference ABC be $(\alpha_0\beta_0\gamma_0)$. The equation of the axis of homology of O with respect to this triangle will be

$$L_0 \equiv \frac{\alpha}{\alpha_0} + \frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0} = 0$$

If $\lambda + \mu + \nu = 0$, the following six points will lie on L_0, viz. :—

$$\Omega_1(\alpha_0\lambda,\ \beta_0\mu,\ \gamma_0\nu),\ \Omega_2(\alpha_0\mu,\ \beta_0\nu,\ \gamma_0\lambda),\ \Omega_3(\alpha_0\nu,\ \beta_0\lambda,\ \gamma_0\mu)$$
$$O_1(\alpha_0\lambda,\ \beta_0\nu,\ \gamma_0\mu),\ O_2(\alpha_0\nu,\ \beta_0\mu,\ \gamma_0\lambda),\ O_3(\alpha_0\mu,\ \beta_0\lambda,\ \gamma_0\nu).$$

The three Ω points in which λ, μ, ν are permuted in cyclical order and the three O points in which λ, ν, μ are permuted in cyclical order each form what is called a related triad. Such triads will be referred to as the triads $(\lambda\ \mu\ \nu)$, $(\lambda\ \nu\ \mu)$.

When the co-ordinates of a point are $(\alpha_0\lambda,\ \beta_0\mu,\ \gamma_0\nu)$, that point will be called the point $(\lambda,\ \mu,\ \nu)$, if no confusion appear likely to arise from the omission of the multipliers α_0, β_0, γ_0.

The symbols (X. Ω), (T. P) mean respectively the axis of homology of the point Ω and the tangent at the point P.

Let there be taken the two associated conics—

$$\Sigma \equiv \sqrt{\frac{\alpha}{\alpha_0}} + \sqrt{\frac{\beta}{\beta_0}} + \sqrt{\frac{\gamma}{\gamma_0}} = 0$$

$$S \equiv \frac{\alpha_0}{\alpha} + \frac{\beta_0}{\beta} + \frac{\gamma_0}{\gamma} = 0.$$

The axes of each of the triads $(\lambda\ \mu\ \nu)$, $(\lambda\ \nu\ \mu)$ form a triangle inscribed in S and touching Σ.

Let $(X.\Omega_2)(X.\Omega_3)$; $(X.\Omega_3)(X.\Omega_1)$; $(X.\Omega_1)(X.\Omega_2)$ intersect in the points A, B, C, respectively. Then the co-ordinates of these points will be respectively $\left(\frac{1}{\lambda}, \frac{1}{\mu}, \frac{1}{\nu}\right)\left(\frac{1}{\mu}, \frac{1}{\nu}, \frac{1}{\lambda}\right)\left(\frac{1}{\nu}, \frac{1}{\lambda}, \frac{1}{\mu}\right)$. B_1C_1, C_1A_1, A_1B_1 will touch Σ in the points $(\lambda^2, \mu^2, \nu^2)$ $(\mu^2, \nu^2, \lambda^2)$ $(\nu^2, \lambda^2, \mu^2)$ respectively. Thus from the triad $(\lambda\ \mu\ \nu)$ lying on L_0 we derive a triad $\left(\frac{1}{\lambda}\ \frac{1}{\mu}\ \frac{1}{\nu}\right)$ lying on the conic S and a triad $(\lambda^2\ \mu^2\ \nu^2)$ lying on the conic Σ.

The axes of all points of S with respect to the triangle $A_1B_1C_1$ pass through O, while the axes of all points on L_o with respect to the same triangle envelope the conic

$$\sqrt{(X.\Omega_1)} + \sqrt{(X.\Omega_2)} + \sqrt{(X.\Omega_3)} = 0,$$

which on expansion reduces to the conic Σ.

In order to establish a triad on the line L_o, draw any straight line through O, and find the point H, of which this line is the axis. Since H must lie on the conic S, we may assume its co-ordinates to be $\left(\frac{\alpha_o}{\lambda}, \frac{\beta_o}{\mu}, \frac{\gamma_o}{\nu}\right)$ when $\lambda + \mu + \nu = 0$.

AH, BH, CH will meet L_o in the points $H_1(\lambda, \nu, \mu)$, $H_2(\nu, \mu, \lambda)$, $H_3(\mu, \lambda, \nu)$, *i.e.*, $H_1\ H_2\ H_3$ constitute the triad $(\lambda\ \nu\ \mu)$ on L_o.

$(X.H_2)(X.H_3)$ will meet in $A'\left(\frac{1}{\lambda}, \frac{1}{\nu}, \frac{1}{\mu}\right)$: $(X.H_3)(X.H_1)$ will meet in $B'\left(\frac{1}{\nu}, \frac{1}{\mu}, \frac{1}{\lambda}\right)$: $(X.H_1)(X.H_2)$ will meet in $C'\left(\frac{1}{\mu}, \frac{1}{\lambda}, \frac{1}{\nu}\right)$.

Let AA′, BA′, CA′; AB′, BB′, CB′; AC′, BC′, CC′ meet L_o in the points $D_1\ E_1\ F_1$; $D_2\ E_2\ F_2$; $D_3\ E_3\ F_3$ respectively. For the co-ordinates of these nine points we obtain—

$$\begin{array}{ccc} (\lambda, \mu, \nu) & (\mu, \nu, \lambda) & (\nu, \lambda, \mu) \\ (\nu, \lambda, \mu) & (\lambda, \mu, \nu) & (\mu, \nu, \lambda) \\ (\mu, \nu, \lambda) & (\nu, \lambda, \mu) & (\lambda, \mu, \nu) \end{array}$$

showing that AA_o', BB_o', CC_o' meet in D_1, that BA′, CB′, AC′ meet in E_1, that CA′, AB′, BC′ meet in F_1, and that the points $D_1\ E_1\ F_1$ establish the triad $(\lambda\ \mu\ \nu)$.

If the point $\Omega_1(\lambda, \mu, \nu)$ be given on L_o, we may find the two other points of the triad as follows:—Determine the point $A_1\left(\frac{1}{\lambda}, \frac{1}{\mu}, \frac{1}{\nu}\right)$ — for the construction of this point see § 2— : Draw BA_1 CA_1 meeting L_o in $H_2(\nu\ \mu\ \lambda)$ and $H_3(\mu\ \lambda\ \nu)$: $(X.H_2)$ $(X.H_3)$ will meet on S in $A''\left(\frac{1}{\lambda}, \frac{1}{\nu}, \frac{1}{\mu}\right)$: AA″ BB″ CC″ will meet L_o in $(\lambda\ \mu\ \nu)$ $(\mu\ \nu\ \lambda)$ $(\nu\ \lambda\ \mu)$.

The axes of the triad $(\lambda\ \mu\ \nu)$ will touch Σ in the points $P_1(\lambda^2\ \mu^2\ \nu^2)$, $P_2(\mu^2\ \nu^2\ \lambda^2)$, $P_3(\nu^2\ \lambda^2\ \mu^2)$. If now lines be drawn from the vertices of the triangle ABC to $P_1\ P_2\ P_3$, we obtain nine points on L_o, which may be arranged to form three distinct triads.

§ 2. *On the concurrent determination of points on and tangents to the associated conics S and Σ.*

On L° let any point $\Omega_1(\lambda\ \mu\ \nu)$ be taken. The equation of the line joining Ω_1 and $O(\alpha_o\beta_o\gamma_o)$ will be

$$\frac{\alpha}{\alpha_o}(\mu - \nu) + \frac{\beta}{\beta_o}(\nu - \lambda) + \frac{\gamma}{\gamma_o}(\lambda - \mu) = 0.$$

This line is the axis of a point $A_2\left(\frac{1}{\mu - \nu}\ \frac{1}{\nu - \lambda}\ \frac{1}{\lambda - \mu}\right)$ lying on S.

The equation of A_2O is—

$$\frac{\alpha}{\alpha_o}\lambda(\mu - \nu) + \frac{\beta}{\beta_o}\mu(\nu - \lambda) + \frac{\gamma}{\gamma_o}\nu(\lambda - \mu) = 0.$$

This line will meet $(X.\Omega_1)$ in the point $P_1(\lambda^2\ \mu^2\ \nu^2)$; this point will lie on the conic Σ, as may be seen from inspection.

The equation of A_2O is satisfied by the point $A_1\left(\frac{1}{\lambda}\ \frac{1}{\mu}\ \frac{1}{\nu}\right)$ which clearly lies on the conic S. To determine the position of A_1, we may proceed as follows :—

The equation of AA_2 may be written—

$$\mu\nu\left(\frac{\beta}{\beta_0\mu} + \frac{\gamma}{\gamma_0\nu}\right) + \lambda\left(\frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0}\right) = 0.$$

The equation—

$$\mu\nu\left(\frac{\beta}{\beta_0\mu} + \frac{\gamma}{\gamma_0\nu}\right) - \lambda\left(\frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0}\right) = 0$$

reduces to—

$$\frac{\beta}{\beta_0}\mu + \frac{\gamma}{\gamma_0}\nu = 0.$$

Let L_0 and $(X.\Omega_1)$ meet $\alpha = 0$ in H and K respectively : Then AA_2, AH, AK and the line whose equation is—

$$\frac{\beta}{\beta_0}\mu + \frac{\gamma}{\gamma_0}\nu = 0$$

form an harmonic pencil.

This last line determines the point in which

$$(X.A_1) \equiv \frac{\alpha}{\alpha_0}\lambda + \frac{\beta}{\beta_0}\mu + \frac{\gamma}{\gamma_0}\nu = 0$$

meets $\alpha = 0$. Therefore since $(X.A_1)$ passes through O, two points in the line are known. Hence $(X.A_1)$ is found, and consequently A_1 can be constructed geometrically.

$(X.A_1)$ will meet L_0 in the point Ω' whose co-ordinates are $(\mu - \nu\ \ \nu - \lambda\ \ \lambda - \mu)$. The equation of $(X.\Omega')$ is—

$$\frac{\alpha}{\alpha_0(\mu - \nu)} + \frac{\beta}{\beta_0(\nu - \lambda)} + \frac{\gamma}{\gamma_0(\lambda - \mu)} = 0 \quad :$$

this line will touch Σ in the point $P_2\left[(\mu - \nu)^2\ (\nu - \lambda)^2\ (\lambda - \mu)^2\right]$; it may be at once verified that P_2 lies on the straight line A_1 O P_1 A_2.

The equation of $(T.A_1)$ is

$$\frac{\alpha}{\alpha_0}\lambda^2 + \frac{\beta}{\beta_0}\mu^2 + \frac{\gamma}{\gamma_0}\nu^2 = 0.$$

Since $\lambda^2 - \mu\nu = \mu^2 - \nu\lambda = \nu^2 - \lambda\mu \equiv \Theta$, this equation may be written—

$$\Theta\left(\frac{\alpha}{\alpha_0} + \frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0}\right) + \lambda\mu\nu\left(\frac{\alpha}{\alpha_0\lambda} + \frac{\beta}{\beta_0\mu} + \frac{\gamma}{\gamma_0\nu}\right) = 0.$$

Hence $(T.A_1)$ passes through the intersection of L_0 and $(X.\Omega_1)$: $(T.A_1)$ can therefore be constructed.

$(T.A_1)$ will meet L_0 in the point $\Omega''\left[\lambda(\mu - \nu)\ \ \mu(\nu - \lambda)\ \ \nu(\lambda - \mu)\right]$, therefore, since L_0 is the polar of O with respect to S, the line $A_2\Omega''$ is the tangent to S at the point A_2.

The axis of Ω'' will touch Σ in the point—

$$P_3\left[\lambda^2(\mu - \nu)^2\ \ \mu^2(\nu - \lambda)^2\ \ \nu^2(\lambda - \mu)^2\right].$$

The equation of P_1P_3 is—

$$\frac{\alpha}{\alpha_0}\mu\nu(\mu - \nu) + \frac{\beta}{\beta_0}\nu\lambda(\nu - \lambda) + \frac{\gamma}{\gamma_0}\lambda\mu(\lambda - \mu) = 0.$$

This line is satisfied by the co-ordinates of Ω_1 : hence P_3 is the point of intersection of the lines $(X.\Omega'')$ and $\Omega_1 P_1$.

The equation of P_2P_3 is—

$$\frac{\alpha}{\alpha_0}\frac{\lambda}{\mu-\nu}+\frac{\beta}{\beta_0}\frac{\mu}{\nu-\lambda}+\frac{\gamma}{\gamma_0}\frac{\nu}{\lambda-\mu}=0 :$$

hence the points P_2 and P_3 are collinear with the point—

$$\Omega'[\mu-\nu \quad \nu-\lambda \quad \lambda-\mu].$$

The line A_1OA_2 is the axis of a point A_3, lying on S, whose co-ordinates are—

$$\left[\frac{1}{\lambda(\mu-\nu)} \quad \frac{1}{\mu(\nu-\lambda)} \quad \frac{1}{\nu(\lambda-\mu)}\right]$$

The equation of $(T.A_3)$ is—

$$\frac{\alpha}{\alpha_0}\lambda^2(\mu-\nu)^2+\frac{\beta}{\beta_0}\mu^2(\nu-\lambda)^2+\frac{\gamma}{\gamma_0}\nu^2(\lambda-\mu)^2=0$$

$$\equiv \Theta\left[\frac{\alpha}{\alpha_0}\lambda^2+\frac{\beta}{\beta_0}\mu^2+\frac{\gamma}{\gamma_0}\nu^2\right]-3\lambda\mu\nu\left[\frac{\alpha}{\alpha_0}\lambda+\frac{\beta}{\beta_0}\mu+\frac{\gamma}{\gamma_0}\nu\right]=0$$

$$\equiv \Theta\,(T.A_1)-3\lambda\mu\nu(X.A_1)$$

$$\equiv (\lambda^2+\mu^2+\nu^2-\mu\nu-\nu\lambda-\lambda\mu)\ (T.A_2)$$
$$-3(\mu-\nu)(\nu-\lambda)(\lambda-\mu)\ (X.A_2)$$

Hence $(T.A_3)$ is determined as the line joining the intersection of $(T.A_1)$ with $(X.A_1)$ to the intersection of $(T.A_2)$ with $(X.A_2)$.

A_1OA_2 will meet L_0 in the point $\Omega'''(\Theta_1\ \Theta_2\ \Theta_3)$, where $\Theta_1\equiv\lambda^2+2\mu\nu$, $\Theta_2\equiv\mu^2+2\nu\lambda$, $\Theta_3\equiv\nu^2+2\lambda\mu$.

The equation of OA_3 is—

$$\frac{\alpha}{\alpha_0}\lambda(\mu-\nu)\Theta_1+\frac{\beta}{\beta_0}\mu(\nu-\lambda)\Theta_2+\frac{\gamma}{\gamma_0}\nu(\lambda-\mu)\Theta_3=0.$$

It is at once verified that OA_3 and S are both satisfied by the point $A_4\left(\frac{1}{\Theta_1}\ \frac{1}{\Theta_2}\ \frac{1}{\Theta_3}\right)$.

To determine the position of A_4, we have—

$$(X.A_4)\equiv\frac{\alpha}{\alpha_0}\Theta_1+\frac{\beta}{\beta_0}\Theta_2+\frac{\gamma}{\gamma_0}\Theta_3=0.$$
$$\equiv (T.A_1)+2\lambda\mu\nu(X.\Omega_1).$$

Hence $(X.A_4)$ is the line joining O to the intersection of $(T.A_1)$ and $(X.\Omega_1)$, and therefore A_4 can be constructed geometrically.

$(X.\Omega''')$ will touch Σ at the point $P_4(\Theta_1^2\ \Theta_2^2\ \Theta_3^2)$ and the equation of OP_4 will be—

$$\frac{\alpha}{\alpha_0}(\Theta_2^2-\Theta_3^2)+\frac{\beta}{\beta_0}(\Theta_3^2-\Theta_1^2)+\frac{\gamma}{\gamma_0}(\Theta_1^2-\Theta_2^2)=0,$$

which easily reduces to—

$$\frac{\alpha}{\alpha_0}\lambda(\mu-\nu)\Theta_1+\frac{\beta}{\beta_0}\mu(\nu-\lambda)\Theta_2+\frac{\gamma}{\gamma_0}\nu(\lambda-\mu)\Theta_3=0.$$

Hence OP_4 is identical with OA_3, that is to say, P_4 is the point of intersection of OA_3 with $(X.\Omega''')$.

To find $T.A_4$, it is only necessary to join A_4 to the intersection of $(T.A_3)$ with L_0.

Here starting with any point Ω_1 on L_0 we have determined four points on each of the conics S and Σ, together with the tangents to the conics at those points.

§ 3. *On the curve whose equation is—*

$$\sqrt[3]{\frac{a}{a_0}} + \sqrt[3]{\frac{\beta}{\beta_0}} + \sqrt[3]{\frac{\gamma}{\gamma_0}} = 0.$$

If any point $P(a'\ \beta'\ \gamma')$ be taken on the conic Σ, its axis of homology is—

$$\frac{a}{a'} + \frac{\beta}{\beta'} + \frac{\gamma}{\gamma'} = 0.$$

The envelope of this line, subject to the relation—

$$\sqrt{\frac{a'}{a_0}} + \sqrt{\frac{\beta'}{\beta_0}} + \sqrt{\frac{\gamma'}{\gamma_0}} = 0,$$

is easily shown to be—

$$\sqrt[3]{\frac{a}{a_0}} + \sqrt[3]{\frac{\beta}{\beta_0}} + \sqrt[3]{\frac{\gamma}{\gamma_0}} = 0,$$

$$\text{or}\quad \left(\frac{a}{a_0} + \frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0}\right)^3 - 27\,\frac{a\beta\gamma}{a'\beta'\gamma'} = 0.$$

It may be at once verified that any point on the cubic may be expressed in any one of the following forms:—

$$(a_0\lambda^3,\ \beta_0\mu^3,\ \gamma_0\nu^3),\ \left[a_0(\mu-\nu)^3,\ \beta_0(\nu-\lambda)^3,\ \gamma_0(\lambda-\mu)^3\right],$$

$$\left[a_0\lambda^3(\mu-\nu)^3,\ \beta_0\mu^3(\nu-\lambda)^3,\ \gamma_0\nu^3(\lambda-\mu)^3\right],$$

$$(a_0\Theta_1^3,\ \beta_0\Theta_2^3,\ \gamma_0\Theta^3),$$

where $\lambda + \mu + \nu = 0$.

The equation of the tangent at any point $Q_1(a_0\lambda^3,\ \beta_0\mu^3,\ \gamma_0\nu^3)$ on the cubic is—

$$\frac{a}{a_0} + \frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0} - \lambda\mu\nu\left(\frac{a}{a_0\lambda^3} + \frac{\beta}{\beta_0\mu^3} + \frac{\gamma}{\gamma_0\nu^3}\right) = 0,$$

showing that the tangent at Q_1 is the line joining Q_1 to the intersection of L_0 and $(X.Q_1)$.

The above equation easily reduces to—

$$\frac{a}{a_0\lambda^2} + \frac{\beta}{\beta_0\mu^2} + \frac{\gamma}{\gamma_0\nu^2} = 0,$$

showing that the axis of P_1 touches its envelope at the point $Q_1(a_0\lambda^3,\ \beta_0\mu^3,\ \gamma_0\nu^3)$.

To find the point Q_1 we have that the equation of $O\Omega_1$, viz.:—

$$\frac{\alpha}{\alpha_0}(\mu-\nu) + \frac{\beta}{\beta_0}(\nu-\lambda) + \frac{\gamma}{\gamma_0}(\lambda-\mu) = 0$$

is satisfied by the values $(\lambda^3\ \mu^3\ \nu^3)$.

Hence Q_1 is determined as the intersection of $O\Omega_1$ and $(X.P_1)$.

Similarly the axis of P_2—

$$\frac{a}{a_0(\mu-\nu)^2}+\frac{\beta}{\beta_0(\nu-\lambda)^2}+\frac{\gamma}{\gamma_0(\lambda-\mu)^2}=0$$

touches the cubic at the point Q_2 whose co-ordinates are—

$$\left[(\mu-\mu)^3\ (\nu-\lambda)^3\ (\lambda-\mu)^3\right].$$

Now the equations of $(X.P_1)$ and $(X.P_2)$ are both satisfied by the point Q_3,

$$\left[\lambda^3(\mu-\nu)^3\ \mu^3(\nu-\lambda)^3\ \nu^3(\lambda-\mu)^3\right],$$

which clearly is on the cubic curve.

Hence the cubic may be regarded as the locus of the intersection of the axes of the extremities of chords of Σ drawn through O.

The axes of P_3 and P_4 will touch the cubic at—

$$Q_3\left[\lambda^3(\mu-\nu)^3\ \mu^3(\nu-\lambda)^3\ \nu^3(\lambda-\mu)^3\right] \text{ and } Q_4\left[\Theta_1^3\ \Theta_2^3\ \Theta_3^3\right]$$

respectively, and intersect each other on the curve at the point—

$$\left[\lambda^3(\mu-\nu)^3\Theta_1^3\ \mu^3(\nu-\lambda)^3\Theta_2^3\ \nu^3(\lambda-\mu)^3\Theta_3^3\right].$$

We may show that, in general, four axes pass through any point on the cubic, and find the equation of those axes as follows:—

Take any point $(a_1\beta_1\gamma_1)$ on the cubic; the conic—

$$S_1\equiv\frac{a_1}{a}+\frac{\beta_1}{\beta}+\frac{\gamma_1}{\gamma}=0$$

will meet Σ in four points. Suppose that $a'\beta'\gamma'$ are the co-ordinates of a point of intersection of Σ and S_1.

The axis of $(a'\beta'\gamma')$ is—

$$\frac{a}{a'}+\frac{\beta}{\beta'}+\frac{\gamma}{\gamma'}=0,$$

also—

$$\frac{a_1}{a'}+\frac{\beta_1}{\beta'}+\frac{\gamma_1}{\gamma'}=0.$$

Therefore—

$$\frac{1}{a'}:\frac{1}{\beta'}:\frac{1}{\gamma'}=\beta\gamma_1-\beta_1\gamma\ :\ \gamma a_1-\gamma_1 a\ :\ a\beta_1-a_1\beta,$$

and as—

$$\sqrt{\frac{a'}{a_0}}+\sqrt{\frac{\beta'}{\beta_0}}+\sqrt{\frac{\gamma'}{\gamma_0}}=0,$$

we have for the equation of the four axes—

$$\frac{1}{\sqrt{a_0(\beta\gamma_1-\beta_1\gamma)}}+\frac{1}{\sqrt{\beta_0(\gamma a_1-\gamma_1 a)}}+\frac{1}{\sqrt{\gamma_0(a\beta_1-a_1\beta)}}=0.$$

If now $(a_1\beta_1\gamma_1)$ be the point Q_3, and if the above quartic be expanded, we know that two of its factors are $(X.P_1)$ and $(X.P_2)$, and find that the other factor is the square of $(X.P_3)$, multiplied by a constant quantity. Hence we infer that the conic S_1 touches Σ at the point P_3, a conclusion which may be verified by finding the tangent at P_3, viz.—

$$\frac{a}{a_0\lambda(\mu-\nu)}+\frac{\beta}{\beta_0\mu(\nu-\lambda)}+\frac{\gamma}{\gamma_0\nu(\lambda-\mu)}=0.$$

From this we may learn the condition of tangency of S_1 and Σ, viz.,

$$\kappa\alpha_1 = \alpha_0\lambda^3(\mu - \nu)^3,\ \kappa\beta_1 = \beta_0\mu^3(\nu - \lambda)^3,\ \kappa\gamma_1 = \gamma_0\nu^3(\lambda - \mu)^3,$$

and therefore $\sqrt[3]{\frac{\alpha_1}{\alpha_0}} + \sqrt[3]{\frac{\beta_1}{\beta_0}} + \sqrt[3]{\frac{\gamma_1}{\gamma_0}} = 0,$

i.e., if $\alpha_1\beta_1\gamma_1$ lie on the cubic—

$$\sqrt[3]{\frac{\alpha}{\alpha_0}} + \sqrt[3]{\frac{\beta}{\beta_0}} + \sqrt[3]{\frac{\gamma}{\gamma_0}},$$

the conics Σ and S_1 will touch, and the co-ordinates of the point of contact will be $(\sqrt[3]{\alpha_0\alpha_1^2},\ \sqrt[3]{\beta_0\beta_1^2},\ \sqrt[3]{\gamma_0\gamma_1^2})$.

§ 4. *On the curve whose equation is*—

$$\sqrt{\frac{\alpha_0}{\alpha}} + \sqrt{\frac{\beta_0}{\beta}} + \sqrt{\frac{\gamma_0}{\gamma}} = 0.$$

The above curve may be easily shown to be the locus of points whose axes of homology touch the conic S.

A point on the curve may be expressed in any of the following forms:—

$$R_1\left(\frac{1}{\lambda^2}\ \frac{1}{\mu^2}\ \frac{1}{\nu^2}\right),\quad R_2\left[\frac{1}{(\mu-\nu)^2}\ \frac{1}{(\nu-\lambda)^2}\ \frac{1}{(\lambda-\mu)^2}\right],$$

$$R_3\left[\frac{1}{\lambda^2(\mu-\nu)^2}\ \frac{1}{\mu^2(\nu-\lambda)^2}\ \frac{1}{\nu^2(\lambda-\mu)^2}\right],\quad R_4\left[\frac{1}{\Theta_1^2}\ \frac{1}{\Theta_2^2}\ \frac{1}{\Theta_3^2}\right].$$

The tangent at the point $R_1\left(\frac{1}{\lambda^2}, \frac{1}{\mu^2}, \frac{1}{\nu^2}\right)$ is—

$$\frac{\alpha}{\alpha_0}\lambda^3 + \frac{\beta}{\beta_0}\mu^3 + \frac{\gamma}{\gamma_0}\nu^3 = 0,$$

which may be written—

$$\Theta\left(\frac{\alpha}{\alpha_0}\lambda + \frac{\beta}{\beta_0}\mu + \frac{\gamma}{\gamma_0}\nu\right) + \lambda\mu\nu\left(\frac{\alpha}{\alpha_0} + \frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0}\right) = 0,$$

or $\Theta.(X.A_1) + \lambda\mu\nu\, L_0 = 0.$

Hence as $(T.A_1)$ has been found, we can construct the point R_1; the line joining R_1 to the intersection of $(X.A_1)$ and L_0 will be the tangent at R_1.

The line joining R_1 and R_2—the axis of which latter point is $(T.A_2)$—is—

$$\frac{\alpha}{\alpha_0}\lambda^3(\mu - \nu)^3 + \frac{\beta}{\beta_0}\mu^3(\nu - \lambda)^3 + \frac{\gamma}{\gamma_0}\nu^3(\lambda - \mu)^3 = 0,$$

but this is the equation to the tangent to the above quartic at the point R_3.

Hence the quartic may be regarded as the envelope of the line joining the two points whose axes are the tangents to S at the extremities of chords of S drawn through O.

The lines $(T.A_3)$ $(T.A_4)$ are the axes of two points—

$$R_3\left[\frac{1}{\lambda^2(\mu-\nu)^2}, \frac{1}{\mu^2(\nu-\lambda)^2}, \frac{1}{\nu^2(\lambda-\mu)^2}\right], R_4\left[\frac{1}{\Theta_1^2}, \frac{1}{\Theta_2^2}, \frac{1}{\Theta_3^2}\right]$$

on the quartic. The equation of $R_3\,R_4$ is—

$$\frac{\alpha}{\alpha_0}\lambda^3(\mu - \nu)^3\Theta_1^3 + \frac{\beta}{\beta_0}\mu^3(\nu - \lambda)^3\Theta_2^3 + \frac{\gamma}{\gamma_0}\nu^3(\lambda - \mu)^3\Theta_3^3 = 0,$$

showing that $R_3\,R_4$ touches the quartic at the point—

$$\left[\frac{1}{\lambda^2(\mu-\nu)^2\Theta_1^2}, \frac{1}{\mu^2(\nu-\lambda)^2\Theta_2^2}, \frac{1}{\nu^2(\lambda-\mu)^2\Theta_3^2}\right]$$

Among other relations which connect the quartic with Σ is the following :—

The equation of the line $\Omega_1 P_1$ is—

$$\frac{\alpha}{\alpha_0}\mu\nu(\mu-\nu)+\frac{\beta}{\beta_0}\nu\lambda(\nu-\lambda)+\frac{\gamma}{\gamma_0}\lambda\mu(\lambda-\mu)=0,$$

which may be written $L'-L''=0$,

$$\text{where } L'\equiv\frac{\alpha}{\alpha_0}\mu^2\nu+\frac{\beta}{\beta_0}\nu^2\lambda+\frac{\gamma}{\gamma_0}\lambda^2\mu=0$$

$$L''=\frac{\alpha}{\alpha_0}\mu\nu^2+\frac{\beta}{\beta_0}\nu\lambda^2+\frac{\gamma}{\gamma_0}\lambda\mu^2=0$$

L' is satisfied by $R'\left(\frac{1}{\mu^2}\ \frac{1}{\nu^2}\ \frac{1}{\lambda^2}\right)$ and L'' is satisfied by $R''\left(\frac{1}{\nu^2}\ \frac{1}{\lambda^2}\ \frac{1}{\mu^2}\right)$.

$R_1\ R'\ R''$ form the related triad $\left(\frac{1}{\lambda^2}\ \frac{1}{\mu^2}\ \frac{1}{\nu^2}\right)$ on the quartic—

$$L'+L''\equiv\frac{\alpha}{\alpha_0}+\frac{\beta}{\beta_0}+\frac{\gamma}{\gamma_0}=L_0.$$

Hence Ω_1P_1, Ω_1R', Ω_1R'' form with L_0 an harmonic pencil.

The lines $A_1R_1\ B_1R'\ C_1R''$ intersect L_0 in the points $\Omega_1\ \Omega_2\ \Omega_3$ respectively.

§ 5. *On some special relations of triads.*

Let $(X.\Omega_2)$ $(X.\Omega_3)$ touch Σ in the points P'' $(\mu^2, \nu^2, \lambda^2)$ P''' $(\nu^2, \lambda^2, \mu^2)$. Then the equation of $P''P'''$ is—

$$\frac{\alpha}{\alpha_0}(\lambda^2+\mu\nu)+\frac{\beta}{\beta_0}(\mu^2+\nu\lambda)+\frac{\gamma}{\gamma_0}(\nu^2+\lambda\mu)=0,$$

which may be written—

$$(T.A_1)+\lambda\mu\nu\,(X.\Omega_1)=0.$$

We have also—

$$\ominus L_0\equiv(T.A_1)-\lambda\mu\nu\,(X.\Omega_1)=0.$$

Hence $P''P'''$, L_0, $(T.A_1)$, $(X.\Omega_1)$ form an harmonic pencil whose vertex is at the point Ω''.

The lines— $(T.A_1)$, A_1O, $(X.\Omega_2)$ $(X.\Omega_3)$:
AA_1, AB_1, AC_1, AA_2
AA_1, AA_2, AO, $A\Omega'''$

all form harmonic pencils, while the four points—

$$\Omega_1\ \Omega_2\ \Omega_3\ \Omega'$$

constitute an harmonic range.

The conic whose equation is—

$$(X.\Omega_1)^2+(X.\Omega_2)^2+(X.\Omega_3)^2=0$$

reduces to—

$$\frac{\alpha^2}{\alpha_0^2}+\frac{\beta^2}{\beta_0^2}+\frac{\gamma^2}{\gamma_0^2}=0,$$

showing that the axes of any triad on L_0 form a triangle self-conjugate with respect to the above conic.

By forming the conics whose equations are—

$$\frac{1}{(T.A_1)} + \frac{1}{(T.B_1)} + \frac{1}{(T.C_1)} = 0,$$

$$\text{and } (T.A_1)^2 + (T.B_1)^2 + (T.C_1)^2 = 0,$$

we find that the tangents to S at any related triad of points on S form triangles whose vertices lie on the conic—

$$L_o^2 + S = 0,$$

while such triangles are self-conjugate with respect to the conic—

$$L_o^2 - S = 0.$$

If L_1 L_2 L_3 be the three chords of Σ formed by joining a triad of points on that conic, then from the equations—

$$\sqrt{L_1} + \sqrt{L_2} + \sqrt{L_3} = 0$$

$$L_1^2 + L_2^2 + L_3^2 = 0,$$

we learn that the triangle $L_1L_2L_3$ envelopes the conic—

$$5L_o^2 - 16S = 0,$$

and is self-conjugate with respect to the conic—

$$3L_o^2 - 8S = 0.$$

§ 6. *On the common tangents of* S_1 *and* S_2.

$$\text{Let } S_1 \equiv \frac{a_1}{a} + \frac{\beta_1}{\beta} + \frac{\gamma_1}{\gamma} = 0$$

$$S_2 \equiv \frac{a_2}{a} + \frac{\beta_2}{\beta} + \frac{\gamma_2}{\gamma} = 0.$$

Then the lines—

$$t' \equiv \frac{a}{a_1}\lambda_1^2 + \frac{\beta}{\beta_1}\mu_1^2 + \frac{\gamma}{\gamma_1}\nu_1^2 = 0$$

$$t'' \equiv \frac{a}{a_2}\lambda_2^2 + \frac{\beta}{\beta_2}\mu_2^2 + \frac{\gamma}{\gamma_2}\nu_2^2 = 0$$

will touch S_1 and S_2 respectively.

If t_1 and t_2 represent a common tangent of S_1 and S_2, then

$$\frac{\lambda_1^2}{a_1} = \kappa\frac{\lambda_2^2}{a_2},\ \frac{\mu_1^2}{\beta_1} = \kappa\frac{\mu_2^2}{\beta_2},\ \frac{\nu_1^2}{\gamma_1} = \kappa\frac{\nu_2^2}{\gamma_2}.$$

Hence $\lambda_1 = \pm\,\lambda_2\sqrt{\kappa\frac{a_1}{a_2}}$, $\mu_1 = \pm\,\mu_2\sqrt{\kappa\frac{\beta_1}{\beta_2}}$, $\nu_1 = \pm\,\nu_2\sqrt{\kappa\frac{\gamma_1}{\gamma_2}}$,

and therefore since $\lambda_1 + \mu_1 + \nu_1 = 0$, we obtain—

$$\pm\,\lambda_2\sqrt{\frac{a_1}{a_2}} \pm \mu_2\sqrt{\frac{\beta_1}{\beta_2}} \pm \nu_2\sqrt{\frac{\gamma_1}{\gamma_2}} = 0,$$

which represents only four distinct equations of condition.

Writing a, b, c for $\sqrt{\frac{a_1}{a_2}}$, $\sqrt{\frac{\beta_1}{\beta_2}}$, $\sqrt{\frac{\gamma_1}{\gamma_2}}$ respectively, these equations are—

$$c_1 \equiv \lambda_2 a + \mu_2 b + \nu_2 c = 0$$

$$c_2 \equiv \lambda_2 a - \mu_2 b - \nu_2 c = 0$$

$$c_3 \equiv -\lambda_2 a + \mu_2 b - \nu_2 c = 0$$

$$c_4 \equiv -\lambda_2 a - \mu_2 b + \nu_2 c = 0$$

Solve now for the ratios $\lambda_2 : \mu_2 : \nu_2$ from each of these equations in turn and $\lambda_2 + \mu_2 + \nu_2$; insert the values of λ_2, μ_2, ν_2, so found in equation t'', and we at once obtain for the equations of the four common tangents of S_1 and S_2 the following :—

$$t_1 \equiv \alpha P_0^2 + \beta Q_0^2 + \gamma R_0^2 = 0$$
$$t_2 \equiv \alpha P_0^2 + \beta Q_1^2 + \gamma R_1^2 = 0$$
$$t_3 \equiv \alpha P_1^2 + \beta Q_0^2 + \gamma R_1^2 = 0$$
$$t_4 \equiv \alpha P_1^2 + \beta Q_1^2 + \gamma R_0^2 = 0$$

where—

$$P_0 = \sqrt{\beta_1\gamma_2} - \sqrt{\beta_2\gamma_1}\,,\ Q_0 = \sqrt{\gamma_1\alpha_2} - \sqrt{\gamma_2\alpha_1}\,,\ R_0 = \sqrt{\alpha_1\beta_2} - \sqrt{\alpha_2\beta_1}$$
$$P_1 = \sqrt{\beta_1\gamma_2} + \sqrt{\beta_2\gamma_1}\,,\ Q_1 = \sqrt{\gamma_1\alpha_2} + \sqrt{\gamma_2\alpha_1}\,,\ R_1 = \sqrt{\alpha_1\beta_2} + \sqrt{\alpha_2\beta}$$

The tangents $t_1\ t_2\ t_3\ t_4$ will touch S_1 in the points—

$$\left(\frac{\sqrt{\alpha_1}}{P_0}, \frac{\sqrt{\beta_1}}{Q_0}, \frac{\sqrt{\lambda_1}}{R_0}\right); \quad \left(\frac{\sqrt{\alpha_1}}{P_0}, \frac{\sqrt{\beta_1}}{Q_1}, \frac{\sqrt{\gamma_1}}{R_1}\right)$$
$$\left(\frac{\sqrt{\alpha_1}}{P_1}, \frac{\sqrt{\beta_1}}{Q_0}, \frac{\sqrt{\gamma_1}}{R_1}\right); \quad \left(\frac{\sqrt{\alpha_1}}{P_1}, \frac{\sqrt{\beta_1}}{Q_1}, \frac{\sqrt{\gamma_1}}{R_0}\right)$$

The points of intersection of two conics—

$$\Sigma_1 \equiv \sqrt{\frac{\alpha}{\alpha_1}} + \sqrt{\frac{\beta}{\beta_1}} + \sqrt{\frac{\gamma}{\gamma_1}} = 0$$
$$\Sigma_2 \equiv \sqrt{\frac{\alpha}{\alpha_2}} + \sqrt{\frac{\beta}{\beta_2}} + \sqrt{\frac{\gamma}{\gamma_2}} = 0$$

may be at once found by the above method from the consideration that at a point of intersection we have—

$$\alpha_1\lambda_1^2 = \kappa\alpha_2\lambda_2^2\,,\ \beta_1\mu_1^2 = \kappa\beta_2\mu_2^2\,,\ \gamma_1\nu_1^2 = \kappa\gamma_2\nu_2^2 :$$

The co-ordinates required will be—

$$(\alpha_1\alpha_2P_0^2,\ \beta_1\beta_2Q_0^2,\ \gamma_1\gamma_2R_0^2),\ (\alpha_1\alpha_2P_0^2,\ \beta_1\beta_2Q_1^2,\ \gamma_1\gamma_2R_1^2),$$
$$(\alpha_1\alpha_2P_1^2,\ \beta_1\beta_2Q_0^2,\ \gamma_1\gamma_2R_1^2),\ (\alpha_1\alpha_2P_1^2,\ \beta_1\beta_2Q_1^2,\ \gamma_1\gamma_2R_0^2).$$

Hence since the cubics—

$$C_1 \equiv \sqrt[3]{\frac{\alpha}{\alpha_1}} + \sqrt[3]{\frac{\beta}{\beta_1}} + \sqrt[3]{\frac{\gamma}{\gamma_1}} = 0$$
$$C_2 \equiv \sqrt[3]{\frac{\alpha}{\alpha_2}} + \sqrt[3]{\frac{\beta}{\beta_2}} + \sqrt[3]{\frac{\gamma}{\gamma_2}} = 0$$

are the envelopes of the axes of points lying on Σ_1 and Σ_2 respectively, we have for the equations of the four common tangents of the two cubics—

$$\frac{\alpha}{\alpha_1\alpha_2P_0^2} + \frac{\beta}{\beta_1\beta_2Q_0^2} + \frac{\gamma}{\gamma_1\gamma_2R_0^2} = 0$$

and three others, which may be at once written down.

Also the common points (other than the vertices of the triangle of reference) of the two quartics—

$$Q_1 \equiv \sqrt{\frac{\alpha_1}{\alpha}} + \sqrt{\frac{\beta_1}{\beta}} + \sqrt{\frac{\gamma_1}{\gamma}} = 0$$

$$Q_2 \equiv \sqrt{\frac{\alpha_2}{\alpha}} + \sqrt{\frac{\beta_2}{\beta}} + \sqrt{\frac{\gamma_2}{\gamma}} = 0$$

are the four points whose axes are the common tangents of S_1 and S_2. The co-ordinates of these points of intersection are at once seen to be—

$$\left(\frac{1}{P_o^2}, \frac{1}{Q_o^2}, \frac{1}{R_o^2}\right), \left(\frac{1}{P_o^2}, \frac{1}{Q_1^2}, \frac{1}{R_1^2}\right), \left(\frac{1}{P_1^2}, \frac{1}{Q_o^2}, \frac{1}{R_1^2}\right), \left(\frac{1}{P_1^2}, \frac{1}{Q_1^2}, \frac{1}{R_o^2}\right).$$

§ 7. *On certain special triads.*

The lines AO, BO, CO will meet L_o in points which determine on that line the triad $(-2\ 1\ 1)$ ·: the axes of this triad form a triangle whose vertices are at the triad $(-\frac{1}{2}\ 1 1)$ on S and whose sides touch Σ in the triad (4 1 1).

Calling the points (4, 1, 1) (1, 1, 4) (1, 4, 1) p_1 p_2 and p_3 respectively, the lines Ap_2 Ap_3 : Bp_3 Bp_1 . Cp_1 Cp_2 determine on L_c six points constituting the two triads $(-5\ 4\ 1)$ $(-5\ 1\ 4)$; the axes of these triads determine on Σ the triads (25 16 1) (25 1 16).

If these six points on Σ be joined to A B and C we obtain the following triads :—

$$(-17\ 16\ 1)\ (-17\ 1\ 16)\ (-26\ 25\ 1)\ (-26\ 1\ 25)$$
$$(-41\ 16\ 25)\ (-41\ 25\ 16)$$

lying on L_o.

This process can be continued *ad infinitum* to the determination of triads on L_o S and Σ.

§ 8. *On some particular constructions.*

If with the conditions given in the following cases, the point O $(\alpha_o, \beta_o, \gamma_o)$ can be found, the construction required can be effected.

It is to be noticed that the tangent to S at the vertex A of the triangle of reference makes with AB, AC and AO an harmonic pencil.

Case 1.—To construct conic through five given points and to find tangents to conic at such points.

Taking A B C as the vertices of a triangle of reference, the axes of the two remaining points D and E with respect to the triangle ABC will intersect in O. Join AO and construct (T.A) making with AB AC and AO an harmonic pencil ; similarly construct (T.B) and (T.C). To find tangent at D, take the triangle BCD. Draw BO′ so that BC, BD, (T.B) and BO′ form an harmonic pencil. Draw CO′ so that CB, CO′, CD, (T.C) form an harmonic pencil ; then the fourth harmonic to DC, DB, DO′ will be (T.D).

Case 2.—To construct conic touching give given straight lines.

Taking three of the given lines as the triangle of reference, assume the equation of the conic touching the five lines to be Σ and let the two remaining lines be

$$\frac{a}{a_1} + \frac{\beta}{\beta_1} + \frac{\gamma}{\gamma_1} = 0$$

$$\frac{a}{a_2} + \frac{\beta}{\beta_2} + \frac{\gamma}{\gamma_2} = 0$$

The two points $(a_1\beta_1\gamma_1)$ $(a_2\beta_2\gamma_2)$ must lie on L_o hence

$$\frac{1}{a_o} : \frac{1}{\beta_o} : \frac{1}{\gamma_o} = \beta_1\gamma_2 - \beta_2\gamma_1 : \gamma_1 a_2 - \gamma_2 a_1 : a_1\beta_2 - a_2\beta_1.$$

The equation of the line joining $(a_1\beta_1\gamma_1)$ $(a_2\beta_2\gamma_2)$ is—

$$a(\beta_1\gamma_2 - \beta_2\gamma_1) + \beta(\gamma_1 a_2 - \gamma_2 a_1) + \gamma(a_1\beta_2 - a_2\beta_1) = 0$$

$$i.e., \quad \frac{a}{a_o} + \frac{\beta}{\beta_o} + \frac{\gamma}{\gamma_o} = 0.$$

Hence to construct the required conic, find the two points whose axes are two of the given lines with respect to the triangle formed by the remaining three lines. The line joining these points will be the axis of $(a_o\beta_o\gamma_o)$ with respect to the same triangle.

Case 3. To construct a parabola touching four given straight lines.

Taking three of the lines as the triangle of reference, construct the point whose axis with respect to this triangle is the fourth given line. Join this point to the centroid of the triangle of reference ; this joining line is the axis of $(a_o\beta_o\gamma_o)$.

Case 4. To construct conic through three given points and touching a given line at a given point.

Let A B C be the given points and D the point of contact of the tangent DE. Construct the axis of A with respect to the triangle B C D; construct a line making with DB, DC, DE an harmonic pencil. The intersection of the lines so drawn will be the point $(a_o\beta_o\gamma_o)$.

Case 5. To find conic through a given point and touching two given straight lines at given points.

Let A be the given point and B and C the points of contact on the tangents DB, DC. Draw BO_1 so that BD, BC, BO_1, BA form an harmonic pencil; draw CO_2 so that CD, CB, CO_2, CA form an harmonic pencil. BO_1 and CO_2 will intersect in $(a_o\beta_o\gamma_o)$.

Case 6. To construct conic through two given points and having a given self-conjugate triangle.

[If the conic pass through the point $(a_1\beta_1\gamma_1)$ it will also pass through the points $(-a_1\beta_1\gamma_1)$ $(a_1 - \beta_1\gamma_1)$ $(a_1\beta_1 - \gamma_1)$.]

If D and E be the two given points, ABC being the self-conjugate triangle, construct the points D_1 D_2 D_3 which form with D a standard quadrangle. The axes of D and E with respect to the triangle D_1 D_2 D_3 will intersect in the point $(a_o\beta_o\gamma_o)$.

2.—ON STEINER'S QUARTIC SURFACE.

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§ 1. The surface known as Steiner's quartic, whose equation is of the form—

$$\sqrt{\frac{a}{p}} + \sqrt{\frac{\beta}{q}} + \sqrt{\frac{\gamma}{r}} + \sqrt{\frac{\delta}{s}} = 0,$$

is usually obtained as the reciprocal of a cubic surface, whose equation is of the form—

$$\frac{a}{a} + \frac{b}{\beta} + \frac{c}{\gamma} + \frac{d}{\delta} = 0$$

by means of the auxiliary quadric—

$$a^2 + \beta^2 + \gamma^2 + \delta^2 = 0.$$

The object of this paper is to describe another method of obtaining the equation of the surface in question, and to point out certain results which follow immediately from the method employed.

§ 2. Let ABCD be the vertices of the tetrahedron of reference, and let a point O whose quadriplanar co-ordinates are $(a_0\beta_0\gamma_0\delta_0)$ be taken. Let the lines AO, BO, CO, DO meet the opposite faces of the tetrahedron in a, b, c, d respectively. It may be easily shown that the lines of intersection of the four pairs of planes BCD, *bcd*; CDA, *cda*; DAB, *dab*; ABC, *abc* lie in a plane whose equation is—

$$\frac{a}{a_0} + \frac{\beta}{\beta_0} + \frac{\gamma}{\gamma_0} + \frac{\delta}{\delta_0} = 0.$$

This plane will, for the sake of brevity, be called the Steiner plane P_0 of the point $(a_0\beta_0\gamma_0\delta_0)$.

Let a' β' γ' δ' be the co-ordinates of any point on the plane P_0; the equation of its Steiner plane will be—

$$\frac{a}{a'} + \frac{\beta}{\beta'} + \frac{\gamma}{\gamma'} + \frac{\delta}{\delta'} = 0.$$

To find the envelope of this plane, subject to the condition—

$$\frac{a'}{a_0} + \frac{\beta'}{\beta_0} + \frac{\gamma'}{\gamma_0} + \frac{\delta'}{\delta_0} = 0,$$

we have, by the method of undetermined multipliers,

$$\frac{a}{a'^2} = \frac{\lambda}{a_0}, \frac{\beta}{\beta'^2} = \frac{\lambda}{\beta_0}, \frac{\gamma}{\gamma'^2} = \frac{\lambda}{\gamma_0}, \frac{\delta}{\delta'^2} = \frac{\lambda}{\delta_0},$$

whence we at once obtain—

$$\Sigma_0 \equiv \sqrt{\frac{a}{a_0}} + \sqrt{\frac{\beta}{\beta_0}} + \sqrt{\frac{\gamma}{\gamma_0}} + \sqrt{\frac{\delta}{\delta_0}} = 0$$

as the "norm" equation of the envelope of the Steiner planes of points lying in the plane P_0. The surface Σ_0 is Steiner's quartic surface, and is of the fourth degree.

Intimately related to the quartic surface Σ_0 is the cubic surface, whose equation is—

$$S_0 \equiv \frac{\alpha_0}{\alpha} + \frac{\beta_0}{\beta} + \frac{\gamma_0}{\gamma} + \frac{\delta_0}{\delta} = 0,$$

which for the sake of brevity will be referred to as the Steiner cubic surface S_0. It is at once seen to be the locus of points whose Steiner planes pass through the fixed point $\alpha_0\beta_0\gamma_0\delta_0$.

§ 3. Two Steiner cubic surfaces S_1 and S_2 determine by their intersection a curve of the ninth degree, which consists of a cubic curve and the six edges of the fundamental tetrahedron.

The Steiner plane of any point lying on this cubic curve evidently passes through the line joining the points $(\alpha_1\ \beta_1\ \gamma_1\ \delta_1)$, $(\alpha_2\ \beta_2\ \gamma_2\ \delta_2)$.

If a third point $(\alpha_3\ \beta_3\ \gamma_3\ \delta_3)$ be taken on the line joining the two above points its Steiner cubic S_3 will pass through the cubic curve of intersection of S_1 and S_2: for let any point $(\alpha'\ \beta'\ \gamma'\ \delta')$ be taken on that curve, we then have—

$$\frac{\alpha_1}{\alpha'} + \frac{\beta_1}{\beta'} + \frac{\gamma_1}{\gamma'} + \frac{\delta_1}{\delta'} = 0$$

$$\frac{\alpha_2}{\alpha'} + \frac{\beta_2}{\beta'} + \frac{\gamma_2}{\gamma'} + \frac{\delta_2}{\delta'} = 0$$

whence—

$$\frac{\alpha_1 - \alpha_2}{\alpha'} + \frac{\beta_1 - \beta_2}{\beta'} + \frac{\gamma_1 - \gamma_2}{\gamma'} + \frac{\delta_1 - \delta_2}{\delta'} = 0$$

also since $(\alpha_1\beta_1\gamma_1\delta_1)$ $(\alpha_2\beta_2\gamma_2\delta_2)$ $(\alpha_3\beta_3\gamma_3\delta_3)$ are collinear,

$$\frac{\alpha_3 - \alpha_1}{\alpha_1 - \alpha_2} = \frac{\beta_3 - \beta_1}{\beta_1 - \beta_2} = \frac{\gamma_3 - \gamma_1}{\gamma_1 - \gamma_2} = \frac{\delta_3 - \delta_1}{\delta_1 - \delta_2}$$

and therefore it at once follows that—

$$\frac{\alpha_3}{\alpha'} + \frac{\beta_3}{\beta'} + \frac{\gamma_3}{\gamma'} + \frac{\delta_3}{\delta'} = 0,$$

showing that S_1 S_2 and S_3 have a common curve of intersection.

Any three Steiner cubic surfaces S_1 S_2 S_3 have in general one common point apart from the edges of the fundamental tetrahedron, namely, the point whose Steiner plane contains the points $(\alpha_1\ \beta_1\ \gamma_1\ \delta_1)$ $(\alpha_2\ \beta_2\ \gamma_2\ \delta_2)$ $(\alpha_3\ \beta_3\ \gamma_3\ \delta_3)$.

§ 4. The curve of intersection of S_1 and S_2 will in general meet the plane P_0 in three points, the Steiner planes of which will pass through the line joining $(\alpha_1\ \beta_1\ \gamma_1\ \delta_1)$ and $(\alpha_2\ \beta_2\ \gamma_2\ \delta_2)$ and touch Σ_0. Hence through any straight line three tangent planes can in general be drawn to touch Σ_0. To obtain the equation of these tangent planes let $(\alpha'\beta'\gamma'\delta')$ be a point of intersection of the plane P_0 with the curve of intersection of S_1 and S_2. Then—

$$\frac{\alpha}{\alpha'} + \frac{\beta}{\beta'} + \frac{\gamma}{\gamma'} + \frac{\delta}{\delta'} = 0$$

$$\frac{\alpha_1}{\alpha'} + \frac{\beta_1}{\beta'} + \frac{\gamma_1}{\gamma'} + \frac{\delta_1}{\delta'} = 0$$

$$\frac{\alpha_2}{\alpha'} + \frac{\beta_2}{\beta'} + \frac{\gamma_2}{\gamma'} + \frac{\delta_2}{\delta'} = 0$$

$$\frac{\alpha'}{\alpha_0} + \frac{\beta'}{\beta_0} + \frac{\gamma'}{\gamma_0} + \frac{\delta'}{\delta_0} = 0$$

From the first three equations we learn—

$$\frac{1}{a'} : \frac{1}{\beta'} : \frac{1}{\gamma'} : \frac{1}{\delta'} = \Delta_1 : -\Delta_2 : \Delta_3 : -\Delta_4$$

Where $\Delta_1\, \Delta_2\, \Delta_3\, \Delta_4$ are the determinants obtained by omitting in turn each of the columns, starting from the left-hand corner of the determinant—

$$\begin{vmatrix} a & \beta & \gamma & \delta \\ a_1 & \beta_1 & \gamma_1 & \delta_1 \\ a_2 & \beta_2 & \gamma_2 & \delta_2 \end{vmatrix}$$

The equation of the tangent planes is therefore—

$$\frac{1}{a_0\,\Delta_1} - \frac{1}{\beta_0\,\Delta_2} + \frac{1}{\gamma_0\,\Delta_3} - \frac{1}{\delta_0\,\Delta_4} = 0,$$

which, as $\Delta_1\, \Delta_2\, \Delta_3\, \Delta_4$ are each of the first degree in $(a\,\beta\,\gamma\,\delta)$, represents an equation of the third degree.

§ 5. Let two Steiner quartics $\Sigma_1\, \Sigma_2$ be taken: since these surfaces are the envelopes of the Steiner planes of points lying on the planes P_1 and P_2, it follows that the Steiner planes of the line of intersection of P_1 and P_2 will be the common tangent planes of Σ_1 and Σ_2, and also that, since the line of intersection of P_1 and P_2 will meet the Steiner cubic surface S_0 in three points, three planes can be drawn through the point $(a_0\beta_0\gamma_0\delta_0)$ to touch both Σ_1 and Σ_2.

§ 6. Any three Steiner quartics $\Sigma_1\, \Sigma_2\, \Sigma_3$ have in general one common tangent plane distinct from the faces of the fundamental tetrahedron, namely, the Steiner plane of the point common to the Steiner planes P_1, P_2, P_3, but if these Steiner planes have a common line of intersection the Steiner planes of points lying on that line will touch each of the surfaces $\Sigma_1\, \Sigma_2\, \Sigma_3$.

§ 7. If $\lambda + \mu + \nu + \rho = 0$, the co-ordinates of any point on P_0 may be taken to be $(\lambda a_0, \mu\beta_0, \nu\gamma_0, \rho\delta_0)$ and the Steiner plane of this point will touch Σ_0 at the point $(\lambda^2 a_0, \mu^2\beta_0, \nu^2\gamma_0, \rho^2\delta_0)$: any point on S_0 may be represented by the co-ordinates $\left(\frac{a_0}{\lambda}, \frac{\beta_0}{\mu}, \frac{\gamma_0}{\nu}, \frac{\delta_0}{\rho}\right)$ and the tangent plane to S_0 at this point will have for its equation—

$$\lambda^2\frac{a}{a_0} + \mu^2\frac{\beta}{\beta_0} + \nu^2\frac{\gamma}{\gamma_0} + \rho^2\frac{\delta}{\delta_0} = 0.$$

Hence it may be easily shown that the envelope of the Steiner planes of points lying on Σ_0 is the surface whose equation is—

$$\sqrt[3]{\frac{a}{a^0}} + \sqrt[3]{\frac{\beta}{\beta_0}} + \sqrt[3]{\frac{\gamma}{\gamma_0}} + \sqrt[3]{\frac{\delta}{\delta_0}} = 0$$

and that the locus of points whose Steiner planes touch S_0 is the surface whose equation is—

$$\sqrt{\frac{a_0}{a}} + \sqrt{\frac{\beta_0}{\beta}} + \sqrt{\frac{\gamma_0}{\gamma}} + \sqrt{\frac{\delta_0}{\delta}} = 0.$$

3.—ON A FORM OF GREEN'S THEOREM.

By EVELYN G. HOGG, M.A., Christ's College, Christchurch, New Zealand.

§ 1. If S be a closed surface, l, m, and n the direction-cosines of the normals to S at the point $(x\ y\ z)$, and if u, v, and w be, with their first derivatives, finite, continuous, single-valued functions of the variables x, y, z, then by a modification of Green's Theorem

$$\iint (lu + mv + nw)\, d\mathrm{S} = \iiint \left(\frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz}\right) d\mathrm{V}, \ldots\ldots\ldots(1)$$

where the double integral is taken over the surface S, and the triple integral through the volume enclosed by S.

$$\text{Now let } u = x\,\Sigma f(r)$$
$$v = y\,\Sigma f(r)$$
$$w = z\,\Sigma f(r)$$

where Σ is a homogeneous function of degree $2k$ in the variables x, y, z, and $r^2 = x^2 + y^2 + z^2$.

$$\text{Then } \frac{du}{dx} = \Sigma f(r) + x\frac{d\Sigma}{dx} f(r) + \frac{x^2}{r}\Sigma\frac{df}{dr},$$

with similar expressions for $\frac{dv}{dy}$ and $\frac{dw}{dz}$.

$$\text{Hence } \frac{du}{dx} + \frac{dv}{dy} + \frac{dw}{dz} = \Sigma\left\{(2k+3) f(r) + r\frac{df}{dr}\right\}$$

Hence (1) takes the form—

$$\iint (lx + my + nz)\,\Sigma f(r)\, d\mathrm{S} =$$
$$\iiint \Sigma\left\{(2k+3) f(r) + r\frac{df}{dr}\right\} d\mathrm{V}.$$

$$\text{Now let } r\frac{df}{dr} + (2k+3) f(r) = \mathrm{F}(r), \text{ then}$$

$$f(r) = \mathrm{C}r^{-(2k+3)} + r^{-(2k+3)}\int r^{2k+2}\,\mathrm{F}(r)\, dr$$

where C is a constant, and

$$\mathrm{C}\iint \frac{\Sigma(lx + my + nz)\, d\mathrm{S}}{r^{2k+3}} + \iint \frac{\Sigma(lx + my + nz)}{r^{2k+3}}$$
$$\times\left[\int r^{2k+2}\,\mathrm{F}(r)\, dr\right] d\mathrm{S} = \iiint \Sigma\,\mathrm{F}(r)\, d\mathrm{V}.$$

Now since the integral multiplied by C is independent of F (r), it must vanish identically—hence we obtain the following equations:—

$$\iint \frac{\Sigma(lx + my + nz)}{r^{2k+3}}\left[\int r^{2k+2}\,\mathrm{F}(r)\, dr\right] d\mathrm{S}$$
$$= \iiint \Sigma\,\mathrm{F}(r)\, d\mathrm{V}\ldots\ldots\ldots(2).$$

$$\iint \frac{\Sigma(lx + my + nz)}{r^{2k+3}}\, d\mathrm{S} = 0\ldots\ldots\ldots(3).$$

If θ be the angle between the normal to S at x, y, z, and the radius vector (r) to that point from the origin, then $\cos.\theta = \frac{lx + my + nz}{r}$; also $dS \cos.\theta = r^2\, d\omega$, where $d\omega$ is the solid angle subtended at the origin by the element of area dS, hence the equations (2) and (3) transform to—

$$\int \frac{\Sigma}{r^{2k}} \left[\int r^{2k+2}\, F(r)\, dr \right] d\omega = \iiint \Sigma\, F(r)\, dV \ldots\ldots\ldots (2')$$

$$\int \frac{\Sigma\, d\omega}{r^{2k}} = 0 \ \ldots\ldots\ldots (3')$$

If in the above equations k is made zero, we obtain—

$$\iint \frac{lx + my + nz}{r^3} \left[\int r^2\, F(r)\, dr \right] dS = \iiint F(r)\, dV \ldots\ldots\ldots (4)$$

$$\iint \frac{lx + my + nz}{r^3}\, dS = 0 \ldots\ldots\ldots (5)$$

$$\int \left[\int r^2\, F(r)\, dr \right] d\omega = \iiint F(r)\, dV \ldots\ldots\ldots (4')$$

$$\int d\omega = 0 \ldots\ldots\ldots (5')$$

The limitations placed initially on the functions u, v, w require that equations (3), (3′), (5), and (5′) be restricted to cases in which the origin of co-ordinates lies outside the surface S. In certain cases the equations may be applied by imagining an infinitely small sphere drawn about the origin of co-ordinates and taking the integrals over the original surface and that of the sphere and through the volume bounded by those surfaces.

The subsequent part of the paper illustrates the application of the above equations to the cases of the sphere and anchor-ring.

§ 2. Let the equations of a sphere be—

$$(x - b^2) + y^2 + z^2 = a^2,$$

where $b > a$.

The direction-cosines of the normal at the point x, y, z on the sphere will be—

$$\frac{x - b}{a}, \frac{y}{a}, \frac{z}{a},$$

and $r^2 = a^2 + b^2 + 2ab \cos.\theta$, where θ is the vectorial angle to x, y, z drawn from the centre of the sphere and measured from the diameter passing through the origin of co-ordinates; also

$$dS = 2\pi\, a^2 \sin.\theta\, d\theta.$$

Hence equations (2) and (3) give—

$$2\pi a \int_0^{\pi} \frac{r^2 - bx}{r^{2k+3}}\, \Sigma \left[\int r^{2k+2}\, F(r)\, dr \right] \sin.\theta\, d\theta$$

$$= \iiint \Sigma\, F(r)\, dV \ldots\ldots\ldots (6)$$

$$\int_0^{\pi} \frac{r^2 - bx}{r^{2k+3}}\, \Sigma \sin.\theta\, d\theta = 0 \ldots. (7)$$

A more useful form of integral may be obtained by changing the variable from θ to r by means of the relation $r\,dr = -\,ab \sin.\theta\, d\theta$;

Also since $x = b + a \cos.\theta$,

$$r^2 - bx = \tfrac{1}{2}(r^2 - b^2 + a^2)$$

Hence we obtain the general integrals—

$$\frac{\pi}{b}\int_{b-a}^{b+a} \frac{\Sigma}{r^{2k}}\left(1 - \frac{b^2 - a^2}{r^2}\right)\left[\int r^{2k+2}\,\mathrm{F}(r)\,dr\right] dr$$

$$= \iiint \Sigma\, \mathrm{F}(r)\, d\mathrm{V} \ldots\ldots\ldots (8)$$

$$\int_{b-a}^{a+b} \frac{\Sigma}{r^{2k}}\left(1 - \frac{b^2 - a^2}{r^2}\right) dr = 0 \ldots\ldots\ldots (9)$$

§ 3. Let $\mathrm{F}(r) = r^n$ and $k = 0$

$$\int r^2\,\mathrm{F}(r)\,dr = \int r^{n+2}\,dr = \frac{r^{n+3}}{n+3}$$

$$\iiint r^n\, d\mathrm{V} = \frac{\pi}{b\,(n+3)}\int_{b-a}^{b+a}\left(1 - \frac{b^2 - a^2}{r^2}\right) r^{n+3}\, dr$$

$$= \frac{2\pi}{b\,(n+2)(n+3)(n+4)}\Big\{ (b + a)^{n+3}\left[(n+3)\,a - b\right]$$

$$+ (b - a)^{n+3}\left[(n+3)\,a + b\right]\Big\} \ldots\ldots\ldots (10)$$

This expression takes the form $\frac{0}{0}$ if $n = -\,2$, or $-\,3$, or $-\,4$.

For these particular cases we have—

$$(\alpha)\ \iiint \frac{d\mathrm{V}}{r^2} = \frac{\pi}{b}\int_{b-a}^{b+a}\left(1 - \frac{b^2 - a^2}{r^2}\right) r\, dr$$

$$= 2\,\pi\, a - \frac{\pi\,(b^2 - a^2)}{b} \log.\frac{b+a}{b-a} \ldots\ldots\ldots (11)$$

$$(\beta)\ \iiint \frac{d\mathrm{V}}{r^3} = \frac{\pi}{b}\int_{b-a}^{b+a}\left(1 - \frac{b^2 - a^2}{r^2}\right) \log. r\, dr$$

$$= 2\pi\left\{\log.\frac{b+a}{b-a} - \frac{2a}{b}\right\} \ldots\ldots\ldots (12)$$

$$(\gamma)\ \iiint \frac{d\mathrm{V}}{r^4} = \frac{\pi}{b}\int_{b-a}^{b+a}\left(\frac{b^2 - a^2}{r^2} - 1\right)\frac{dr}{r}$$

$$= \frac{\pi}{b}\left\{\frac{2ab}{b^2 - a^2} - \log.\frac{b+a}{b-a}\right\} \ldots\ldots\ldots (13)$$

If $b = a$, $$\iiint r^n\, d\mathrm{V} = \frac{2\pi\,(2a)^{n+3}}{(n+3)(n+4)} \ldots\ldots\ldots (14)$$

If $b < a$,

$$\iiint r^n \, dV = \frac{2\pi}{b\,(n+2)(n+3)(n+4)} \Big[(a+b)^{n+3} \{ (n+3)\,a - b \} - (a-b)^{n+3} \{ (n+3)\,a + b \} \Big] \ldots\ldots\ldots (15)$$

This integral becomes infinite for values of n less than -2, and takes the form $\frac{O}{O}$ when $n = -2$. For this particular case we have—

$$\iint \frac{dV}{r^2} = 2\pi a + \frac{\pi}{b}(a^2 - b^2) \log. \frac{a+b}{a-b} \ldots\ldots\ldots (16)$$

The result reduces to the value $4\pi a$ when $b = o$.

For $n = -1$, we obtain the result—

$$\iint \frac{dV}{r} = \frac{2\pi}{3}(3a^2 - b^2) \ldots\ldots\ldots (17)$$

§ 4. If the sphere be cut by the planes $x = c$, $x = d$, where $b + a > c > d > b - a$, and $\iiint r^n \, dV$ be required for the volume enclosed by the planes and the surface of the sphere cut off by the planes, the part of the surface-integral arising from the spherical surface will be—

$$\frac{\pi}{b\,(n+3)} \int_{d'}^{c'} \left(1 - \frac{b^2 - a^2}{r^2}\right) r^{n+3}\, dr,$$

$$\text{where } c'^2 = a^2 + 2bc - b^2$$

$$d'^2 = a^2 + 2bd - b^2$$

Since the direction-cosines of the c-plane and d-plane are respectively $(1, 0, 0)$ and $(-1, 0, 0)$, the integrals arising from the plane surfaces are—

$$\frac{c}{n+3} \int_c^{c'} r^n \, dS, \text{ and } -\frac{d}{n+3} \int^{d'} r^n \, dS_2.$$

We may put dS_1 and dS_2 equal to $2\pi\rho \; d\rho$ where ρ is the radius of a circle on the plane face having its centre on the x-axis; also, since $r^2 = c^2 + \rho^2$ for the c-plane, and $d^2 + \rho^2$ for the d-plane, we have in both cases $r\,dr = \rho\,d\rho$. The surface-integrals are therefore—

$$\frac{2\pi c}{n+3} \int_c^{c'} r^{n+1}\, dr \text{ and } -\frac{2\pi d}{n+3} \int_d^{d'} r^{n+1}\, dr$$

Hence—

$$\iiint r^n \, dV = \frac{\pi}{b\,(n+3)} \left\{ \frac{c'^{n+4} - d'^{n+4}}{n+4} - \frac{(b^2 - a^2)(c'^{n+2} - d'^{n+2})}{n+2} \right\}$$

$$+ \frac{2\pi}{(n+2)(n+3)} \left\{ c\,(c'^{n+2} - c^{n+2}) - d\,(d'^{n+2} - d^{n+2}) \right\} \ldots . (18)$$

Among other forms of F (r), for which the integral $\iiint$ F (r) dV may be evaluated, are—

$$F(r) = r^n \log. r, \ n \text{ a positive integer, zero or } - 1$$

$$F(r) = (\log. r)^2$$

$$F(r) = \frac{(\log. r)^2}{r}$$

§ 5. If in equation (2) we make F $(r) = 1$,

$$\text{then} \iiint \Sigma \, dV = \frac{1}{2k + 3} \iint \Sigma \, (lx + my + nz) \, dS.$$

Making $\Sigma = x^m$ and taking the integrals through the volume and over the surface of the sphere previously employed, we obtain the general integral—

$$\iiint x^m \, dV = \frac{2\pi}{(m + 1)(m + 2)(m + 3)} \Big\{ (b + a)^{m + 2}$$

$$\Big[(m + 2) a - b\Big] + (b - a)^{m + 2} \Big[(m + 2) a + b\Big] \Big\} \ldots\ldots\ldots (19)$$

This integral becomes indeterminate for the values $m = -1$, or -2, or -3. For these particular cases—

$$\iiint \frac{dV}{x} = \pi \left[2ab - (b^2 - a^2) \log. \frac{b + a}{b - a} \right] \ldots\ldots\ldots (20)$$

$$\iiint \frac{dV}{x^2} = 2\pi \left[- 2a + b \log. \frac{b + a}{b - a} \right] \ldots\ldots\ldots (21)$$

$$\iiint \frac{dV}{x^3} = \pi \left[\frac{2ab}{b^2 - a^2} - \log. \frac{b + a}{b - a} \right] \ldots\ldots\ldots (22)$$

§ 6. Let an anchor-ring be formed by the revolution about the axis of z of the circle whose equation in the zx plane is—

$$(x - b)^2 + z^2 = a^2,$$

where $b > a$.

Let a plane be drawn through the axis of z, making an angle ϕ with the plane xz.

The co-ordinates of any point P on the surface of the anchor-ring are given by—

$$x = (b + a \cos. \theta) \cos. \phi$$

$$y = (b + a \cos. \theta) \sin. \phi$$

$$z = a \sin. \theta,$$

where θ is the vectorial angle to P from the centre of the circular section measured from the diameter of the section which passes through the origin of co-ordinates.

The direction cosines of the normal to the surface at P will be cos. θ cos. ϕ, cos. θ sin. ϕ, sin. θ.

Hence $lx + my + nz = b \cos. \theta + a$.

The element of surface dS may be regarded as formed by the revolution of a circular arc of length $ad\theta$ about the axis of z; hence $dS = 2\pi (b + a \cos. \theta)\, a\, d\theta$.

The limits of θ will be 2π and O, hence we have—

$$\iiint \Sigma F(r)\, dV = 2\pi a \int_0^{2\pi} \frac{\Sigma (a + b \cos. \theta)(b + a \cos. \theta)}{r^{2k+3}} \left[\int r^{2k+2} F(r)\, dr\right] d\theta \ldots\ldots\ldots (23)$$

$$\int_0^{2\pi} \frac{\Sigma (a + b \cos. \theta)(b + a \cos. \theta)}{r^{2k+3}}\, d\theta = 0 \ldots\ldots\ldots (24)$$

Let $k = 0$ and $F(r) = r^{2a}$.

Then since $r^2 = a^2 + b^2 + 2ab \cos. \theta$, we have—

$$\iiint r^{2n}\, dV = \frac{2\pi a}{2n+3}$$

$$\times \int_0^{\pi} (a + b \cos. \theta)(b + a \cos. \theta)(a^2 + b^2 + 2ab \cos. \theta)^n\, d\theta \ldots\ldots (25)$$

$$\int_0^{2\pi} \frac{(a + b \cos. \theta)(b + a \cos. \theta)}{a^2 + b^2 + 2\, ab \cos. \theta)^{\frac{3}{2}}}\, d\theta = 0 \ldots\ldots\ldots (26)$$

The single integral in (25) can (if n be a positive integer) be expanded in powers of cosine θ and integrated.

It will be noticed that—

$$\int_0^{2\pi} \cos.^{2m+1} \theta\, d\theta = 0$$

$$\int_0^{2\pi} \cos.^{2m} \theta\, d\theta = \frac{(2m-1)(2m-3)\ldots 3.\ 1}{2^{m-1} \lfloor m} . \pi.$$

Thus—

$$\iiint r^2\, dV = 2\pi^2 a^2 b\, (a^2 + b^2) \ldots\ldots\ldots (27)$$

$$\iiint r^4\, dV = 2\pi^2 a^2 b \left\{ (a^2 + b^2)^2 + a^2 b^2 \right\} \ldots\ldots\ldots (28)$$

4.—ON THE INFLUENCE OF THE SPEED OF THE α-PARTICLE UPON THE STOPPING-POWER OF THE MEDIUM THROUGH WHICH IT PASSES.

By W. H. BRAGG, M.A., Elder Professor of Mathematics and Physics in the University of Adelaide.

(Abstract.)

When the stopping-powers of substances were first measured by Bragg and Kleeman (*Phil. Mag.*, Sept., 1905) it was observed that the swifter α-particles from Ra.C. were more hindered in passing through a metal sheet than the slower particles of Ra. itself. Kucera and Masek have recently (*Phys. Zeit.*, 7, Nos. 18 and 19) investigated this effect, and have concluded that the stopping-powers of metals are approximately proportional to the speed of the α-particle.

It is now pointed out that the results of Kucera and Masek are inconsistent with the results obtained by Rutherford, Levin, and others. For Rutherford has shown (*Phil. Mag.*, Aug., 1906) that the particle spends its energy at a uniform rate on its way through aluminium; and this must be true of air also, since the loss of range caused by a sheet of aluminium is proportional to its thickness. And further it might be inferred from experiments described by Kucera and Masek that this is true also of Au and Pt, since the loss of range caused by two sheets—one of Al and the other of Au or Pt—is independent of the order in which the particle passes through them.

The author has made further experiments on this point, from which he draws conclusions differing in some respects from those of Kucera and Masek. The stopping-power of Al is nearly independent of the speed of the particle: on the other hand, the stopping-power of Sn increases with the speed; and the stopping-powers of Au and Pt do so to a more marked degree than that of tin. Consequently the stopping-power of two sheets of different metals must depend on the order in which the particle passes through them; and this appears to be the case from the author's experiments, though Kucera and Masek did not find it to be so.

It is further shown that this result will probably account for the experimental results of Mme. Curie, who found different values for the ionisation current above two metal sheets depending on their order.

5.—THE BRITISH GRAVITATION SYSTEM OF UNITS.

By W. R. JAMIESON, M.A., B.Sc.

6.—THE DEFINITION OF THE CO-EFFICIENT OF EXPANSION.

By W. R. JAMIESON, M.A., B.Sc.

7.—ON THE VELOCITY OF EJECTION OF THE ELECTRON FROM AN IONISED MOLECULE.

By R. D. KLEEMAN, B.Sc., 1851 *Exhibition Scholar of the University of Adelaide.*

[ABSTRACT.]

It has been shown by the author (Phil. Mag., Oct., 1906) that initial recombination does not occur in the case of ions made by β, γ, or X rays, so that the effect is peculiar to the ions made by α rays. In explanation, it is now suggested that the electron is ejected from the atom with different speeds by these different ionising agents. Curie and Sagnac have shown that the negative particles displaced from a metal plate by X rays have considerable penetrating power, and it is to be assumed that electrons ejected from gaseous molecules by the same rays also move with large velocities. Thus they soon become well separated from their parent molecules, and the phenomenon of initial recombination does not occur. On the other hand, Füchtbauer (Phys. Zeit., Nov., 1906) has shown that the secondary radiation due to canal rays has very little penetrating power; and it may be assumed, therefore, that this is true also in the case of the α rays, which are so very similar to canal rays. Hence the electron ejected by the α particle does not get away from the influence of its parent atom, and is apt to recombine with it. It is suggested that the electrons are ejected at slower speeds as the α particle slows down, which may explain why the α particle, though it produces more ions towards the end of its course, spends its energy at a uniform rate as it goes.

8.—AUSTRALIAN GEODESY.

By W. ERNEST COOKE, M.A., F.R.A.S., Government Astronomer for Western Australia.

[ABSTRACT.]

Probably no problem in geodesy more urgently awaits solution than the determination of the true shape of the earth; and no place is so well suited for this work as Australia, with its clear atmosphere, immense plains, and the advantage of being under a single Government which has control of all the telegraph lines.

This compact little continent, of nearly 30° by 40° is peculiarly adapted for the latest geodetic methods, such as are now being used in mid-Europe by the International Geodetic Bureau, and may be summarised thus:—

1. A careful triangulation is made of the prepared field of operations.

2. Determinations of latitude and either azimuth or differences of longitude are made by the most refined methods.

3. Latitudes and longitudes of each principal astronomical station are computed from the triangulation, on the assumption that the earth has some definite figure—say, Clarke's or Bessel's ellipsoid.

4. Each principal station is connected with *every other station* by a formula including corrections to the figures for the ellipsoids and error of astronomical position due to the deflection of the vertical.

5. Many equations are thus formed, and the above quantities finally determined from a least-square solution.

The final quantities depend on a mass of observations covering the whole continent, and possess the weight of the united mass. Also the exact geographical position of *each* principal station will be found with an accuracy depending on the united strands of an entire network—not on links of a chain.

An important practical advantage in surveying the country properly and in granting indisputable titles to land would be gained by such work, as is pointed out in a quotation from a letter written by Sir David Gill to Lord Grey, then Administrator of Rhodesia. "There is one and only one remedy, and that is to connect all detached surveys with a general system of triangulation; and it will save the Government and the inhabitants generally a vast amount of money to establish this triangulation as quickly as possible, so that every farm survey, when it is made, may at the same time be connected with existing well-established points of this rigorous system."

This geodetic work, if done at all, must be done by united Australia, and the good work hitherto done by the several Survey Departments of the States could be utilised.

9.—OUR WINTER STORMS: WHENCE DO THEY COME?

By W. ERNEST COOKE, M.A., F.R.A.S., Government Astronomer of Western Australia.

[Abstract.]

In this paper the author brings forward the theory that "many, probably most, and possibly all, of the disturbances which affect the weather of Western Australia come from the Indian Ocean, and are probably born in the tropics." He attacks the theory frequently urged that the winter storms in Western Australia are due to the extension of a tongue of low pressure from the Antarctic belt into the belt of high pressure which usually exists between latitudes 25° and 30° S. This theory has been found barren of results. The attempt to connect the weather at either the Cape of Good Hope, Durban, or Mauritius with that of Western Australia has been a fruitless one. As an illustration, the remarkably severe series of the winter type of storm which visited the Cape in January, 1901, failed altogether to make itself felt in Australia.

The clue for the new hypothesis was found in Dr. Meldrum's investigations into the cyclone tracks in the South Indian Ocean. From December to March, Mauritius lies in the regular path of a series of

cyclones which come from the north-east, recurve about latitude 20°, and then travel to the south-east or east-south-east. As the winter approaches, the number of cyclones at Mauritius diminishes, and their location moves eastward, the latitude of recurvature at the same time decreasing. If the point of recurvature were sufficiently far to the north or east of Mauritius, the storm would strike the west coast of Western Australia. There is evidence that a great many of the winter storms have approached from the Indian Ocean. A classification made from January to September, 1906, showed that of 31 of the winter type of storms experienced in Western Australia 21 distinctly came from the Indian Ocean. It is thought that the other 10 also came from this quarter, but that their path lay so far to the west that their approach was not perceived until nearing the Leeuwin. It is not exactly known what takes place in the atmosphere when a disturbance breaks down from the tropics through the normal high-pressure belt, but the illustrations given show that they do take this course. Suitable observations taken at a height of, say, 5,000ft. in the free atmosphere would help to elucidate this point.

It is not denied that sometimes a storm does seem to surge northwards from the Southern Ocean in Australian longitudes. This seems to happen more frequently in the vicinity of South-Eastern Australia. It is suggested that the upward surge referred to is induced by a "low" coming down from the Indian Ocean and separating out the high-pressure belt into anticyclones. Instances of two disturbances of the kind forming a trough of low pressure across Australia are frequent, and have been noted as one of the sets of conditions which are associated with a general rain in South Australia. It is thought that these upward surges of low pressure from the Southern Ocean, which sometimes bring unexpected storms and floods, especially in the south-eastern portions of Australia, might profitably be studied in conjunction with the hypothesis that they are in some way connected with the passage of a disturbance coming down from the north-west, perhaps only perceptible over Australia in the upper portions of the atmosphere.

10.—STANDARD ASTRONOMICAL WORK IN AUSTRALIA.

By W. ERNEST COOKE, M.A., F.R.A.S., Government Astronomer of Western Australia.

[ABSTRACT.]

A scheme of standard work is suggested for international co-operation, so that a "series of first-class positions of the same stars will be determined every 11 or 12 years, and the observer in other departments of astronomy will find suitable reference points in any field he may wish to investigate." Each Australian observatory might undertake a zone of 2° per year, if two assistants were employed upon the transit work, doing both observing and computing, and if the new

eye-piece which is suggested should prove satisfactory. Nearly all astronomical research is based on observations taken with a transit circle. The observatories of Sydney, Melbourne, Adelaide, and Perth are equipped with good transit telescopes, and it is proposed that Australia should "take permanent charge of that portion of the southern sky situated between 20° and 60° declination. Perth has already committed itself to the unit 31°-41°; Melbourne might be asked to take the most southerly zone, 51°-61°; Sydney, 41°-51°; and Adelaide, 21°-31°."

If transit observations hitherto made had been properly co-ordinated, it would not be possible, as it now, unfortunately, is, for an astronomer to be unable to find in existing catalogues a number of well-determined reference points in the particular field he is investigating

This standard work is to be based on two main principles—(*a*) A list of stars to be prepared such that where possible three stars are included in each square degree; (*b*) each observatory to take a definite zone, either 10° or 20° of declination (one or two units), and constantly observe the same stars, taking at least three first-class observations of each star every 10 or 12 years.

There should be a list of fundamental stars. The Royal Observatory at the Cape and the Argentine National Observatory might keep up the positions of these. The secondary standards should contain three or four stars per hour of right ascension for every 2° of declination, and include all the fundamentals. At the commencement of the work one year is to be given to observing the secondary standards; and as soon as the list has been completely observed the work is to begin again in the same way. By such co-operation over-lapping of work, as well as important omissions, will be made impossible; also all transit observers engaged in it will feel that the whole of their work is important and will certainly be used, and therefore will themselves become more interested and accurate, and a large section of the sky will have been carefully explored, so that workers will find in it well-determined star-positions.

11.—ON THE PHOSPHORESCENCE OF GLASS EXPOSED TO SUNLIGHT.

By R. C. YATES.

[COMMUNICATED BY PROFESSOR BRAGG, M.A.]

[ABSTRACT.]

Certain kinds of glass, on being exposed to strong sunlight, acquire a violet tint. This fact has already been observed. The author now showed that glass tinted in this way phosphoresced on being heated, and the light was easily visible in a dark room. There was an obvious parallelism between this effect and the thermoluminescence which could be induced in certain substances, particularly by cathode rays.

Section B.

CHEMISTRY, METALLURGY, AND MINERALOGY.

1.—RECENT METHODS OF ROCK ANALYSIS.

By P. G. WYKEHAM BAYLY, A.S.A.S.M., Government Metallurgical Chemist, Melbourne.

Since the work of the chemists of U.S. Geological Survey has become more generally known the quality of rock analysis has been steadily improving. Wherever the general scheme, as developed by Clarke and Hillebrand, has been adopted it has proved an incentive to ever-increasing accuracy and carefulness, and as a result the standard of the work done has been raised. Hillebrand showed the weakness of an analysis, no matter how much time and care had been spent upon it, which ignored certain features essential to its value from the point of view of the petrographer, *e.g.*, the omission of separation of the two oxides of iron, failure to recover completely the silica, neglect of probable and almost certain presence of titanium and other elements. He showed, too, by working with extreme care for each base and blocking every possible source of loss, how necessary were certain precautions if good results were to be obtained. He demonstrated the presence in nearly all igneous rocks of appreciable amounts of elements which, in general, are completely ignored, but which may very possibly have distinct significance to the geologist. Even the undoubted presence of "traces" may quite possibly be of extreme importance in determining a comparison of rocks.

The principal object of this present paper is to urge all chemists in the different States who are called upon to perform rock analyses to take up their task with more regard to uniformity and agreement of method, so that the results may be used comparatively one with another, and so make possible an ultimate combination of the results of analyses of the rocks of Australia for the purpose of classification. It is intended to deal only with the determination of a few of the important elements upon which variations of methods have suggested themselves ; for the remainder, the procedure of Hillebrand is followed as completely as possible.

Nothing better than the lines laid down by that chemist can be suggested, and for the general discussion of his principles I would simply refer to his own published work.(*a*) I propose, however, to suggest a few modifications in some of his methods of procedure which I have found by practice to recommend themselves.

Preparation of Sample.—An amount of 25 grammes of representative chips of the rock is broken down in a diamond mortar, and

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**a* Bulletin of Geological Survey, No. 176.

allowed to fall lightly through a speciai coarse sieve (20-hole) *without rubbing.* The coarse powder is then agated, the value of this during the analysis being well worth the trouble.

SILICA (SiO_2).—One half gramme is always used, as, unless specially large platinum crucibles are available, the silica is dangerous to handle, and the precipitate unwieldy.

After fusion the crucible should not be suddenly chilled in cold water whilst hot, as this soon induces cracking in the platinum, especially if it is of any thickness.

Various methods may be adopted for removing the melt. A useful way is to allow it to cool round a platinum rod and then detach by short, quick heating; this will remove the bulk. The main object is to get the fusion out of the crucible as quickly as possible and with the least chance of mechanical loss or of injury to the crucible. The particular means adopted may be left to individual choice. The melt is now placed in a 5in. porcelain basin, well covered, and dissolved in HCl, after being moistened with water. The portion remaining in the crucible is carefully dissolved out and added to the bulk. After evaporation to dryness on the water bath the mass is twice moistened with HCl (few drops only), taken up with hot water and filtered. Heating the dried mass at 120° C. for half an hour is unnecessary. Its effect is generally to increase the impurity in the SiO_2, as indicated in the residue after treatment with hydrofluoric acid. The dried mass is treated with 10 ccs. HCl and 100 ccs. hot water, and warmed till dissolved. It is then filtered and washed free from chlorides and the silica weighed till constant after prolonged blasting.

Hillebrand insists on a second evaporation of the filtrate, as he says that the silica contained therein is not certain of recovery in the ultimate treatment ofxthe alumina, iron precipitate. A number of experiments were made in endeavoring to satisfy this point, and comparative analyses were performed, using each method.

TABLE I.

In each case A = single evaporation.
" B = double evaporation.

Test.		Volatile Silica (SiO_2) by Hydro-fluoric Acid.	SiO_2 Correction (Recovered from Al_2O_3 Precipitate)	Total SiO_2 Recovered.	Variations in B.		Rock.
					SiO_2.	Al_2O_3.	
1	A	.2954	.0035	.2989	—	—	Trachy phonolite
	B	.2960	.0012	.2972	−.0017	+.0011	
2	A	.3309	.0048	.3357	—	—	Solvsbergite
	B	.3324	.0019	.3343	−.0014	+.0016	
3	A	.2091	.0088	.2179	—	—	Basalt
	B	.2178	.0003	.2181	+.0002	+.0044	

TABLE I.—*continued.*

Test.		Volatile Silica (SiO_2) by Hydro-fluoric Acid.	SiO_2 Correction (Recovered from Al_2O_3 Precipitate.)	Total SiO_2 Recovered.	Variations in B.		Rock.
					SiO_2.	Al_2O_3.	
4	A	.2508	.0078	.2586	—	—	Basalt
	B	.2585	.0010	.2595	+.0009	+.0024	
5	A	.3336	.0017	.3353	—	—	Solvsbergite
	B	.3368	.0010	.3378	+.0025	—	
6	A	.2992	.0013	.3005	—	—	Trap
	B	.3021	.0015	.3036	+.0031	—	
7	A	.2494	.0008	.2502	—	—	Compact trap
	B	.2505	.0002	.2507	+.0005	+.0017	
8	A	.3204	.006?	.3210	—	—	Solvsbergite
	B	.3262	.0011	.3273	+.0063	+.0033	

Of the eight pairs of analyses, the amount of silica ultimately recovered was in six cases higher when two evaporations were used (Nos. 3 to 8), and in two cases lower (Nos. 1 and 2).

Of the six higher results, three cases showed an advantage of under one milligramme—two being almost identical, the excess being only ·0002 and ·0005 grammes. One (No. 8) was higher by ·0063 gramme, but this result may safely be rejected, as the SiO_2 recovered from the Al_2O_3 ppt. in this case (No. 8a) was unusually low (only ·0006 gramme), and the summation of the whole analysis was bad (99·10 per cent.). The result is probably in error.

If the corresponding alumina results are compared, it is seen that in each case the use of double evaporation gave slightly higher results. It would certainly appear that this treatment does tend to render the Al_2O_3 more insoluble when it is finally precipitated.

The above figures were not picked out, but taken in consecutive order from a series of analyses of rocks from Macedon, Victoria, made at the Mines Department laboratory by two chemists working independently and doing only single analyses. The personal factor, I think, largely accounts for the higher Al_2O_3 figures, as, whichever method he adopted, one man nearly always obtained a higher figure for alumina.

The following example given is an analysis made on a rock by one chemist (Mr. Alan G. Hall), when the personal element should be constant. Each method, single and double evaporation, was made in duplicate, and the results for silica and alumina show no advantage from the second evaporation. The advantage of omitting this is not only a saving of time, but also a removal of the danger of contamination which will always accompany a long evaporation. This is especially the case where economy does not permit the unlimited use of large platinum vessels.

As in the previous table, the analyses in which the silica received a single evaporation for SiO_2 are marked A; those marked B receiving two.

TABLE II.

SILICA SiO_2.

	First Weighing of Impure SiO_2.	Volatile SiO_2 by HF.	Correction Volatile SiO_2 Recovered from Al_2O_3 ppt.	Total SiO_2.	Rock.
A—1	.2528	2503	.0078	.2581	Mica basalt
2	.2523	.2508	.0075	.2583	
B—1	.2573	.2547	.0027	.2574	
2	.2582	.2533	.0027	.2560	

ALUMINA, IRON, ETC.

	Combined Al_2O_3, Fe_2O_3, P_2O_5 ppt.	Correction (Volatile SiO_2).	Total Al_2O_3, &c.	
A—1	.1626	.0078	.1548	
2	.1627	.0075	.1542	
B—1	.1568	.0027	.1541	Basic acetate separation
2	.1593	.0027	.1566	" "

These tests were made with every care for each method, and the comparison is interesting. In both silica and alumina the duplicate A figures (single evaporation) are nearer one another than in the B duplicates (double evaporation). The final SiO_2 for A is higher, and in the alumina only 2B is higher, but this one shows a serious discrepancy with its duplicate. In B, the basic acetate separation had been used, but filtration was slow. The extra manipulation involved probably accounts for the poorer figures.

PRECIPITATION OF ALUMINA, IRON, &c.—Hillebrand advises at least one precipitation by basic acetate if any manganese is present at all, but admits that two ammonia precipitations are usually quite satisfactory for complete separation of Al_2O_3, Fe_2O_3, P_2O_5, &c., from the manganese. There is no doubt that the use of basic acetate is apt to give incomplete precipitation of alumina, and it is always liable to serious trouble in filtering, even when the greatest care is exercised.

In experiments tried on this point the filtrate from the silica was boiled, ammoniam chloride (25ccs. saturated sol.) added, then ammonia in slight excess, the solution heated for five minutes and filtered, washed twice with ammonium nitrate sol. (2 per cent.), dissolved in HCl, reprecipitated and filtered. The precipitate and paper was then returned to the beaker, in which precipitation took place, dissolved in HNO_3 (5 ccs. fort) diluted to 50 ccs., warmed and stirred well to break up the filter paper. It was then neutralised with ammonia in slight excess, boiled, filtered, and washed free from any chlorides with ammonium nitrate water. This was readily done, as but little chloride remains present. The precipitate was then ignited, and weighed in the crucible containing the residue from HF evaporation of the main precipitate of silica.

The results of the double duplicate for manganese are very satisfactory, showing the ammonia separation to be quite satisfactory. (See under "Manganese.")

The weighed precipitate containing the ashes from two filters was then fused with $KH\,SO_4$, and filtered. The intermixture of the first filter paper has the effect of keeping the precipitate finely divided, and renders the fusion a very quick one (about 15-20 minutes at most). In the ordinary course the Fe_2O_3 Al_2O_3 precipitate, when ignited, forms hard lumps, which require fusion for two or three hours. Formerly it was our custom to mix the ignited oxides with $KHSO_4$, and agate before fusion; but this is likely to be dangerous. The use of the filter paper overcomes this difficulty of fusion, and no trouble has been experienced in filtering. After ignition, the precipitate should be moistened with strong nitric acid and reignited. Complete reoxidation may not be effected, but the amount of error is so small that when the iron is less than 5 per cent. it may be neglected. With a high iron content it is safer to ignite the precipitate separately from the paper.

The melt from $KHSO_4$ fusion is taken up with hot water and 5 per cent. to 10 per cent. H_2SO_4, which is necessary to prevent precipitation of metatitanic acid. In this, as in all fusions, the greatest care should be exercised lest the platinum be injured. It is convenient to complete the fusion in the evening, and allow the crucible and melt to soak over night. Removal of the melt, by allowing it to solidify around Pt. rod or wire is very simple.

The silica recovered here is filtered, weighed, and evaporated with HF, and the amount added to the weight of the main lot. If only one evaporation has been used for SiO_2, as suggested, this may amount to ·0050, or more, as shown in tables I. and II.

Reduction of Iron.—Experiments have shown that reduction of the ferric iron by amalgamated zinc in contact with platinum gives almost as good results as reduction by H_2S. The zinc must, of course, be free from iron, and can generally be obtained so now. The objections to the zinc reduction are that vanadium, if present, is reduced to V_2O_3, and so will count as iron in the permanganate titration, and that titanium sulphate is also reduced, and the subsequent determination of that element interfered with.

If vanadium is present it will be reduced in either case, though the H_2S method will only produce the condition of V_2O_4, whilst with nascent hydrogen it will partially, if not entirely, reduce to V_2O_3 (Hillebrand).

Experiments were made with each method as follows:—Standard solutions of ferric iron (A) and titanium sulphate (B) were prepared, and titrated with standard $KMnO_4$ (1cc. = ·0050 Fe.).

TABLE III.

No.	Experiment.	Permanganate Required to Color.
1	25 ccs $TiSO_4$ sol. diluted to 200, and titrated direct ...	1 drop
2	25 ccs $TiSO_4$ boiled with Zn. Pt.	0.4 ccs
3	25 ccs $TiSO_4$ with H_2S gas passed and removed by CO_2	1 drop
4	50 ccs $Fe_2(SO_4)_3$ reduced by Zn Pt.	39.7 ccs
5	50 ccs $Fe_2(SO_4)_3$ reduced by H_2S..................	39.9 ccs
6	25 ccs $TiSO_4+50$ $Fe_2(SO_4)_3$ reduced by Zn Pt.	39.8 ccs
7	25 ccs $TiSO_4+50$ Fe $(SO_4)_3$ reduced by H_2S	39.9 ccs

In No. 2 the $TiSO_4$ solution was boiled just as long as No. 4 and No. 6, and a white precipitate appeared. This test is unnecessarily severe. In all cases ferric iron was tested for by NH_4CNS. The H_2S, after reduction, was boiled off under a current of CO_2, and tested for by lead acetate. The results would indicate that—(1) H_2S reduction appears to give a slightly higher value for iron (experiments 5 and 7); (2) H_2S does not reduce $TiSO_4$ to triad (experiment 3); (3) Zn Pt. does reduce $TiSO_4$ (experiment 2), but does not appear to have any great effect until all the iron is reduced (experiments 4 and 6).

In the analysis quoted (Table II.), the titanium results obtained by duplicates on each method of reduction of the iron were identical. The titanium solutions from the above tests were titrated colorimetrically, and no difference was found after reduction. The conclusion is that if desired the zinc reduction may be safely used as far as the small amount of titanium usually present is concerned, providing the iron is titrated as soon as it is reduced, as determined by NH_4CNS. The reduction by H_2S is, however, perfectly simple, and, if properly set up, is as quickly done as the zinc method. If the gas is passed into the hot solution, the platinum will readily come down, and should be filtered off. The H_2S must, of course, be completely removed by boiling under CO_2 before titration of the iron.

TITANIUM.—The TiO_2 is now easily estimated in the solution which has just been titrated for iron. It is necessary that this solution should have had at least 5 per cent. H_2SO_4 to prevent hydrolytic decomposition of the titanium sulphate into granular metatitanic acid. To the solution, after titration with $KMnO_4$, is added three-fifths ccs. hydrogen peroxide (free from F), and it is made up to 250 ccs.; 100 ccs. is measured into a Nessler tube, and the standard $TiSO_4$ (1cc. $=$ ·0005 TiO_2) is run into another tube containing 90 ccs. water and 2 ccs. H_2O_2, until colors almost agree. The blank is then made up nearly to 100, and the titration cautiously finished.

The results are excellent. Varying amounts of hydrogen peroxide, sulphuric acid, temperature or time of standing appear to have no effect. Presence of vanadium or molybdenum would interfere, counting as TiO_2, and the presence of fluorine in the H_2O_2 prevents wholly or in part the formation of the brown color.

ALUMINA.—From the weight of the mixed alumina, iron, &c., precipitate, the Fe_2O_3, SiO_2, TiO_2, P_2O_5, may now be deducted, and the Al_2O_3 determined by difference.

MANGANESE.—" A " solution (ammonia precipitation of iron, &c.). The combined filtrates from the alumina-iron precipitation were evaporated down and filtered, the small amount of Al_2O_3 recovered being added to the main precipitate. The solution was made acid with HCl boiled, ammonia added, and bromine water. The excess of this was then boiled off, and the solution digested for two hours on the hot plate. The manganese was filtered and weighed.

" B " solution (basic acetate separation). In these duplicates Hillebrand's method for manganese was closely followed, separating by sulphuretted hydrogen in ammoniacal solution, and finally precipitating with sodium carbonate.

TABLE IV.

Treatment.	Mn_3O_4.
A (Ammonia precipitation of iron, &c.)	1 .0016
Manganese by bromine	2 .0016
B Acetate precipitation of iron, &c.	1 .0019
Manganese by soda carb.	2 .0016

The complete analyses of this sample were made for the purpose of comparison in methods. The final results were as follows (Mr. Alan Hall) :—

TABLE V.

	A		B	
	1	2	1	2
SiO_2	51.62	51.66	51.48	51.20
Al_2O_3	16.45	16.08	16.34	16.52
Fe_2O_3	4.86	5.14	4.86*	5.14*
FeO	5.14	5.14	5.14	5.14
MgO	2.86	2.86	2.82	2.80
CaO	4.66	4.78	4.70	4.70
Na_2O	3.58	3.58	3.57	3.59
K_2O	3.39	3.39	3.43	3.41
H_2O+(above 110° C.)	1.62	1.63	1.62	1.63
H_2O–(110°)	1.90	1.87	1.90	1.87
CO_2	trace	trace	trace	trace
TiO_2	2.62	2.62	2.62	2.62
ZrO_2	n. d.	n. d.	n. d.	n. d.
P_2O_5	1.31	1.28	1.28	1.31
MnO	0.30	0.30	0.35	0.30
BaO	n. d.	n. d.	n. d.	n. d.
SrO	n. d.	n. d.	n. d.	n. d.
Li_2O	nil	nil	nil	nil
SO_3	nil	nil	nil	nil
Cl	trace	trace	trace	trace
	100.31	100.33	100.11	100.23

* Through an accident in reduction, the figures for total iron in the B analyses were unreliable, so in this case the figures from A were taken ; otherwise the results are quite independent. Three determinations were made of alkalies, the results as shown above being excellent.

PHOSPHORUS.—Hillebrand requires a fusion with alkali carbonate and removal of silica exactly as in the principal determination of SiO_2, except that nitric acid is used instead of HCl. Washington proposes, instead, to break up with nitric and hydrofluoric acids in platinum, to remove SiO_2 by evaporation and filtering, and to precipitate the P_2O_5 as molybdate in the usual manner.

Although no comparative tests have been made, good results have been obtained by careful digestion with *aqua regia*, evaporation to dryness with HNO_3, and direct precipitation in the filtrate with molybdate.

The more severe treatment is desirable, according to Washington, on account of inclusions of apatite, which would not be attacked by the ordinary treatment. If the preliminary agating of the sample is carefully done, this objection does not appear to hold. This point is under further investigation. Hillebrand does not agate his sample in preparation, and insists on a fusion.

FERROUS IRON.—Instead of the water-bath arrangement of Cooke, excellent results have been obtained by heating one gramme of sample in a large platinum crucible, with a well-fitting cover, with sulphuric acid (1-1) and hydrofluoric acid on a hot plate. After 10 minutes the crucible and contents are quietly dropped into a beaker of cold water, and titrated with $KmnO_4$ (1 cc. = ·0050 Fe). With care, perfectly satisfactory results are obtained without using Co_2. Thus, using one gramme of material with 10 ccs. H_2SO_4 (1-1) and 5 ccs. HF.

TABLE VI.

No.	Time Heated.	Conditions.	Permanganate Used.
1	7 min.	Without CO_2	7.95 ccs
2	7 min	do	8.00
3	7 min	Using CO_2.	8.00
4	15 min	do	8.00
5	20 min.	No CO_2	8.00

MOISTURE: LOSS BY IGNITION.—Experiments were made to test the error involved by the "loss on ignition" method, compared with Penfield's method. Hillebrand points out that it is unsafe to apply a correction on the assumption that all ferrous iron present has been oxidised. In the experiments made, this was not taken for granted; but, directly the crucible was weighed after ignition, the actual ferrous iron remaining was estimated as above shown, and the correction applied. The material worked on was a sandstone containing about 10 per cent. $CaCO_3$. The complete analysis is shown below. One gramme taken in a weighed platinum crucible and dried at 110° C. in air-bath till constant. Loss = moisture below 110° C(H_2O–).

The crucible was then treated over a Bunsen flame till weight was constant = total loss on ignition. The ferrous iron remaining was then quickly determined by moistening with water and treating with H_2SO_4 and HF, and titrating with permanganate. An amount equivalent to the gain through oxidation is determined by comparison with the original FeO figure, and this is added to the total loss on ignition.

The carbon dioxide is separately determined by the gravimetric method.

TABLE VII.

	1	2	
Total loss on ignition	.0868	.0863	
Correction (+) for FeO	.0050	.0050	Determined as above
	.0918	.0913	
Carbon dioxide	.0465	.0465	Separate estimation
Total water	.0453	.0448	
Water at 110° (H_2O-)	.0172	.0172	
Water above 110° (H_2O+)......	.0281	.0276	
Penfield's Method—			
(1) Total =................	.0471	.0460	
(2) Water at 110° =........	.0172	.0172	Figure obtained above
H_2O=................	.0299	..0288	

Average—

Ignition loss method	.0279
Penfield method..............	.0293

Any organic matter present would be included in the final figure, obtained by the ignition loss method. The chief ground of objection raised to this method is the influence of FeO and CO_2, and the above example shows that with the precaution suggested the results are quite good.

The complete analysis of the rock was as follows, viz. :—

TABLE VIII.

SiO_2	52.90 %
Al_2O_3	16.49
Fe_2O_3	0.78
FeO	4.86
MgO	2.92
CaO	7.14
Na_2O	2.58
K_2O	1.73
H_2O+	2.79
H_2O-	1.72
CO_2	4.65
TiO_2..................................	1.10
MnO	trace
Li_2O..................................	n. d.
P_2O_5	0.25
SO_3	nil
Cl	trace
	99.91 %

In the remaining determinations the methods given by Hillebrand, Washington, or Treadwell Hall are followed as closely as possible.

Instead of analyses being made in duplicate, a satisfactory plan to adopt for safe work is for single analyses to be made by two men, and a comparison made. Any serious discrepancy should be checked by repeating. The figures finally chosen, should, however, be those of one analyst—at any rate for each group of determinations.

The variations suggested in this paper have been arrived at only after a long series of analyses worked as closely as possible on the lines laid down by the authorities quoted. No one can deny but that the care and exactness with which a master such as Hillebrand has arrived at his conclusions are worth the closest consideration of any chemist desirous of turning out the best work in the analysis of rocks. The modifications suggested are intended to simplify some of the operations involved, and it is thought that the results obtained are quite within the limits of experimental error.

It is much to be desired that an organised classification of the igneous rocks of Australia should be instituted on the lines adopted by the Geological Survey of U.S.A., and this could be done by the individual chemists of each State, if opportunity were made. But it is surely necessary at the outset in this, as in any independent work which is intended for comparison with other similar work, that a uniformity of method should be adopted which would render such a comparison of the greatest real value.

In the closer sympathy and co-operation which, with the development of Commonwealth ideals, must surely come into scientific work earliest of any, the agreement upon a standard plan of action is surely the first thing to be desired. A Congress such as this, with the record of those that have preceded it, is the best guarantee that such an agreement between analysts in each State would be heartily welcomed. Even if it were not convenient for any particular State to take up its own share at once, it would always be ready to hand, and, under standard conditions, the work of any accredited analyst would always be acceptable for inclusion in the general scheme. In the Geological Survey of Victoria the organised analysis of the igneous rocks of that State has been in operation for several years, and the results are shortly to be issued as a bulletin. Unfortunately, it has not been possible to set apart a definite portion of the staff for this work. This is the most satisfactory manner of conducting such an examination.

I would like here to acknowledge the valuable help and co-operation afforded by Mr. Alan G. Hall, of the Mines Department laboratory, in the preparation of experiments for this paper.

In the ultimate collection and arrangement of the results from different sources much uncertainty would be avoided if the exact value of available analyses could be determined, and this is only possible if the methods adopted and precaution observed are those upon which an agreement has been arrived at and a satisfactory standard fixed.

2.—THE TECHNICAL EXAMINATION OF BOILER WATERS.

By W. A. HARGREAVES, M.A., F.I.C., and W. T. ROWE.

The quantity of literature upon this subject is so great that some apology would seem necessary for further increasing it, but it is chiefly on account of this very abundance that it is advisable now and again to attempt to compile brief methods embodying the results of the researches of others. No originality is therefore claimed for any of the details about to be set out, nor even for the general principles contained in the method. All that we state is that a working scheme has been evolved based on the suggestions of others too numerous to individually acknowledge, which appears, so far as our experience goes, to be an improvement on any methods that we have seen published.

In this country, where so many raw waters previously untested or analysed have to be taken into use, much of the work of the analyst is of a pioneering nature, and it is necessary that he should make a large number of rapid examinations rather than detailed analyses of a few samples made with the greatest accuracy possible.

The following scheme will be found to permit of these fairly rapid examinations being made with an accuracy very closely approximating to that given by a detailed analysis by ordinary methods.

SCHEME FOR ANALYSIS OF SALTS IN BOILER WATERS.

Determine the following:—

1. *Alkalinity* (= A), by titrating 70c.c. of the sample with $N/_{10}$ HCl. and methyl orange.—Let a c.c. be required.

Then A (*i.e.* alkalinity) = 5a
= Ht. + Na_2CO_3 (in terms of $CaCO_3$)
= total CO_3 (in terms of $CaCO_3$)

Permanent Hardness (= Hp).—Boil 70c.c. of the water with considerable excess (*i.e.*, at least 30c.c. in one and 40c.c. in the duplicate) of $N/_{10}$ Na_2CO_3 for half an hour (or until reduced to small bulk), filter while hot, wash three times (not more) with boiled hot distilled water, titrate filtrate with $N/_{10}$ HCl. and methyl orange.

Let N be the quantity of $N/_{10}$ Na_2CO_3 taken, and n c.c. $N/_{10}$ HCl be used in the titration. Then Hp = 5 (N − n), and Total Hardness = H = Hp + A (*i.e.* the algebraical sum) and Temporary Hardness = Ht = H − Hp.

If the water contains Na_2CO_3, the Hp. will be a minus quantity, and its amount represents the Na_2CO_3 in terms of $Ca.CO_3$. If the Hp is zero or a positive quantity, there is no Na_2CO_3 in the water, and then A = Ht.

Hardness due to Calcium (= Hca).—Boil 350c.c. of sample with few drops HNO_3; then add about 0·5 gramme of AmCl, make alkaline with ammonia, and boil; then add boiling solution of ammonium oxalate; filter; wash with boiling distilled water till free from oxalates; prick the filter; dissolve the ppt. with hot dilute H_2SO_4; boil solution, and titrate hot with $KMnO_4 N/_{10}$ sol.

Let C be number of c.c.'s required.

Then Hca = C.

And hardness due to magnesium = Hmg = H — Hca.

4. *Chlorine.*—Determine in the usual way—by titrating 70c.c. of sample with standard $AgNO_3$ (4·7888 grammes per litre) and $K_2Cr_2O_7$.

Let S = number of c.c.'s required.

S × 1·408 = Cl in terms $CaCO_3$ per gallon.

5. *Sulphates.*—Determine as usual, by precipitation with $BaCl_2$, using 350c.c. of sample.

Mgms of $BaSO_4$ from 70c.c. of sample × 0·4285 = SO_4 in terms of $CaCO_3$ per gallon.

6. *Total Solids.*—Evaporate 70c.c. in platinum dish on asbestos pad over low flame burner to dryness; bake in air oven 150°C.

This is the whole of the laboratory work required for the calculation of the assumed composition of the total solids. For all practical purposes only determinations 1, 2, and 3 need be made, and from these three alone suitable treatment can be calculated thus:—

I. Using CaO and Na_2CO_3—

1. 0·56 × (Ht + Hmg) = lbs. of real CaO required per 7,000 gallons of sample.
2. 1·06 × Hp = lbs. of real dry Na_2CO_3 required per 7,000 gallons of sample.

II. Using NaOH and Na_2CO_3—

1. 0·8 × (Ht + Hmg) = lbs. of NaOH required per 7,000 gallons of sample.
2. 1·06 × [Hp — (Ht + Hmg)] = lbs. of dry Na_2CO_3 required per 7,000 gallons of sample.

The treated water can be quickly examined by determinations 1, 2, and 3, and the water treatment readily controlled.

Calculation of Total Solids.—For purposes of report or comparison with other analyses, it may be desirable to set out the composition of the salts. For this, determinations of 4, 5, and 6 are required in addition to the first three. Although the bases and acids are probably not combined as salts in the water, still it is usual to calculate the composition of the total solids upon some assumption as to the preference of certain basic ions for certain acid ions. Two assumptions present themselves, namely—either that the acid ions should be allotted to the basic ions in sequence (as chlorine to sodium, potassium, magnesium, and calcium in succession, then CO_3 and SO_4 allotted in turn), or else the basic ions are distributed to the acid ions in succession. For many reasons we adopt the latter, and the results seem more in accord with those shown by the method of analysis stated above.

Our ideas are concentrated by the following arrangement, with example taken from an actual case:—

$\left.\begin{matrix} CaCO_3 \\ MgCO_3 \\ Na_2CO_3 \end{matrix}\right\}$ = A = 19 .... In terms of $CaCO_3$ per gallon

Na_2CO_3 = (– Hp) = nil .... do.

$\left.\begin{matrix} CaCO_3 \\ MgCO_3 \end{matrix}\right\}$ = Ht = 19 .... do.

$\left.\begin{matrix} CaCl_2 \\ CaSO_4 \\ MgCl_2 \\ MgSO_4 \end{matrix}\right\}$ = Hp = 15 .... do.

$\left.\begin{matrix} CaCO_3 \\ CaCl_2 \\ CaSO_4 \end{matrix}\right\}$ = Hca = 12 .... do.

$\left.\begin{matrix} MgCO_3 \\ MgCl_2 \\ MgSO_4 \end{matrix}\right\}$ = Hmg = 22 .... do.

Total Hardness = H = 34............ do.

Chlorine = 62·38 .... do.

SO_4 = 12·14 .... do.

Total Solids = 113·2 .... do.

All results are stated in equivalent terms of grains of $CaCO_3$ per gallon, and this statement is maintained throughout the calculation until the final conversion to actual quantities is made. This method has the very great advantage of reducing the labor of the calculations to a minimum, most of the work consisting merely of subtraction and addition. Assuming then that the calcium combines first with the CO_3, then with SO_4, and lastly with chlorine, that magnesium combines with the acids in the same order, but following calcium, and that the alkali metals pursue an opposite order (except that we know whether Na_2CO_3 is present or absent), we note in the example that since the Hca is less than Ht, all Ca exists as $CaCO_3$, and there is no $CaCl_2$ or $CaSO_4$, and since the Hmg is greater than the SO_4, all the SO_4 is combined with Mg, and there is no Na_2SO_4.

We get, then, the following:—

	Expressed in Equivalent Grains of $CaCO_3$ per Gallon.	Actual Quantities in Grains per Gallon.
$CaCO_3$	12·0	12·0
$MgCO_3$	7·0	5·91
Na_2CO_3	nil	nil
$CaCl_2$	nil	nil
$CaSO_4$	nil	nil
$MgCl_2$	2·86	2·73
$MgSO_4$	12·14	14·62
Na_2SO_4	nil	nil
NaCl..................	59·52	69·63

The conversion to actual quantities shown in the last column is made by using the following factors:—

	Factor.	Logarithm.		Factor.	Logarithm.
$CaCO_3$ into $MgCO_3$ ..	0·844	$\bar{1}$·9263	$MgCO_3$ into $CaCO_3$ ..	1·1850	·0737
“ “ $CaSO_4$ ..	1·360	·1335	$CaSO_4$ “ “ ..	0·7353	$\bar{1}$·8665
“ “ $CaCl_2$ ..	1·110	·0453	$CaCl_2$ “ “ ..	0·9010	$\bar{1}$·9547
“ “ $MgSO_4$ ..	1·204	·0806	$MgSO_4$ “ “ ..	0·8307	$\bar{1}$·9194
“ “ $MgCl_2$.	0·954	$\bar{1}$·9795	$MgCl_2$ “ “ ..	1·0480	·0205
“ “ Na_2CO_3 .	1·060	·0253	Na_2CO_3 “ “ ..	0·9434	$\bar{1}$·9747
“ “ Ca	0·400	$\bar{1}$·6021	Ca “ “ ..	2·5000	·3979
“ “ Mg.. ..	0·244	$\bar{1}$·3874	Mg “ “ ..	4·0990	·6126
“ “ SO_4 ..	0·960	$\bar{1}$·9823	SO_4 “ “ ..	1·0420	·0177
“ “ Cl_2 ..	0·710	$\bar{1}$·8513	Cl_2 “ “ ..	1·4080	·1487
“ “ CO_3 ..	0·600	1·7782	CO_3 “ “ ..	1·6660	·2217
“ “ 2NaCl ..	1·170	·0682	2NaCl “ “ ..	0·8547	$\bar{1}$·9318
“ “ $BaSO_4$ ..	2·334	·3681	$BaSO_4$ “ “ ..	0·4285	$\bar{1}$·6319
“ “ Na_2SO_4 .	1·420	·1523	Na_2SO_4 “ “ ..	0·7042	$\bar{1}$·8477
$BaSO_4$ “ SO_4 ..	0·4115	$\bar{1}$·6144	SO_4 “ $BaSO_4$..	2·4300	·3856

As a check upon the method an analysis may be made by any of the older methods. So far as boiler waters are concerned, the crucial test is in the magnesium. In the example quoted the magnesium, as directly determined, was 5·31, while the result obtained by calculation from the Hmg = 22 × ·244 = 5·37.

Notes.—In selecting this mode of analysis a large number of suggestions were experimented upon. For instance, the total hardness may be obtained directly by making the titration in determination 1 to *exact* neutrality, boiling off the CO_2, adding excess of $N/_{10}Na_2CO_3$, and continuing as in determination 2. In this case the total hardness = 5 (N — n). This may be used as a check on the other determinations. Again, it has been suggested to determine the Hmg directly by means of lime water; but this, and a scheme for treatment calculations based upon a lime factor in which lime water is used, failed to give satisfactory results in practice. These were not abandoned without regret, for they seemed very promising and appeared to further simplify the analysis.

Slight modifications in detail have been tested. The only ones, however, that we found equally as satisfactory as the method to which preference has been given are in determination 2. These modifications are—

(*a*) Boil 140c.c. of the water with considerable excess (*i.e.*, at least 60c.c. in one and 80c.c. in the other) of $N/_{10}Na_2CO_3$, for half an hour or) until reduced to small bulk); cool, and transfer to 200c.c. flask and make to mark with cold recently boiled distilled water; mix thoroughly and filter through a dry filter, rejecting the first portion of filtrate; draw off 100c.c. of filtrate (= 70c.c. of original water) and titrate with $N/_{10}HCl$ and methyl orange. This method, although apparently quicker than the way chosen, in practice occupies much more time and attention. It is, however, somewhat more accurate, since if in determination 2 the ppt. is not washed free of Na_2CO_3, low results will be obtained, and if it is washed too much a sufficient amount of the precipitated carbonates will be dissolved to vitiate the results. If three and not more washings are made in following out determination 2, the results are practically correct. On account of the quicker and simpler work required, this way has been given the preference.

(*b*) The other modification is to use a mixture containing equal volumes of $N/_{10}NaOH$ and $N/_{10}Na_2CO_3$ ("soda reagent") in place of the $N/_{10}Na_2CO_3$. So far as our experience goes there is no practical advantage in this, provided a considerable excess of $N/_{10}Na_2CO_3$ is used in determination 2. This has been confirmed by Gardner & Lloyd (J.S.C.I., April, 1905).

If only a slight excess is used the $MgCO_3$ is not fully precipitated, and erroneous results are obtained. The "soda reagent" has apparently the advantage that it represents more nearly the action which will take place in the actual softening treatment of the water, but this in practice does not render the determination any more accurate. Careful tests made with both yielded agreeing results, so that either reagent may be used in determining the permanent hardness. Jena, or resistance glass vessels, should be used in this determination to reduce the action on the soda, and this is especially necessary in the case of the mixed "soda reagent" being used.

The method of analysis here outlined possesses many advantages over the older methods, in that a water can be tested with less labor, in less time, and at less cost of materials; and further than this—more practical information as to the character of the water is obtained than by the more usual method of determining the bases and acids independently and calculating the salts. The method is therefore worthy of attention by those who are called upon to make technical examinations of boiler waters.

3.—THE FLASH POINT OF KEROSINE.

By W. A. HARGREAVES and W. T. ROWE.

In examining kerosine one of the principal tests is to ascertain the temperature at which it gives off inflammable vapor. There are several methods in use which indicate this temperature, but the method officially adopted in most countries is to heat the oil in a closed vessel and apply a light to the imprisoned vapor on top of the oil.

An instrument devised by Sir Frederick Abel is described in the British Petroleum Act, 1879, and a method of using it is prescribed. This is, therefore, the legal method of testing kerosine in Great Britain. This test was adopted in Australia, and was in force up to November, 1904, when a proclamation was issued by the Governor-General prescribing the "Abel-Pensky" test, which is a modification of the British one. A detailed specification of this test is set out in the schedule to this proclamation. The important point of difference between this and the British test consists in the fact that whereas, in the British test, the ordinary hand slide is used, in the Australian test a clockwork arrangement (known as the Pensky apparatus) replaces the slide, but it is to be adjusted "so as to give the same results as the Abel standard."

The directions for preparing and using the test apparatus prescribed are carefully set out in both instances, but they apply only to kerosine flashing at or about 73° F. For oils of a higher flash-point no instructions are given in the Australian proclamation; but in the British test it is provided that if it is desired to employ the test apparatus the procedure is to be modified as follows:—

The air chamber which surrounds the cup is filled with cold water to a depth of 1½in., and the heating vessel or water bath is filled as usual, but also with cold water. The lamp is then placed under the apparatus, and kept there during the entire operation. If a very heavy oil is being dealt with, the operation may be commenced with water previously heated to 120°, instead of with cold water.

Where only one test is to be made, this method is simple enough; but when a number of tests are to be made at one time it is clumsy, and, in order to devise a method which will facilitate the labor and shorten the time without vitiating the results, experiments were made, which are detailed in tables A, B, C, D, E, and F.

All these tests were made with American kerosine, known as "White Rose" oil, which is the ordinary kerosine used in household lamps.

In table A the British directions are followed, except that the Pensky slide is used, the White Rose oil being regarded as an oil of low volatility; while in table B a similar set of tests are shown, with the difference that no water is placed in the air chamber. It will be seen that the flash-points obtained range from 105° to 109°, with the average 106°·4 in table A, and from 104° to 108° with average 105°·6 in table B, so that so far as this oil is concerned practically no difference results from leaving the water out of the air chamber. As this reduces the labor in making successive tests, the water was omitted from the air chamber in subsequent tests, for although the actual duration of the test when water is used, as in table A, is less than that shown in table B, the saving in time is more than compensated for by the fact that the temperature rises too rapidly, and greater care is required in testing to prevent the results obtained being too high.

In tables C and D a modification is introduced to avoid the necessity of waiting for the water bath to cool down, or of emptying it and refilling with cold water. This modification follows the principle of the prescribed test for oil of 73° flash-point, in that the temperature of the water bath at the time the oil cup is inserted is arranged so as to give a result without having the burner going during the test. In table C the temperature chosen is 180°, and in table D it is 160°, and the tables show that this variation does not materially affect the flash-points, and further they show that the results are comparable with those obtained in following the British method (of tables A and B), where the bath is heated throughout the test, starting all cold. It follows, therefore, that the test may be begun with the water bath at any temperature between 160° and 180° when testing this kerosine. As time is saved by heating the bath to 160° F. only, this temperature was adopted in the succeeding tests.

Throughout these tests (tables A, B, C, and D) it will be seen that the flash-points obtained are not too satisfactory, for although the averages 106°·4, 105°·6, 105°·3, and 106°·1 are concordant, the individual tests range from 104° to 109°, and this in spite of the greatest care taken by experienced operators.

It occurred to us, therefore, that the fault was in the Pensky slide, and an investigation of three of these attachments disclosed the facts that they did not agree amongst themselves, and that they all differed materially from the ordinary hand slide with respect to the times of opening and closing the port holes in the oil cup cover.

The Abel apparatus described by the British Petroleum Act, 1879, defines the nature of the slide to be used, and the instructions state that the slide is to be slowly and regularly opened during three swings of a pendulum of 24in. in length and quickly closed at the fourth swing. The whole opening and closing occupies, therefore, a total of 3·1416 seconds of time. Now, the Pensky clockwork attachment, which is prescribed in Germany, occupies only two seconds, and the variation of time allowed for the slide movement is 0·2 second over or under the prescribed standard.

Three of these Pensky slides, which are supposed to be standard attachments, were timed and found to take 2·4, 2·4, and 2·6 seconds respectively, thus agreeing neither with the German prescription nor with the Australian one, which requires them to be adjusted "so as to give the same results as the Abel standard."

That this difference in time is material is shown by a comparison of tables D and E, from which it will be seen that while the Pensky slide, having a time of 2·4 seconds, gives an average of 106°·1 as the flash-point, the ordinary slide, having 3·1 seconds, gives an average of 102°·8, or 3° lower. Further than this, the individual tests made with the hand slide agree amongst themselves, whereas with the Pensky slide a difference of 5° between the lowest and highest tests is shown.

One of the Pensky slides was altered so as to lengthen the time of operation. It was found impossible to make it take three seconds without rebuilding the whole apparatus; but by increasing the length of the cam the time was increased to 2·8 seconds.

A series of tests with this altered slide were made (table F), which shows that the average test is now reduced to 104°·2, and the individual tests agree rather better amongst themselves. Probably if the time could be made the same as in the Abel tests the results would be closer to those shown in table E; but, as the arrangement of the port holes is on the circumference of a circle, instead of being in a straight line, the Pensky slide could probably never be adjusted to give exactly the same results as the Abel standard. We have devised an attachment which we anticipate will agree with the Abel slide, but have not yet had an opportunity of perfecting the arrangement and testing it.

From what we have shown in these tests, it is evident that the Pensky clockwork attachment does not give results which are the same as those of the Abel standard, and therefore the specification of the "Abel-Pensky" test apparatus set out in the schedule to the proclamation as the standard for the purposes of the Commonwealth Customs Act, 1901, cannot be complied with.

In table G we have extended the principle of starting the testing of kerosine with the water bath heated to a definite temperature to other kerosines. This table is based upon a very large number of tests made from time to time for years past upon kerosines of different flash-points, details of which are not here included. This table, which is calculated to give results comparable with those obtained by starting all cold, will be found useful by those who have a large number of tests to make at one time.

In studying this question the remarkable fact was found that very few of the Abel instruments on the market are made strictly in accordance with the specifications prescribed. Not only do the instruments err in dimensions of the several parts, but in most cases the gauge of material to be used, although carefully specified, is not adhered to by manufacturers. This discrepancy was seen in several instruments which were stamped correct by the Board of Trade, and on investigation we found the further remarkable fact that in the directions to manufacturers distributed by the Board of Trade no reference is made to the gauge of material to be used.

As variations in gauge or dimensions do, as we have proved, seriously affect the flash-points obtained, it is well for us to give a note of warning, and advise all who may have to test kerosine to see that the instrument used complies in every way with the prescribed specification.

TABLES A TO F.

Table.	1 Water in Inner Bath or Not.	2 Temp. of Oil when Cup Inserted.	3 Temp. of Oil at Starting to Test.	4 Temp. of Bath when Oil Cup Inserted.	5 Temp. of Bath when Starting to Test.	6 Temp of Bath at Flash Point.	7 Time Required from Inserting Cup to Starting to Test.	8 Time from Starting to Flash-point.	9 Duration of Test.	10 Temp. of Flash-point.	Remarks.
							Min.	Min.	Min.		
A	Yes	69	95	cold	115	127	12½	14	1½	106	Pensky slide used
	Yes	74	95	cold	117	128	9	11½	2½	106	
	Yes	74	95	cold	116	130	9½	12½	3	109	
	Yes	76	95	cold	115	127	9¼	12	2¾	106	
	Yes	77	95	cold	115	123	8	11	3	105	
									Average	=106·4	
B	No	78	95	cold	137	159	14	19	5	108	Pensky slide used
	No	78	95	cold	137	155	13½	18	4½	105	
	No	79	95	cold	135	157	12	17½	5½	106	
	No	79	95	cold	142	160	14½	18½	4	105	
	No	67	95	cold	157	170	20	24	4	104	
									Average	=105·6	
C	No	66	95	180	177	174½	7	10¾	3¾	107	Pensky slide used; bar. = 30.15.
	No	72	95	180	177	175	4½	8½	4	108	
	No	72	95	180	177	175	5½	8¾	3¼	105	
	No	71	95	180	177	175	5½	8½	3	104	
	No	72	95	180	177	176	5¼	8	2¾	104	
	No	71	95	180	177	176	5¼	8	2¾	104	
									Average	=105·3	
D	No	71	95	160	155	154	6½	10½	4	104	Pensky slide used; bar. = 30·15.
	No	75	95	160	157	157	6½	10¼	3¾	104	
	No	66	95	160	158	155	9	14	5	108	
	No	67	95	160	157	154	8½	14	5½	106	
	No	69	95	160	157	154	8	13½	5½	106	Pensky slide used; bar. = 29·90.
	No	66	95	160	155	150	9	15	6	106	
	No	70	95	160	156	153	8¾	14½	5¾	106	
	No	69	95	160	156	153	8¼	15	6¾	109	
									Average	=106·1	
E	No	66	95	160	155	153	8¾	12¼	3½	103	Ordinary hand slide used; bar. = 30·0.
	No	70	95	160	154	152	7¾	11¼	3½	103	
	No	73	95	160	157	155	7	10	3	103	
	No	70	95	160	157	155	8	11½	3½	103	
	No	72	95	160	157	155	7½	10¾	3¼	103	
	No	72	95	160	158	156	7½	10½	3	103	Ordinary hand slide used; bar. = 29·65.
	No	77	95	160	159	157½	7	10	3	103	
	No	73	95	160	159	157	7¼	10¼	3	103	
	No	74	95	160	158	156	6¾	9¼	2½	102	
	No	75	95	160	157	156	6¾	9½	2¾	102	
									Average	=102·8	
F	No	70	95	160	158	156	7	10½	3½	103	Altered Pensky slide used; bar. = 30·29.
	No	75	95	160	158	156	6	10	4	104	
	No	75	95	160	157½	156	6	10¼	4¼	105	
	No	74	95	160	158	156	6	10¼	4¼	105	
	No	74	95	160	156½	154½	8½	13¼	4¾	105	
	No	77	95	160	158	156	6	11	5	106	
	No	77	95	160	157½	156	5¾	10	4¼	105	
	No	77	95	160	158	156	5	9	4	104	
	No	76	95	160	158	156	6	9½	3½	104	
	No	78	95	160	157½	157	5	8	3	104	
	No	82	95	160	157½	156	4¾	8	3¼	104	
	No	76	95	160	157	156	6	10	4	104	
	No	80	95	160	158	157	5	8	3	102	
									Average	=104·2	

TABLE G.

Expected Flash-point.	Temp. of Water Bath.	Air Chamber.	Oil Cup to be Cooled when Necessary to Tempt. not Exceeding—	Start Testing at or Below.
Under 73° F.	130°	No water	50° or lower, and oil to be cooled to 50° or lower.	56° or lower
73°	130°	No water	60°	63°
83°	145°	No water	70°	73°
100°	160°	No water	85°	90°
115°	140°	1½″ cold water	100°	105°
125°	150°	1½″ cold water	110°	115°
135°	160°	1½″ cold water	120°	125°
150°	180°	1½″ cold water	135°	140°

4.—THE ANALYST AND THE COMMERCE ACT.

[ABSTRACT.]

By W. A. HARGREAVES, M.A., F.I.C.

The "Commerce (Trade Descriptions) Act, 1905," introduces new legislation respecting the supervision and examination of foods, drugs, wearing apparel, etc., with the purpose of protecting honest traders from unfair competition, of protecting the public from dishonest dealers, and of building up a reputation for Australian exports. The essential features of this Act are that merchants shall state what they sell and sell what they state, that, as far as practicable, all goods offered for sale shall be called by their real names, and that whatever descriptions are applied to them shall be true in every particular. This Act applies, however, only to imported and exported goods, and, to make it effective, it needs to be supplemented by State legislation on similar lines. Such legislation wisely administered would be superior to the present kind modelled upon the "Sale of Food and Drugs Act," although the latter would be enormously increased in value by the addition of a section similar to that contained in "The Fertilisers Act, 1900," of South Australia, which authorises the publication in the daily newspapers of the particulars contained in the analyst's certificate.

By the Commerce Act a very great responsibility is placed upon the analyst, which indicates the need of the adoption of standards of food, drugs, &c., and of accuracy of chemical work, and, further, it shows that an association of analysts is almost a necessity.

With the adoption of State legislation in accord with the Commerce Act, the practical work of giving effect to such is a question more for the chemist than for the health officer. It is to the analyst that both producers and public will look for assistance, not only on matters of detail, but, to an increasing extent, on questions of administration.

5.—NOTES ON FODDER ANALYSIS.

By J. C. BRUNNICH, F.I.C., and FRANK SMITH, B.Sc.

[ABSTRACT.]

It has, in the course of work on fodder materials, seemed to us desirable to adopt a simple scheme of analysis that will provide a wider basis of comparison of nutritive values than that based upon the usual determinations of moisture, crude fat, ash, protein, crude fibre, and nitrogen free extract (by difference), and especially to render a more precise account of those substances generally grouped under the last head.

W. E. Stone (J. Amer. S.C., 1897, XIX., 183-197 and 347-349) extracts successively with (1) boiling alcohol, (2) cold water, (3) diastase, (4) boiling dilute hydrochloric acid, (5) boiling 1·25 per cent. caustic soda solution, and obtains a residue of crude fibre. Since this method gave only 7·18 per cent. pentosan in a sample of hay, a class of substance yielding approximately 20 per cent. by the approved Phlorogluein method, and since the fibre of the author must necessarily be contaminated by furfurol-yielding substances, it was not deemed suitable for dealing with food materials very rich in pentosan and cellulose bodies.

Brown and Beistle (J. Amer. C.S., 1901, XXIII., 229) contend that the older methods of procedure, while sufficient for many purposes, are by no means scientifically accurate, and urge that a closer study be made of the nitrogen free extract. The scheme set forth by them comprises successive extractions with (1) anhydrous ether, (2) 95 per cent. alcohol, (3) cold water, (4) diastase solution, (5) dilute acid and alkali and chlorination and alkali treatment, and examination of the extracts.

They thus directly estimate crude fat, sugars, dextri , starch, lignic acids, lignin, cellulose, pentosans, protein, and ash, with gums indirectly. They also show that the solvents employed dissolve pentose bodies, which pass to some extent into the aqueous and diastase extracts, and further admit that their cellulose contains a furfurol-yielding body, possibly of an oxy-cellulose nature. This method, as well as that of P. Schweitzer (J. Amer. C.S., 1904, XXVI., 252), who differentiates the carbohydrates present in feeding stuffs into pure fibre, fibro-pentosan, pectose, pecto-pentosan, sugar, starch, and "indefinite carbohydrates," has not recommended itself, and it has been the custom in our laboratory to make the following determinations :—Moisture, true protein (soluble and insoluble in water), crude fibre (König), pentosans, "starch," carbohydrates (soluble in water), crude fat, ash, total matter soluble in water, soluble ash, and amides, chlorophyll, &c., by difference.

Preparation of the Sample.—It is rarely possible to carry out the analysis on the material in the fresh-cut condition, and it has, therefore, been customary to deal with it in the air-dry state—a condition approximating to that of natural hay. The analysis is done on the material ground to uniform fineness, and passed through a 1 m.m. mesh sieve.

The Determination of Moisture.—We have considered it sufficient for practical purposes to dry in the steam oven at 98°-99° C.

The Determination of Protein.—The total nitrogen is determined by the Kjeldahl method, and the "true proteid nitrogen" by Stutzer's cupric-hydrate method. The water soluble nitrogen is also determined, and the soluble and insoluble protein calculated, by the use of the factor 6·25. We consider, on account of their wide variation in amount at different stages of plant growth, and their inferior food value, the determination of amides is of considerable importance.

The Determination of Crude Fibre.—The method of König (Zeit. für Untersuch der Nahrungs-und Genussmilttel, I., 3-16, Abstr. Analyst, 1898, XXIII., 47) for the determination of crude fibre has found wide acceptance among European chemists, and has been largely used by us. According to König, a body consisting of cellulose and lignin, and practically free from pentosans, is obtained, though it is slightly richer in nitrogen than the fibre of the Henneberg (acid-alkali) process. This is, however, of little consequence in materials poor in nitrogen, and we have found the amount of contained pentosans to be negligible.

The method has been unfavorably criticised by American chemists (Nineteenth Annual Convention, A.O.A.C., 1903, Referee's Report on Cattle Feeds) on account of its slow filtering and variation in duplicates. We prefer to filter through a layer of glass-wool with suction, and, provided the material be kept off the filter till well washed, no special difficulty has been experienced. Duplicates agree within 1 per cent. The method is recommended as giving an estimate, practically free of pentosan, of the least valuable portion of feeding materials. Since pentosans are separately determined, this is to be commended. In treatment of materials rich in protein we would suggest the further digestion of the fibre with dilute alkali for the removal of residual protein which König has shown may amount to between 1 per cent. and 2 per cent. Or an estimation of the contained nitrogen may be made and correction of the percentage of crude fibre. In our work this refinement has not been introduced. Determinations of crude fibre in a number of fodder materials by acid-alkali and König methods follow in table II.

The Determination of Pentosans.—We employ the method of Tollens, as modified by Kröber and Rimbach (Abstr. Analyst, 1902, p. 279). This method has been found so satisfactory that no trial has been made of the recent method of A. Jolles (Abstr. Analyst, May, 1906, p. 163), in which the furfurol is volumetrically estimated by titration with sodium bi-sulphite solution.

The Determination of Starch.—It had been our custom to determine the starch in fodder materials by the method of Maercker and Morgan, as for grain (König: Untersuchung landwertshaft-licker Stoffe, p. 221), the determination generally being carried out on the material without previous extraction of the existing sugars, for which allowance was made in the starch figure obtained. In spite of the contention of Sherman (School of Mines Quarterly, 1896, XVII., 356–365, Abstr.

Analyst, 1897, p. 19), that the method of Maercker gives results comparable with those of the diastase method, we have come to consider it quite unsuitable for the estimation of "true" starch in grasses and like materials. The susceptibility of pentosans and hemi-celluloses to hydrolysis with the formation of reducing bodies has been noticed by Krug and Wiley (J. Amer. C.S., 1898, xx., 266-268). O. Lietz (Abstr. Analyst, 1903, p. 150) states of a variety of methods, including digestion under pressure, that none give accurate results, owing to hydrolysis of pentosans. The influence of the presence of pentosans upon the estimation of starch by Maercker and Morgan's method is undoubted. That these bodies are rendered soluble is shown by the fact that the residues from the autoclave of two grasses (*Astrebla pectinata* and *Panicum jubiflorum*), themselves containing respectively 20·52 per cent. and 20·32 per cent. pentosans, yielded only 7·96 per cent. and 7·98 per cent. The method described by Lietz (*loc. cit.*) has not invariable given lower starch percentages. If the pentosans are unaffected by the solutions employed it is evident that substances of cellulose nature are brought into solution, and are reckoned as "true" starch. No test of the author's contention as to the non-interference of pentosans has been made by us. A short experiment was carried out upon a sample of corn-cob husk, previously washed to remove water-soluble material. A qualitative examination led us to believe that the amount of starch present was very small. Determinations of starch were made in this substance by autoclave digestion at 5-6 kgm. per sq. cm.; 2-3 kgm. per sq. cm. by Lietz's method, and by the method of Wilforth, as given in "Researches on the Assimilation of the Elements of Nutrition of Plants during different Periods of their Growth" (translated by Emslie: Vinton & Co., London, 1905). We consider this last identical with the diastase method referred to by other chemists. The starch percentages by the different methods, together with the percentage of pentosan found in the autoclave or diastase extracts, and which would be estimated as starch, are herewith given.

	Starch.	Pentosan.
Maercker and Morgan—Autoclave 5-6 kgm.	28·15	19·86
" " 2-3 kgm.	13·26	9·95
Lietz method	25·57	—
Wilforth—Diastase extraction	1·12	trace

The sample of husk itself was found to contain 37·83 per cent. pentosan and 29·50 per cent. crude fibre (König).

We conclude that the diastase method gives the most correct estimate of the "true" starch in plant substances of the class dealt with. In view, however, of the possible close approximation in nutritive value to starch of the substances soluble under the conditions of the Maercker-Morgan method, we would tentatively recommend its provisional adoption, and the estimation of all substances behaving similarly to starch under well-defined conditions as such.

Determination of Water Soluble Constituents.—From the determination of extractives, which are considered the most rapidly assimilable portion of a feeding stuff, we would form some estimate of its palatability and stimulating properties. To obtain an aqueous extract, we adhere to the following procedure:—Twenty grms. of the sample are allowed to stand with 50-100 ccs. water overnight. A few drops of chloroform may be added to prevent fermentation. Shake frequently, decant off, repeat operation, adding water, and decant again. Finally digest in water bath for one hour, and after cooling add to previous extracts, making up to 500 ce. Determine in aliquot parts—(1) total soluble matters; (2) total soluble ash; (3) soluble nitrogen; (4) soluble carbohydrates after inversion.

In the case of very starchy substances the digestion may be omitted, as it is difficult in this way to obtain a clear solution. Extraction of the soluble carbohydrates of two samples of grass—*Astrebla pectinata* and *Panicum jubiflorum*—with alcohol and water gave the following results:—

	Astrebla pectinata.		*Panicum jubiflorum.*
Invert sugar	2·95 per cent.		2·57 per cent.
Cane sugar	1·42 "		1·41 "
Dextrin	1·25 "	(cont. soluble starch)	1·09 "
Total	5·62 per cent.		5·07 per cent.

Determined in the usual way, as above, and calculated as dextrose, water soluble carbohydrates amounted respectively to 6·41 and 6·00 per cent.

The Undetermined Residue in the analyses in table I. amounts to between 2·96 and 15·62 per cent., and is considered as made up of amide bodies, chlorophyll, undetermined extractives, as tannin, and carbohydrates of an intermediate nature and akin to cellulose. These are not included in pentosan or provisional starch determinations, nor contained in the crude fibre of König. The amount of these substances may be roughly gauged by subtracting the undetermined portion of the water soluble extract from the total undetermined matter, and would appear to vary widely in plant substances.

We have felt that the difficulty attendant upon all elaborate schemes of fodder analysis has been in the practical interpretation of results. This has arisen from the as yet imperfect knowledge possessed as to the physiological action and nutritive properties of the substances determined.

In this laboratory in the evaluation of fodder materials from their analyses special regard is had to the percentages of true protein, total water soluble material, soluble protein, soluble carbohydrates, starch, and to the low content of crude fibre.

In the present state of our knowledge we would place the feeding value of the constituent carbohydrates of feeding stuffs in the order—soluble carbohydrates, starch, pentosans, undetermined carbohydrates, and crude fibre.

Table I.—Analyses of Grasses (Indigenous and Introduced).

Variety and Locality.		Tons per Acre.	Moisture.	Total Dry Substance.	Soluble Proteids.	Insoluble Proteids.	Total Proteids N. x 6.25.	Woody Fibre (Konig's Meth.).	Pentosans.	Starch.	Soluble Carbohydrate (Sugars).	Crude Fat.	Chlorophyl Amides, etc., by difference.	Crude Ash.	In Ash. Lime.	In Ash. Potash.	In Ash. Phosphor. Acid.	Watery Extract. Total Sol. Matter.	Watery Extract. Sol. Nitrog.	Watery Extract. Sol. Ash.	Total Nitrogen.	Proteid Nitrogen (Stutzer's Method.	Albuminoid Ratio.
Blue Grass........................	*grass*	10·80	41·23	55·77	·53	1·34	1·87	19·22	11·47	6·03	2·39	1·02	8·10	5·62	·25	·67	·16	8·68	·180	2·01	·388	·301	1 : 25
(*Andropogon sericeus*)	hay	6·48	7·03	92·97	·89	2·23	3·12	32·10	19·12	10·05	3·98	1·70	13·50	9 40	·41	1·11	·27	14·30	·302	3·35	·646	·502	
Weeping Mitchell Grass ...	*grass*	14 58	62 08	37·02	16	1·38	1·54	11·58	9·20	5·12	2·24	·69	4·48	3·02	·15	·62	·12	5·67	·135	1·29	·346	·253	1 : 22
(*Astrebla pectata., v. clym.*)	hay	5·94	6·98	93 02	·41	3·35	3·76	28 42	22·70	12·56	5·50	1·70	11·01	7·37	·38	1·53	·30	13·90	·330	3·15	·885	·620	
Curly Mitchell Grass.........	*grass*	10·30	53·43	46·57	·44	1·76	2·20	13·90	16·26	6 69	2·81	·79	6·35	3 58	·20	·56	·15	7·60	·217	2·10	·401	344	1 : 18
(*Astrebla pectata., v. curv.*)	hay	5·40	6·96	93·04	·88	3·53	4·41	27·87	20·52	13·18	5·62	1·58	12·69	7·17	·41	1·11	·29	15·20	·435	4 20	·953	·689	
Eriochloa punctata	*grass*	12·96	61·08	38·92	·44	2·06	2·50	10·07	7·67	5·86	1·54	·69	4·60	4·77	20	1·57	·20	7·74	·359	3·12	·688	·397	1 : 12·5
	hay	4·86	6·52	93·48	1·04	4·94	5·98	24·15	18·38	14·05	3·70	1·66	11·03	11·35	·48	3·77	·49	18·60	·860	7·50	1 650	·956	
Brown Top or Sugar Grass	*grass*	8·64	42·23	57·77	·30	1·48	1·87	16·47	13·06	12·17	3·45	·91	2·98	4 97	·16	·37	·13	7·53	·086	1·12	·317	·298	1 : 27
(*Pollinia fulva*)	hay	5·40	7·57	92 43	·63	2 36	2·99	26·33	20·90	19·50	5·50	1·46	4·78	7·96	·26	·59	21	12·05	·129	1·80	·506	·478	
Rat's-tail Grass	*grass*	7·02	42 83	57·17	·50	1·31	1·81	19·05	11·71	13·17	3·44	·86	1 81	6·53	·21	·55	·25	6·25	·147	1·17	·356	·289	1 : 27
(*Ischæmum laxum*)	hay	4·32	7·07	92·93	·81	2·13	2·94	31·00	19·04	21·91	5·60	1·40	2·96	10·53	·31	·89	·10	10·15	·239	1·90	·579	·470	
Panicum jubiflorum	*grass*	15·12	66·63	33·37	·35	1·65	2·00	9·70	7·20	4·44	1·81	·52	4·16	3·45	12	·01	·08	6·45	·256	1·59	·521	·321	1 : 13
	hay	5·40	6·60	93·40	·99	4·63	5·62	27·16	20·32	12·44	5·07	1·46	11·65	9·68	·32	2·56	·22	18·05	·719	4·45	1·460	·899	
Flinders Grass.......	*grass*	?	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
(*Anthistiria membran.*)	hay	?	7·88	92·12	·07	2·74	2·81	29·20	18·28	17·57	5·50	1·40	5·56	11·80	·29	1·12	·32	13·05	·182	2·15	·630	·419	1 : 27
Couch Grass.........	*grass*	4·02	54·88	45·12	88	2·61	3·49	10·25	6·07	9·32	2 24	·60	7·83	4·42	—	—	—	7·04	·140	1·89	·670	·558	1 : 14·3
(*Cynodon dactylon*)	hay	2·01	9·99	90·01	1·75	5·21	6 96	20·45	13·90	18·58	4·47	1·20	15·62	8·83	—	—	—	14·05	·280	3·78	1·335	1·112	
Buffalo Grass	*grass*	7·56	77·42	22·58	1·06	1·07	2·13	4 56	5·90	5·17	·01	·50	·02	2·49	—	—	—	4·05	·248	1·29	·438	·341	1 : 9·0
(*Stenotaphrum American*)	hay	1·88	9·10	90·90	4·28	4 30	8·58	18·35	23 72	20·82	3·67	2·00	3 74	10·02	—	—	—	16·30	1·017	5·20	1·754	1·372	
Paspalum dilatatum........	*grass*	6·35	74·18	25·82	·99	40	2·39	5·86	5·54	5·01	1·43	·54	2·23	4·12	—	—	—	4·95	·158	1·45	·501	·382	1 : 8·5
	hay	1·83	10·86	89 14	3·41	4·83	8·24	20·25	19·12	17·32	3·90	1·85	6·52	11·94	—	—	—	19·18	·546	5·00	1·727	1·317	

Notes.—(1) The above table has been published in the annual report of this laboratory for 1905-6.
(2) Starch results given are by Lietz's method (Aus. Analyst, 1903, p. 150).

Table II.—A Comparison of Maercker-Morgan and Lietz Methods for Starch, and of Konig's and Acid-Alkali Methods for Crude Fibre.

	Starch.		Crude Fibre.	
	Maercker-Morgan Method.	Lietz Method.	Acid-Alkali Method.	König Method.
Blue Grass (*Andropogon sericeus*)	18·04	10·05	43·26	32·10
Weeping Mitchell Grass (*Astrebla pectata., var. elym.*)	17·53	12·56	41·66	28·42
Curly Mitchell Grass (*Astrebla pectata., v. curv.*)	17·46	13·18	41·70	27·87
Eriochloa punctata	13·46	14·05	38·26	24·15
Brown Top or Sugar Grass (*Pollinia fulva*)	18·98	19·50	41·34	26·38
Rat's-tail Grass (*Ischæmum laxum*)	17·47	21·91	43·38	31·00
Panicum jubiflorum	15·05	12·44	39·26	27·16

6.—THE DETECTION AND ESTIMATION OF FORMALDEHYDE IN MILK.

By J. C. BRUNNICH, F.I.C., Agricultural Chemist.

[Abstract.]

The author draws attention to the constantly increasing number of reactions for formaldehyde, and gives a *resume* of a number of recent tests, viz. :—

Morphine Test (F. Bonnet, jun., J. Amer. C.S., 1905, pp. 601-605) is recommended both for ease of application and sensitiveness. The test is conveniently conducted in covered Petri dishes. As claimed by Bonnet, no coloration is obtained from pure fresh milk, even after standing over night; but sour milk, to which no formalin has been added, gives a pink coloration after three hours. One part formalin in in 1,000,000 parts of fresh milk was indicated by a pink coloration, obtained in one to one and a half hours, at 26° to 28° C. In milk kept for two weeks only one part in 100,000 could be detected. Throughout, temperature conditions were found to influence the time requisite for the obtaining of reactions. Uniform coloring of the morphine reagent, rather than the color rings mentioned by Bonnet, were obtained.

Leach's Hydrochloric Acid Test and Gallic Acid Test (R. H. Williams and H. C. Shermann, J. Amer. C.S., 1905, pp. 1497 to 1505).

Schiff's Reagent.—Contrary to the experience of Hehner ("Analyst," 1896, p. 94), who obtained positive reactions with pure water after half an hour's standing, this test is highly satisfactory. Special care should, however, be given to the preparation of the reagent ("Allen's Commercial Organic Analysis," vol. I., third edition, p. 219). The test is also of greater delicacy than found by Hehner, distinct reactions being obtained with a solution containing one part formalin in 2,000,000, and with the distillate from milk containing one part in 1,000,000. Distillates from sour milks may give a faint reaction in absence of formalin, but the coloration is dispelled on acidulation with a few drops of dilute sulphuric acid. This test is serviceable for the quantitative estimation of formaldehyde. Fifty ccs. of milk are acidified with 1cc. dilute sulphuric acid (1 : 3), and on distillation from fresh milk approximately 50 per cent. of the contained formaldehyde is collected in the first 25ccs. of distillate. The distillate is made up to 50ccs. in a Nessler cylinder, and 1cc. of Schiff's reagent added. After half an hour's standing, comparison of color is made with formaldehyde solutions of known strength similarly treated.

Eury's Test (Abstr. II., J.C.S., 1904, p. 687) is preferred to Leach's test. The test is modified by the use of dilute sulphuric acid (1 : 2) in lieu of acid (1 : 1); the boiling is done in a casserole, and the observation of color in test tubes. Pure milks give a delicate flesh tint; milks containing one part formaldehyde in 500,000 showing a distinct purple shade. With sour milks the reaction is less sharp, and of a brownish tint.

Lebbin's Resorcinol Test (J.C.S., Abstr., 1897, vol. II., p. 606) detects one part formaldehyde in 300,000 (*c.f.*, Pilhashy, J. Amer. C.S., 1900, p. 133). With more than 1 : 100,000 the color is permanent for a few hours. The reaction is not given by other aldehydes.

Phloroglucin Test (L. Vanino, J.S.C., I., 1899, p. 403) is sensitive to 1 : 100,000, the color being transient.

Nessler's Reagent gives a sharp and characteristic reaction, but the test is not suitable for colorimetric estimation.

Pheny'hdyrazine Test (Arnold and Mentzel, "Analyst," 1902, p. 227) can detect 1 : 10,000 in milk, even after keeping four weeks.

The subjects of the disappearance of formaldehyde from milk on keeping and the recovery of the aldehyde from milk by distillation have been investigated by Leonard and Smith ("Analyst," 1897, p. 5) and B. H. Smith (J. Amer. C.S., 1903, p. 1036). R. Steenegger ("Landwirthechaftliches Jahrbuch der Schweiz," 1905) shows that combination of the aldehyde with the Amino groups of the milk proteids occurs.

Conclusions.—(1) For the qualitative detection of formaldehyde in fresh milk, Eury's or Bonnet's morphine test may be applied to the samples direct, and tests with Schiff's reagent, resorcin, phloroglucin, gallic acid, and phenylhydrazine to the distillate. (2) The qualitative detection of formaldehyde in old and sour milks presents no difficulties. (3) For the estimation of minute traces of formaldehyde in fresh milk, colorimetric methods—either Bonnet's, with the original samples, or Schiff's reagent, with the distillate—may be used with advantage. (4) In milks kept any length of time these methods will indicate less quantity of formaldehyde than originally present, depending mainly on the length of keeping.

7.—THE ANALYSIS OF MALT EXTRACT.

By E. S. RICHARDS, B.Sc.

The production of concentrated malt extracts has greatly increased in recent years. It is already well known as a food and also a valuable digestive agent, but it is now beginning to command attention in some of the fermentation industries, notably in the process of breadmaking and manufacture of alcohol.

Hence a knowledge of its constituents is of importance. Very few analyses of malt extracts have been published. Ling and Rendle ("Analyst," XXIX., p. 244) have published the results of an examination of nine samples. From these results it will be seen that dextrose occurs as an invariable constituent, as much as 22 per cent. being found. Previous to this, the presence of dextrose was taken to indicate adulteration with glucose syrup.

In the following list of analyses the dextrose varies from 10·9 per cent. to 26·2 per cent. They are results obtained from commercial extracts obtainable on the market. No. 3, which shows 24·1 per cent. dextrose was known to be free from glucose syrup, its manufacture being carefully followed. Harrison and Gair gave the results of an examination of 13 samples at the British Pharmaceutical Conference held at Birmingham in July, 1906. But in their results they attribute the whole of the reducing power to maltose, totally neglecting the effect of dextrose.

In the analyses published by Ling and Rendle the dextrose was determined as glucosazone, the maltose being calculated from the reducing power, less that due to the amount of dextrose found, whilst the dextrin was calculated from the rotatory power after deducting that due to dextrose and maltose. In following out this method it was found that in the cases of some of the extracts under examination the observed rotation was insufficient to account for even the dextrose and maltose, while at the same time there was certainly an appreciable amount of dextrin present, *e.g.*, in sample No. 3 the specific rotation for the dextrose and maltose found should be 61°·9, while the observed specific rotation is only 60°·6. Evidently in the extract in question the total rotation is not the sum of the rotations of the constituents. To overcome this difficulty the dextrin was estimated by Wiley's method of oxidising the sugars, maltose, and dextrose to optically inactive compounds, and then determining the dextrin left by its rotation. The methods of analysis adopted were as follows :—

WATER.

Brown, Millar, and Morris have shown (J.C.S. Trans., 1897, p. 73) that the drying of such solutions is a very laborious operation, and it requires very special processes to expel the last traces of moisture. Also, unless these special processes are adopted, the results obtained by determining the specific gravity of the solution are quite as accurate if not more so. To determine the percentage of water present the specific gravity of a 10 per cent. solution was found by means of a specific gravity bottle, and amount of dissolved solids determined, using the solution factor 3·92. After allowing for the ash, the percentage of water was obtained.

Dextrose.

The dextrose was determined by the method of precipitating as glucosazone, described by Davis and Ling (J.C.S., Trans., 1904, p. 24). Under these conditions it was found that 0·1 gram of dextrose gave ·0731 gram of glucosazone, using approximately the proportions—maltose, 2 ; dextrose, 1 ; dextrin, 1. This is the same value as found by Ling and Rendle for approximately equal proportions. To determine the dextrose, 10ccs. of a 10 per cent. solution were placed in a boiling tube, 1·5cc. of 50 per cent. acetic acid added, and then 1cc. of freshly distilled phenylhydrazine. This was then made up to 20ccs. with distilled water, and boiled in a water bath for one hour. Liquid and precipitate is then poured into a tared Gooch crucible. After liquor has drained away precipitate is washed with boiling water, so that total filtrate does not exceed 50ccs.

Maltose.

Ten ccs. of the 10 per cent. solution of malt extract are made up to 200ccs. with distilled water. The reducing power is then determined volumetrically by means of Fehling's solution. To determine the end point the starch iodide indicator described by Harrison (Pharm. Journ., Aug. 1st, 1903, p. 170) was used. It is possible by this means to determine the end point very sharply. The total reducing power having been determined in this way, the percentage of maltose can be found by making allowance for the dextrose already found.

Dextrin.

To determine the dextrin, 25ccs. of this 10 per cent. solution are treated with 50ccs. of a solution of mercuric aganide prepared by making up 120 grams of mercuric cyanide and 120 grams of sodium hydroxide to one litre. This mixture is then raised to the boiling-point of water in a water bath, and kept at that temperature for three minutes. After cooling, the alkali is neutralised by strong hydrochloric acid, volume made up to 100ccs. Solution is then decolorised by animal charcoal, and rotation determined in a 200mm. tube by means of a Schmidt-Haensch half shadow polarimeter. From the observed rotation the percentage of dextrin is calculated.

Albuminoids

Were determined by Wanklyn's albuminoids ammonia process, as recommended by C. Graham (Allen's Com. Org. Analysis, vol. I., p. 326). The method is much shorter and gives as good results as the Kjeldahl method. Ten ccs. of 10 per cent. solution are diluted to 100ccs. ; of this diluted solution 10ccs. are taken, added to 500ccs. of ammonia free distilled water. To this is added 100ccs. of Wanklyn's alkaline permanganate solution. Distillation is continued until 200ccs. have passed over. The ammonia in the distillate is estimated by Nessler's solution, and the amount found multiplied by 5·2 gives the amount of albuminoids present.

Diastase.

The diastasic power was determined by the method recommended by the Malt Analysis Committee to the Council of the Institute of Brewing, December, 1905. A 5 per cent. solution of the extract is taken, from 2ccs. to 7ccs. of this (the amount depending upon the diastasic power) is added to 100ccs. of 2 per cent. solution of soluble starch in a 200ccs. flask. This is allowed to act for one hour at 20° C.; 10ccs. of $\frac{N}{80}$ NaOH are then added to stop further action, the liquid cooled to 15° C., and made up to the mark. This solution is then titrated against 5ccs. of Fehling's solution, using the starch iodide indicator. After allowing for the reducing power of the extract added, the number of ccs. of liquid required for the reduction of 5ccs. of Fehling's can be calculated —the $L^\circ = \frac{1{,}000}{X\,Y}$ L° = diastasic activity; X equals the number of ccs. of malt extract per 100ccs. of diluted starch conversion liquid; and Y equals the number of ccs. of the same liquid required to reduce 5ccs. of Fehling's solution.

Specific Rotation $[a]_D$

was determined in a 100mm. tube by means of a Schmidt-Haensch half-shadow polarimeter; the 10 per cent. solution being used after decolorising by means of animal charcoal.

From these results it is obvious that the method of determining dextrin from the rotatory power after deducting that due to maltose and dextrin does not give correct results. The oxidation method gives results which, though they may not be quite correct, owing to the presence of a large percentage of maltose, certainly give results nearer the truth.

In conclusion I should like to thank the firm of Messrs. Felton, Grimwade, & Co. for permission to communicate the results of this work, which was done in their research laboratory.

Table of Analyses.

Constituent.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Dextrose	19 7%	26·2%	24·1%	10·9%	12·1%	18·2%
Maltose	30·6	32·3	35·4	48·3	46·4	33·1
Dextrin	12·8	8·1	7·6	10·3	12·3	14·4
Albuminoids	7·9	4·1	5·2	3·6	2·6	2·6
Water	26·3	25·9	25·2	23·3	24·5	30·1
Ash	1·7	1·2	1·5	1·7	1·2	1·6
Diastasic power	31°L	30°L	43°L	2°L	11°L	37°L
Specific Rotation $[a]_D$	57·7°	67·1°	60·6°	77·3°	75·1°	54·5°
Calculated Rotation	78·°2	74·°62	77·°10	93·°47	95·°46	91·°54
	99·0	97·8	99·0	98·1	99·1	100·0

8.—NOTES ON THE BEHAVIOUR AND ELIMINATION OF CERTAIN IMPURITIES IN COPPER SMELTING AND REFINING.

By G. C. McMURTRY, A.R.S.M., A.R.C.Sc.

The presence of small amounts of impurities in copper has often a marked effect on the character of the metal, rendering it more suitable for some purposes than for others.

In the metallurgy of iron and steel the influence of these small amounts of other elements is well known, and their presence or absence entirely alters the character of the product produced. But with copper very much remains to be done in the direction of ascertaining the action of these impurities.

The cause of this branch of the metallurgy of copper being so neglected is largely due to the fact that the average consumer of the red metal often knows nothing of the reason why one brand of copper in the market is more suitable for his work than other makes. It is well known, for instance, that a copper containing a fair amount of arsenic is more suitable for such purposes as rolling-plates for the fire boxes of locomotives, or for the manufacture of commercial copper wire, but such copper could never be used for electrical work, and would also be unsuitable for making the best alloys of copper required for fine castings or rolling.

I remember the result of a test of some electrolytic copper wire, as to its suitability or otherwise for telegraphic purposes. This wire passed well all the tests except one—in fact was higher than asked for in most cases; but I think the cause of failure in the one particular might be accounted for by the fact that the sample contained about ·003 per cent. of bismuth. This impurity does not affect (when only present in small quantities) the electrical conductivity of the copper, but is apt to interfere with some of the mechanical tests which are required to be complied with.

The remarks I propose to make are taken from actual results obtained during the years I have been engaged in copper smelting and refining operations, and in many instances the impurities were not present in the original copper ore treated, but became part of the "matte" or "regulus" produced after the first smelting had taken place, and so had to be reckoned with, and means taken to eliminate them. Several of the impurities came from ores of gold and silver, which were smelted with copper and finally separated from this metal by electrolytic refining.

I wish to acknowledge my indebtedness to my predecessor, T. C. Cloud, Esq., A.R.S.M., &c., who was manager of the Wallaroo Smelting Works before myself, as several of the results were obtained during the time I was his assistant.

Antimony.—This metal is one which no copper metallurgist has any love for, it being practically impossible to entirely eliminate, even when the "blister copper" is subsequently electrolytically refined. With few exceptions, the antimony has been an impurity coming from gold ores containing it; but in some cases it has been present in the fahl ores containing silver which were from time to time smelted. I can give, however, no results on the elimination during calcining of antimony from these fahl ores by themselves, as by the time they arrived on the scene antimony was well established as one of our enemies, and had to a large extent been vanquished.

The following is a result of calcining a mixture of copper ore and gold ore containing antimony and arsenic so that the percentage of these in relation to the amount of copper present could be ascertained as a guide for the subsequent smelting operations. The copper ore consisted chiefly of copper pyrites, and the antimony and arsenic as sulphide concentrates, the furnace used being a revolving calciner of the Oxland and Hocking type.

	Raw Ore.	Calcined Ore.	For every 100 parts of Copper.	
			Raw Ore.	Calcined Ore.
Copper	5·62	7·13	—	—
Sulphur	18·23	5·87	324	82
Arsenic	4·56	·25	81	3·5
Antimony	5·69	1·56	101	22

On melting such a mixture of calcined ore the slag produced always carried a fair amount of antimony; but, also, the copper contained in such a slag was high, probably due to the copper being present in the slag to a large extent in combination with antimony.

The furnace used for smelting was a reverberatory, which gives a better elimination of antimony than is obtained by the use of a blast furnace, due to the reducing conditions present in the latter.

Once the antimony is in combination with the copper, or present in a regulus or matte containing copper, its elimination is very imperfect. Calcining a regulus containing antimony only eliminates a comparatively small percentage, as the following result will show:—

	Raw Regulus.	Calcined Regulus.	Per every 100 parts of Copper.	
			Raw Regulus.	Calcined Regulus.
	Per cent.	Per cent.		
Copper	41·7	42·9	—	—
Antimony	0·76	0·52	1·82	1·21

From this it will be seen that two-thirds of the antimony present remained with the regulus. On melting this calcined regulus, however, the antimony present was considerably reduced, as shown by the following result :—

	Per cent.		Per 100 parts of Copper present.
Copper in rich regulus..................	68·6	......	—
Antimony in rich regulus	0·35	......	·510

The total elimination of antimony from the regulus during calcining and subsequent smelting amounted to nearly 72 per cent. The experiment on the elimination of antimony from this rich regulus up to rough copper was not at all satisfactory. The anode copper which was produced contained more antimony than the rich regulus per 100 parts of copper. This may have been accounted for if more copper in proportion to antimony were carried off in the roasting operation; but I think the most probable explanation is that the regulus during the roasting picked up extra antimony from the furnace bottom, as the furnace had been in use for some time treating this class of material.

In the electrolytic refining of copper containing antimony when this latter is present to any extent it is always possible to find this impurity in the cathode copper produced. The anode copper being refined was exceptionally impure, running at times to between 2 per cent. and 3 per cent. of antimony. The amount of antimony that will come down with the cathode copper varies tremendously, being dependent on so many things—such as the composition of the anode copper, amperage employed, composition of the electrolyte.

As a rule, by careful refining, the amount of antimony in the cathode copper may be kept low, even with very impure anodes; but still it is always possible to find small amounts present, however carefully the refining is done, when this element is there in appreciable quantities in the anode copper.

Very much depends on the composition of the electrolyte when dealing with copper containing antimony, it being absolutely essential that the strength in acid and sulphate of copper be maintained in the solution, for if either is allowed to drop to any extent the amount of antimony that will plate out is enough to condemn the refined copper. The subsequent treatment of the slime from the anode copper is complicated considerably by the presence of this impurity, owing to the antimony being probably in combination with the silver and copper, which renders the extraction of the latter metal difficult. A partial analysis of two samples of slime might be of interest :—

Cu	30·03	..	36·6	Fe_2O_3......	0·95	..	1·40
Bi..........	2·36	..	0·75	$PbSO_4$	4·12	..	23·32
As_2O_3......	1·86	..	1·99	S..	10·16	..	8·81
Sb	6·75	..	5·91				

Bismuth.—This element is probably the worst one to be present in copper to any extent, but, fortunately, one process used in treating the copper matte or regulus produced from smelting operations has overcome the question of its elimination very satisfactorily. I refer to the Bessemerising of copper matte, this process being far more effective in getting rid of bismuth than the older process by the treatment in the reverberatory. I have had most to do with this metal in the electrolytic refining of copper containing it, the highest amount present in the anode copper being just over ¼ per cent., which is more than enough to render any copper unsuitable for commercial purposes. The behaviour of this impurity in electrolytic copper refining is peculiar. It is always found, from my experience, like antimony, to a more or less extent, in the cathode copper, though the amount, if properly refined, is very low, running in the fourth place of decimals.

I have noticed that with some copper containing only ·04 per cent. of bismuth that in refining as much as half of this has been plated out with the refined copper; and, on the other hand, I have refined copper containing from ·2 per cent. to ·3 per cent., and yet the bismuth in the finished product has only been found in the fourth place of decimals. This, I have come to the conclusion, is largely due to the state in which the bismuth exists in the original anode copper refined, but unfortunately I had no opportunity of verifying my opinion on this matter.

In the first case, where such a large percentage of the bismuth plated out from the smaller amount present in the anode copper, the pitch of the metal was that of refined copper assaying 99·6 per cent. of copper; in the second case the pitch of the copper was under blister containing from 97 per cent. to 98 per cent. of copper, so that I believe much depends on the form in which the bismuth is present in the anode metal.

In the first case the bismuth was probably present in the anode as either an oxide or metal, and in the second case present as sulphide, so that it was in an easier form to dissolve in the first case than in the second, and once having passed into solution a certain amount plated out. This, I think, must have been the cause of the difference in the behaviour of the impurity.

It may have been that in the second case the bismuth was in combination with some other impurity, as the anode metal was very foul with antimony and lead, but I am inclined to think it was more probably due to the first explanation. Unfortunately, I could not get the opportunity of having the pitch of the anode copper altered in the first case, so was unable to ascertain whether my theory was right or otherwise.-

During the refining of the "blister pitch" anodes containing the high percentage of bismuth, a very peculiar product was obtained in the form of a gelatinous white slime, which coated with cathodes thickly on the outside, but did not deposit in the copper itself. This could easily be scrubbed off, leaving the copper clean and only containing traces of impurities.

The following is a partial analysis of this material:—

	Per cent.		Per cent.
PbO	47·23	Sb_2O_3	4·22
CuO	10·91	NiO	0·43
Bi_2O_3	6·81	Insoluble	2·05
Fe_2O_3	0·43	Undet.	25·80
As_2O_3	2·12		

The undetermined consisted principally of carbon, hydrogen, oxygen, some sulphur, and silver and gold. This material apparently was a kind of soap, but the source of the carbon and hydrogen present was very obscure, although it is probable that a certain amount of hydrocarbon oil may have found its way into the electrolyte.

Before the analysis was done the substance was washed with water, then dilute sulphuric acid (one part acid to eight parts water), again washed with water, and finally three times with ether and dried.

Unfortunately for science, in a smelting works not much time can be found for chemical research work; it is usually enough if the difficulties which occur are successfully overcome.

Nickel.—This metal is often present in copper ores to a small extent, but its elimination by the ordinary smelting process is never complete. The electrolytic refining of copper containing it, however, gets over the difficulty. The presence of nickel to a small extent does no harm to commercial copper; if present in larger quantities, it makes the copper less malleable. The elimination of nickel takes place from the first smelting operation, then through the treatment of the regulus and refining operations. From the results of experiments on various processes, with a view to the elimination of this metal out of a rich regulus or "regule" containing 78 per cent. to 80 per cent. copper on to the blister copper stage, the ordinary Welsh roasting process gives the lowest result; next to that comes the direct refining process of Messrs. Nicholls & James; then the process worked out by Mr. Rogers, A.R.C.Sc., F.I.C., and myself, which gives a better elimination of this element than either of the other two. This process has been patented in my name, and in the treatment of regule consists in crushing the regule down to from ¾in. to ½in., wetting it thoroughly with water, and charging it into an iron converter-pot, on the perforated bottom of which a small fire is burning; then forcing air through the charge until the whole mass becomes red hot, due to the burning of the sulphur. The product is then tipped, broken up, and sent to the refining furnaces direct.

Taking the ordinary Welsh roasting process as one, the elimination of nickel by these three processes is as follows:—Welsh process, 1·0; Nicholls & James', 1·5; McMurtry's, 1·87.

In the electrolytic refining of copper containing nickel one sees the statement that this metal dissolves and goes into the electrolyte. This is undoubtedly true in most cases; but I have known it largely to go into the slime, and in such a form that it could not be readily got out again.

The following is an analysis of a product which came down with the slime in refining, and consisted of bright yellow scales or very thin plates, which could be comparatively easily separated from the heavier parts of the mud containing the gold and silver:—

Copper	27·75
Nickel	18·00
Arsenic	11·51
Antimony	9·95
Lead	7·92
Iron	3·37
Zinc	4·14
Silver	1·69
	84·33

These scales were not the easiset things to decompose : *aqua regia* had very little effect on them ; but they were decomposed by hot concentrated sulphuric acid.

A similar compound to this is described by Hampe as " copper mica," which consists of an antimoniate of copper and nickel, having the formula of 6 Cu_2O, Sb_2O_5 + 8 NiO, Sb_2O_5, except that in the analysis given the antimony has been largely replaced by arsenic, and a fair amount of lead is also present.

In other instances nickel has been present in the slimes with which I have had to deal, but never over ½ per cent. going, as this impurity should, into the electrolyte.

Selenium.—This element remains to a certain extent with the copper, and is found in that metal after the refining process is finished. In the electrolytic refining the selenium goes down with the anode slime, and on boiling this with sulphuric acid and air to extract the copper the selenium is still found with the remaining slime.

Some time ago I had a slime containing a fair amount of selenium, but its presence was unknown to me. However, on treating the boiled slime on a cupel with lead, a product was obtained which caused a large amount of trouble. This product I at first took to be a copper-lead regulus, but its behaviour in the furnace did not agree with what one would expect from such a product. The litharge which was formed seemed to have no action on it, but remained floating on top.

A piece was then sent to the assay office, with instructions to have it run down with twice its weight of litharge in a crucible ; but the product was returned to me with the litharge on top more or less converted into silicate, and the regulus below apparently unchanged, except that a little " moss copper " was showing at the bottom of the button. Seeing the trouble this was causing by retarding the cupelling operation, I had an analysis made, and finally found the material to consist of selenium combined with copper and lead, and not with sulphur, which I had at first thought to be the case.

The following is an analysis of this substance :—

	Per cent.
Copper	39·330
Lead	27·200
Selenium	20·808
Telurium	1·224
Sulphur	4·440
Silver	4·480
Gold	0·012
Total	97·494

The other constituents being only small in amount, were not determined. Once knowing the cause of the trouble, it was not a very difficult matter to overcome it; the addition of a little nitrate of soda to the cupel being all that was necessary.

Although at times the sister element, telurium, has been present in fairly large quantities in slime under treatment, it has never caused any trouble except the difficulty of eliminating it from the gold and silver bullion in cupelling.

The few examples I have given are selected, as in some cases the products obtained were out of the ordinary run, also the behaviour of certain impurities totally different to what is generally stated in text-books bearing on this subject.

9.—THE RADIO-ACTIVITY OF THORIUM.

By G. J. GRAY, B.E., B.Sc.

[WITH PLATE.]

The radio-activity of thorium has been much discussed during the last couple of years.

All the thorium salts of commerce are prepared from minerals from three sources, or from admixtures of these; and when several investigators claimed to have isolated more or less permanently inactive thoria from other minerals, it seemed quite possible that the activity was due to some accidental impurity The constancy of the association was paralleled by that of uranium and thorium in the well-known localities. The isolation of radio-thorium by (*a*) Hahn heightened the interest. It followed thorium closely in properties, hence might easily account for the activity of the latter; whilst if it were a product of thorium, its resemblance in chemical properties to it pointed to sufficient difference in atomic weight to involve several uninvestigated changes.

The question seemed important enough for investigation. The method chosen consisted in the determination of the ratio of the mass of thorium to the mass of radio-thorium present in minerals from several different localities. The minerals are old enough for the various non-volatile products of the radio-chain to have reached equilibrium values. When in equilibrium the ratio of the masses of any two such products will be a constant.

If radio-thorium be a product of thorium, then the ratio of radio-thorium mass to thorium mass will be a constant in all thoriferous minerals, since no volatile product intervenes between the thorium and radio-thorium, so far as is known.

The thorium was determined as ThO_2 analytically as detailed. The radio-thorium was determined from measurements of the activity of the "thorium emanation." Its total activity is proportional to the mass of radio-thorium when in equilibrium, and it reaches its equilibrium value in a very short time. The mineral in solution was placed in a horizontal glass tube, which it partly filled, and a constant current of air was drawn over the solution. The active gas was carried into a testing vessel and its activity measured. After a certain time the amount of emanation formed and carried over per second became constant, and for solutions of the same order of thorium concentration this was proportional to the emanation activity value. The work was started some 18 months ago, but, owing to delay in obtaining specimens and pressure of teaching work, the results are only ready now.

Recently results on the same question have been published.

(*b*) Boltwood obtains the correct total activity by McCoy's method. He estimates the uranium present analytically, and subtracts the activity

(*a*) Hahn: Proc. Roy. Soc., Lond., A., LXXVI., 115, (1905).
(*b*) Boltwood: *American Journal of Science*, XXI., 126, p. 415.

due to it as determined in his previous work. The residual activity, which he supposes due to thorium and its products, is very accurately proportional to the thoria present. Results are given for thorianite (Ceylon), thorite (Norway), monazite (Norway), and monazite (North Carolina). He assumes also that actinium belongs to either the uranium or thorium radio-chain.

(*c*) Dadourian uses the emanation, measuring the excited activity produced by it (which is proportional to the emanation when the two are in equilibrium quantity) after the decay of the excited activity of radium and actinium. The method is very direct, and the results give a constant for the ratio $\frac{\text{Emanation Activity}}{\text{Thoria}}$ for thorianite (Ceylon) and thorite (Norway).

(*d*) McCoy and Ross obtain the correct total activity, estimate the uranium analytically, subtract the activity due to it, and assume the remaining activity wholly due to thorium chain products. The constancy of the ratio is proved for thorite (Norway), monazite (Norway), and monazite (North Carolina). The results are conclusive, but as only two localities are determined without any assumptions regarding the actinium present, and as the localities are the sources of commercial thorium salts, it seems worth while publishing the more extended list. The thirteen (13) minerals examined represented twelve (12) quite distinct mineral provinces.

Analytical Methods.

Uraninite (Colorado) ... Broëggerite (Norway) .... Thorianite (Ceylon)	Dissolved in concentrated HNO_3
Thorite (Norway)........ Thorogummite (Texas).... Gadolinite (West Australia)	Dissolved in concentrated HCl

The solutions were evaporated to dryness, and heated to dehydrate silica. They were then moistened with acid, taken up with water, and filtered. Any undecomposed residues were fused with $KHSO_4$, taken up in water acidulated with HCl, and the oxalates precipitated separately from the main solution. Group II. metals were removed by H_2S, and the rare earths precipitated as oxalates in about 250c.c. solution by 50c.c. of a cold-saturated solution of oxalic acid. The precipitate was allowed to settle out for 24 hours, then filtered, and washed with very dilute oxalic acid water.

Monazites.

The monazite, after being very finely ground in an agate mortar, was treated with concentrated H_2SO_4, in a platinum dish, on an asbestos board, over a medium Bunsen flame, for at least six hours. It was kept covered with a thin clock glass, and the H_2SO_4 was replaced as evaporated. The cooled mass was then poured very carefully into 700c.c. water at 0°C, and allowed to stand in its freezing mixture for several hours, with occasional stirring. The monazites were very carefully hand-picked in every instance, and the residue in all cases was very slight. Any residue was filtered off, and Group II., &c., precipitated by H_2S in

(c) Dadourian: *American Journal of Science*, XXI., 126, p. 427.

(d) McCoy and Ross: *American Journal of Science*, XXI., 126, p. 433.

cold and boiling solution. The clear filtrate was neutralised by ammonium hydrate (5E solution at first, and E very carefully afterwards) till a slight opalescence showed permanently. This was removed by a few c.c of $5EH_2SO_4$. A cold-saturated solution of ammonium oxalate was then added till a heavy precipitate formed permanently: then the precipitation was completed by 50c.c. of cold-saturated solution of oxalic acid.

Pyrochlore (Tasmania)............ }
Aeschynite (Miask, Ural Mountains) }

As these possibly contained both titanium and zirconium, in addition to thorium, they were treated by (*e*) Delafontaine's method. They were fused with twice their weight of acid potassium fluoride, and the melt treated with water faintly acidulated with HF to remove any titanium or zirconium as the double fluorides with potassium. The residue of fluosalts was then treated with concentrated H_2SO_4 till the conversion into sulphates was complete. The sulphates were dissolved in ice-cold water and treated as the monazites. The rare earth oxalates were converted into nitrates, either directly by concentrated HNO_3 or indirectly by conversion into hydroxides (by excess of KOH), which were dissolved in dilute HNO_3. The indirect method was found preferable for the richer thoriferous minerals, as nearly pure thorium oxalate requires much time for complete decomposition by concentrated HNO_3.

For the estimation of the ThO_2 present, two methods—the $Na_2S_2O_3$ method and the *m* nitrobenzoic acid method—were used to check each other.

$Na_2S_2O_3$ Method.

The nitrates obtained as above were evaporated to dryness and taken up with water. (Any basic ceric nitrate was redissolved in HNO_3 and the evaporation remade more carefully.) The solution of about 150c.c. volume was then precipitated by 15-25c.c. of a cold-saturated solution of $Na_2S_2O_3$ (free from sulphate), boiling for five (5) minutes after the addition of the $Na_2S_2O_3$. The precipitate was very thoroughly washed and dissolved in 5EHCl. It was then evaporated to dryness, taken up in 50-120c.c. water, according to richness, two or three drops of concentrated HCl added, and the thorium precipitated by $Na_2S_2O_3$. Another similar purification was made and the resulting precipitate reserved. The three united filtrates were precipitated by NH_4OH, the hydroxides filtered, washed, and dissolved in HCl, and the chlorides evaporated. They were precipitated in about 50c.c. solution by $Na_2S_2O_3$. This precipitate was purified once. The two filtrates were united and treated for thorium, and the resulting precipitate added to the other two. All three were filtered through the same filter paper and washed thoroughly. The united precipitates were then dissolved in 5EHCl, evaporated almost dry, and thorium oxalate precipitated by excess of oxalic acid. The precipitate was ignited and weighed as ThO_2.

Throughout the analysis all sulphur residues remaining after dissolving any thiosulphate precipitates in HCl were ignited and fused with $KHSO_4$, then taken up with water acidulated with HCl and precipitated as hydroxides. These hydroxides were dissolved in HCl and added to the main bulk. The amounts present varied, but were generally very small.

(*e*) Delafontaine: *Chemical News*, 75 (1897), p. 230.

m. *Nitrobenzoic Acid Method.*

A modified combination of the methods of (*f*) Neish and of (*g*) Kolb and Ahrle was used. The almost neutral nitrates were taken up in water and any ceric salts reduced by passing H_2S through for 30 minutes. The H_2S was boiled off and the solution filtered into a large beaker and diluted to 500-1000c.c. A hot solution of analine *m.* nitrobenzoate was added till a permanent precipitate formed. Excess of *m.* nitrobenzoic acid (·5-2·0 gram. according to the amount of ThO_2) was then added in boiling solution, and about one-fourth this weight of aniline *m.* nitrobenzoate to neutralise any free mineral acid. As the amounts of ThO_2 present were approximately known, the amounts of the precipitant necessary could easily be calculated. The amounts correspond in general to four or more times the quantity theoretically necessary. The solution was allowed to settle out on a hot plate, then filtered and washed. The washed precipitate was retransferred to the beaker and treated with excess of dilute KOH solution; warming for about an hour. It was then filtered off, washed, dissolved in $5EHNO_3$; the nitrates evaporated to dryness and the precipitation repeated. The precipitate was partially dried, then ignited in the filter paper and weighed as ThO_2. The oxide was perfectly white (generally better than the $Na_2S_2O_3$ precipitate), and the results seem a little lower than those given by the $Na_2S_2O_3$ method.

As a comparison of the two methods is of interest, I have given the results of the two separately in the table of analytical results. The analyses represent duplicates in all cases.

Analytical Results.

Mineral.	$Na_2S_2O_3$ Method	*m.* Nitrobenzoic Method.	Mean.
	% ThO_2.	% ThO_2.	% ThO_2.
Thorianite (Ceylon)	57·8	58·0	57·9
Thorite (Norway)	49·6	49·2	49·4
Thorogummite (Texas)	40·6	40·2	40·4
Aeschynite (Miask, Ural Mountains).	—	14·6	14·6
Broëggerite (Norway)	6·5	6·7	6·6
Monazite (Brazil)	4·5	—	4·5
Monazite (Queensland)	3·6	—	3·6
Monazite (West Australia)	2·85	—	2·85
Monazite (Tumberumba, N.S.W.) ..	3·6	3·5	3·55
Gadolinite (West Australia)	·17	—	·17
Uraninite (Colorado)	nil	nil	—
Monazite (South Australia)	nil	nil	—
Pyrochlore (Tasmania)	nil	nil	—

Radio-active Measurements.

The apparatus is figured in the sketch. The mineral in solution was placed in the horizontal glass tube A, and the emanation escaping from it carried through B, a drying tube. This tube was filled for about

(*f*) Neish: "Journal of American Chemical Society," XXVI., No. 7.

(*g*) Kolb and Ahrle: "Zeitschrift für Augewandte Chemie," 18 (1905), 92-93.

a quarter of the cross-section with concentrated H_2SO_4, and about the first 5cms. of its length was loosely packed with glass wool. The forward end, C, was bent up into the same straight line with the testing apparatus to prevent possible eddies in the air current. The active gas then passed through D, a brass cylinder with insulated central electrode, where a strong electric field removed any ions or excited activity that would otherwise be carried into the testing cylinder. F, the measuring vessel, consisted of a brass cylinder with a central electrode insulated from the cylinder by sulphur plugs with intermediate guard rings connected to earth. The cylinder ends were capped with brass gauze to prevent alteration in the volume of the field with varying voltages. Glass tubing (G), of the same diameter as the measuring cylinder, connected with the filter-pump by a conical glass tube. The filter-pump was actuated from a cistern with a constant level overflow, and, with its supply pipe, was rigidly fixed. The current was absolutely constant over the whole range of time used in the measurements.

The H_2SO_4 tube was found necessary to keep the insulation in the testing vessel good. It did so quite efficiently, the insulation being constantly tested. Experiments showed that its absorption (if any) was the same for emanation, varying as widely in activity as in the test experiments. The whole apparatus was rigidly fixed. Connections between the tubes were made by rubber tubing, which was painted over afterwards thoroughly with rubber solution. All parts of the measuring system were screened in tinfoil-covered cardboard boxes connected to earth. A key of the type described by (h) Rutherford was used. It gave a constant small electrostatic effect on breaking the earth connection, and the measuring range was taken beyond the influence of this. An electroscope of the C. T. R. Wilson type was used. It was adjusted to its maximum sensitiveness inclination with about 240 volts P.D. between the plate and gold leaf. Earth connections were soldered. A battery of test-tube accumulators was used. Two hundred and fifty volts certainly produced practical saturation, and 280 volts was used. Readings were taken over precisely the same points on the scale as much as possible. As, however, the solubility of the thorium emanation in the solutions was unknown, the different orders of activity were tested against thorianite standards. Thorite, thorogummite, aeschynite, and broëggerite were compared with 1·0000 gram thorianite made up as detailed, and the others with ·2500-·1000 grams thorianite. The mineral tested and its standard were taken over precisely the same range in the measurement. In addition, a known amount of thorianite in solution was added to a sulphate solution of a monozite of known activity. The solution was then made up to standard volume and tested. The total activity was equal to the sum of the separate activities, so that the solvent action of the two sets of solutions used was the same for the quantities involved. The decay of the emanation gave rise to excited activity in the measuring cylinder, and the activity due to this had to be subtracted from the total activity.

In practice, readings were taken with the mineral solution in, till constant readings were reached; then five (5) readings were taken in quick succession over the chosen range. The solution tube was then rapidly cleaned out by a syphon and washed thoroughly with water.

(h) "Rutherford Radio-activity," second edition, p. 97.

One hundred c.c. of water was then put in, and the rate of leak determined. The activity calculated from this rate of leak was subtracted from the total activity. The remainder was the activity of the thorium emanation present.

Solutions.

The solutions were obtained thus: Acid soluble minerals dissolved as in analyses, and made up to 100c.c. with water. Monazites decomposed with H_2SO_4 and evaporated dry; 10c.c. H_2SO_4 was added, and the sulphates dissolved in 120c.c. ice-cold water. The monozites were all pure, and gave only minute residues. The clear solutions could be boiled down quite safely to 100c.c., getting rid of any radium emanation in the process. Aeschynite and pyrochlore were fused with acid potassium fluoride, and then decomposed with concentrated H_2SO_4; dissolved in about 90c.c. ice-cold water; filtered off the residue, which was inactive; made up to 100c.c. The thorianite blanks were made up with the same amount of acid as the minerals.

Radium emanation was removed where possible by prolonged boiling. The aeschynite and pyrochlore solutions were not boiled, the emanation being got rid of by drawing a rapid air current through them for several hours in a separate apparatus.

Actinium emanation practically completely decays before reaching the testing cylinder.

Table of Results.

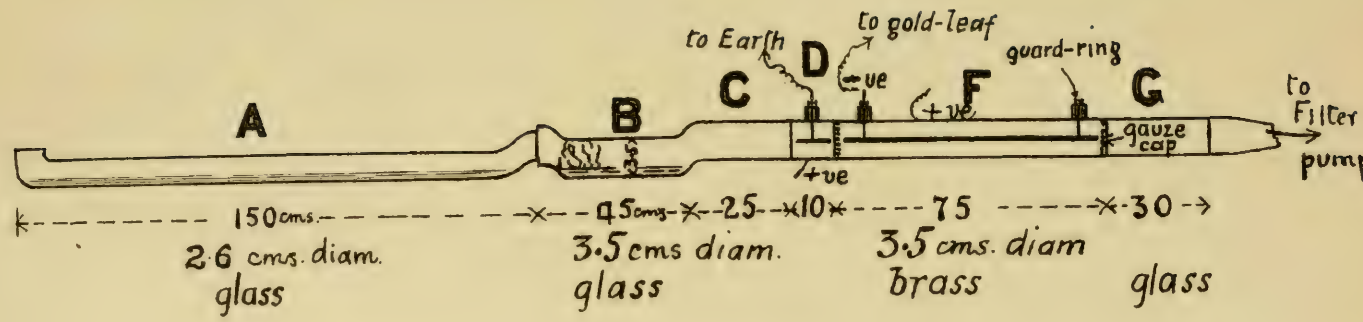
Column I. gives the mineral; column II. the percentage of ThO_2 present in it. Column III. is the amount of the mineral taken for radio-active measurement, and column IV. gives the amount of ThO_2 present in that amount of mineral. In column V. the corrected activity (*i.e.*, total activity less the excited activity on the negative electrode) is tabulated. The activity of thorianite is arbitrarily taken as 100.

The ratio $\frac{\text{corrected activity}}{\text{mass of } ThO_2}$, as calculated from the two series of determinations, is shown in column VI.

Table of Results.

I.	II.	III.	IV.	V.	VI.
Mineral.	ThO_2%	Mineral Taken.	ThO_2 Taken.	Corrected Activity.	$\frac{\text{Corrected Activity}}{ThO_2}$
Thorianite (Ceylon)	57·9	1·0000 grams	·5790 grams	100	173
Thorite (Norway)	49·4	1·0000 "	·4940 "	84·3	171
Thorogummite (Texas)	40·4	1·0000 "	·4040 "	69·8	173
Aeschynite (Ural Mountains)	14·6	2·0000 "	·2920 "	48·8	167
Broëggerite (Norway)	6·6	3·0000 "	·1980 "	34·3	173
Monazite (Brazil)	4·5	1·9010 "	·0855 "	14·5	169
Monazite (Queensland)	3·6	3·0000 "	·1080 "	19·3	179
Monazite (West Australia)	2·85	3·0000 "	·0855 "	14·4	168
Monazite (Tumberumba, N.S.W.)	3·55	3·0000 "	·1065 "	18·1	170
(*a*) Gadolinite (West Australia)	0·17	3·0000 "	·0051 "	·8	157
(*b*) Uraninite (Colorado)	nil	3 0000 "	—	slight, variable	—
(*c*) Monazite (South Australia)	nil	3·0000 "	—	nil	—
(*c*) Pyrochlore (Tasmania)	nil	2·0000 "	—	nil	—

VII. Remarks.—(*a*) Rather small for accuracy. (*b*) Slight activity, probably from Ac. (*c*) Tested mineral—inactive.



SURVEYOR GENERAL'S OFFICE ADELAIDE A Vaughan. Photo-lithographer

Discussion of Results.

The values for the ratio $\frac{\text{“ corrected activity ”}}{ThO_2}$ are quite constant.

As the volume of air whose activity was measured was constant, the time it took to reach the testing vessel constant, and the solubility of the emanation in the solutions constant (by the use of standard checks), this "corrected activity" is proportional to the emanation evolved in unit time, and thus to the total emanation activity. This total emanation activity is proportional to the radio-thorium, hence the radio-thorium is proportional to the thoria.

The constancy of the ratio in such widely different localities and occurrences is explicable only on the assumption that radio-thorium is a product of thorium. The absence of any thorium emanation in non-thoriferous minerals confirms this fact.

Taken in conjunction with the results of Boltwood and McCoy and Ross (cited above), it seems very probable that actinium is a radio-product of either thorium or uranium, probably the latter.

The properties of radio-thorium are somewhat indefinite, owing, no doubt, to the effect of large masses of other rare earths on its real properties; but, judging from those described by Hahn *(loc. cit.)*, it would seem to show enough similarity to thorium to differ from it somewhat in atomic weight. If so, several changes would seem necessary. The work of McCoy and Ross on thorium salts will serve to determine whether any or all of these are rayless.

The experimental work in this paper was carried out in the chemical laboratory of Sydney University; and I would like to express my sincere thanks to Professor Liversidge for his kind assistance and encouragement. I also owe my thanks to Mr. G. W. Card, of the New South Wales Geological Survey, for his kindness in procuring me Australian specimens.

10.—GOLD NUGGETS FROM NEW GUINEA POSSESSING A CONCENTRIC STRUCTURE.

By Professor A. LIVERSIDGE, M.A., F.R.S.

Section C.—GEOLOGY.

1.—DISTRIBUTION OF THE IGNEOUS ROCKS OF NEW ZEALAND.

By P. MARSHALL, M.A., D.Sc.

[With Map.]

Although Captain Hutton published descriptions of many types of igneous rocks of New Zealand, and stated the localities from which his specimens were obtained, he made little or no attempt to define the areas over which such rocks might be found. Other authors have from time to time published descriptions of rocks of small areas, or have given generalised accounts of the occurrence of certain kinds of rock.

Of these authors, Hochstetter, in 1866, laid the foundations of our knowledge of the distribution of igneous rocks of the Auckland and Nelson provinces, and in his account were included detailed descriptions of some of the Taupo rocks by Zirkel.

Sir James Hector, in his "Handbook of New Zealand Geology," distinguishes only between basic and acidic igneous rocks.

In Otago, Hutton, in his "Geology of Otago and Southland," gives a general idea of the distribution of the rocks that he had found within the limits of those provinces. Haast, in his "Geology of Canterbury and Westland," has done similar work for these more northern provinces, while descriptions of many of the volcanic rocks of Banks' Peninsula are to be found in Filhol's "Voyage au Pol Sud."

More recently Rutley has described some of the rocks of the Thames area, and Sollas has added greatly to these in two volumes of rock descriptions lately published by the New Zealand Government.

The important alkaline area of the Otago Peninsula was first recognised by Ulrich, for Hutton had previously described these phonolites as andesites and trachytes. This area has lately been more fully described by the present author (Q.J.G.S., 1906).

In addition to these larger memoirs, other descriptive papers are to be found in some number in the volumes of the "Transactions of the New Zealand Institute." The more important of these are:—Hutton on the Andesites of Coromandel; Cox on the Rhyolites of Mount Somers; Thomas—Rocks of Tongariro and Taupo; Speight—Rocks of Kermadecs and Banks' Peninsula; Marshall—Peridolites of Milford Sound; Park—Andesites of Thames Goldfields; Shrewsbury—The Auckland Volcanoes.

The titles of many others will be found in a list of papers on the Geology of New Zealand that was compiled by Mr. A. Hamilton. (T.N.Z.I., 1902.)

The results obtained in many of these papers were summarised in Hutton's descriptions and classification previously noted. His work is certainly the most important in this as in many other fields of geological inquiry.

For the purposes of this paper it is deemed to be sufficient to give a general account of the igneous rocks of each district, noting their general characters only, and defining, as far as the author's knowledge will allow, the areas over which the various rocks are found. In order to keep the geological bearings of the matter as prominent as possible, the subject will not be developed in the manner that would be demanded if the gradations of petrographical classification were the first consideration. The areas of occurrence of igneous rocks will be taken in order, and consideration of the rock types and of the period of intrusion or of emission will be referred to in connection with each igneous area. In following this method it will be found that very different rocks will be mentioned in close connection, and, on the other hand, one and the same type of rock will have to be mentioned in descriptions of several different areas.

In many instances there is at present no definite knowledge as to the date of intrusion or of eruption of the rock districts that are to be described. In all cases, however, there are certain data that can be relied on for ascribing more or less definite limits to the period during which the formation of the rock masses can have taken place. The igneous areas will be taken in the probable order of their formation.

It is generally agreed that the oldest mass of igneous rocks in New Zealand is the great plutonic gneissic area of the south-west coast of Otago and the greater portion of Stewart's Island. Captain Hutton at first referred the huge mass to the Archæan period (1875), but afterwards regarded the rocks as representing the plutonic reservoir from which volcanic rocks of much more recent date (Carboniferous) were derived. Sir James Hector referred to the whole of this mass of rocks as belonging to the gneiss-granite formation of South America of Hochstetter. I believe that there is at present a tendency amongst New Zealand geologists to regard the whole mass of the rocks as extremely ancient.

The most frequent type of rock is a diorite gneiss. The hornblende is extremely green, and much epidote is to be found in the felspar. Magnetite is always present, and the green hornblende often includes quartz in the manner described by Holland in the charnockites of South India.

Granites and true gneisses are not uncommon. At Golden Bay, Stewart Island, the granite is grey, and has a vein of a very distinct graphic granite, the felspar of which is microcline-microperthite. At Rugged Point, Stewart Island, a large intrusive acidic mass stands on the border line between a graphic granite and a granophyre. At Deas Cove, Thompson Sound, a true gneiss occurs.

Granulites are of frequent occurrence. Usually there is relatively little quartz. Garnet is very abundant, and rutile is nearly always present. A pale-green pyroxene often occurs with the garnet. Green hornblende is frequent in some of the specimens. The granulites usually occur near the western coast, especially in Dusky and Breaksea Sounds. At the entrance to Milford Sound they are denser and more distinctly banded than elsewhere.

In the Darran Mountains, to the north and east of Milford Sound, there is a large mass of mica norite. The diallage, which is abundant, has the pleochroism and the schiller structure of hypersthene. The mica is frequent—a deep brown biotite.

The Bluff Hill and the Round Hill of Orepuke are chiefly composed of norite. The hypersthene in this case does not show schiller structure, and is very largely changed to hornblende. The Rev. R. Baron considers that all the hornblende in this rock is secondary.

At Anita Bay, Milford Sound, a magnesian intrusion occurs. The main mass of it is a kataclastic dunite, which contains here and there a little diopside. There are also large blocks of remarkably fresh hartzbergite, in which the enstatite contains a little magnesite. In some specimens the magnesite completely replaces the enstatite, and the rock becomes marble-like, a granular mixture of magnesite and olivine. The magnetite of this rock contains 10 per cent. of chromium oxide. Some of the boulders are pure enstatite rock. Much of the mass is altered to serpentine and talc.

Throughout the length of the South Island masses of plutonic rock crop out on the western side of the divide. The nearest portion of these to the mass already described is a peridotite area. On the western side at least diorite forms the border of this area; gabbro, pyroxenite, and therzolite constitute its greater portion. The gabbro is coarse-grained; its felspar is almost completely changed to an isotropic substance whose exact nature has not yet been investigated. The pyroxenite is a pure diallage rock of coarse grain. Much of the olivine in the therzolite is kataclastic. There is probably pure dunite as well, for its half serpentinised form constitutes a large mass of rock.

This peridotite area, according to Professor Ulrich, stretches 50 miles or more to the north-east. According to his description the rocks of this extension are much the same as those just mentioned. In addition, Ulrich proved the highly interesting fact that awaruite occurs in this rock mass.

Further northward the plutonic rocks are almost exclusively granites, varying in color from pink to grey, generally porphyritic, and sometimes they carry tourmaline. At Separation Point there is a great deal of sphene, and the porphyritic character is marked. The felspars weather out readily. They have the Baveno form, with large development of the base and clinopinacoid and corresponding reduction of the prism. Baveno twinning was not noticed. Occasionally the ordinary form, with Carlsbad twinning, is found.

The age of these plutonic masses is not definitely known. Hector apparently includes them with the sounds area. Hutton thought them much younger—certainly post-Carboniferous; perhaps Jurassic. Dr. Bell thinks them younger than his Arahura series of perhaps Carboniferous age. The pink granites of Preservation Inlet should perhaps be included here, as they are said to penetrate Maitai (Carboniferous) rocks. Every section that has been examined to the east of them shows that the sedimentary rocks that border them become more and more metamorphic as the granites are approached. They pass from shale through phyllite to slate, mica schist, and gneiss. This seems to constitute an immense but definite contact area. As, however, the age of the sedimentaries is not unquestioned, the fact that the contact changes prove the granites to be of subsequent origin is of little use.

The largest mass of this granite extends from Kahurangi Point to the Little Wanganui River, and reaches 20 miles inland.

There are two other plutonic masses rather further to the east. The one is MacKay's Bluff, 10 miles north-east of Nelson. The rock has been called syenite by Hutton and others, but the relatively large quantity of interstitial quartz perhaps justifies one in calling it a hornblende granite. A bar of boulders of this rock forms the bank that separates Nelson Haven from Tasman Bay.

The other plutonic mass forms the well-known peridotites of the Dun Mountain of Nelson. The characteristic dunite occurs here in large quantity, but many other varieties of rock occur as well. It is a curious fact that the gabbro with isotropic matter (*a*), the pyroxenite, and serpentine diallagites occur here as well as in the southern area previously described. Chromite occurs in masses of notable size in the dunite, and segregations of copper ores have been found in several places, but no awaruite or platinum have been recorded.

It is notable that at Milford Sound hartzbergite occurs near the dunite. At the Cow Saddle, in the southern area to the north of Milford Sound, the associated rock is therzolite, and in the Dun Mountain no pyroxene peridotite occurs, though there are apparently serpentinised representatives of such rocks. Bronzite and hypersthene have been frequently recorded from the Dun Mountain area. During a recent visit the author could find neither of these, though in the pyroxenite bastite occurs rather frequently. Other plutonic rocks occur near the west coast, for boulders collected for me by Mr. J. P. Smith in alluvial drifts at Brunner are mica olivine gabbro. (*b*)

In his recent report Dr. Bell refers to serpentines, bowenite, and nephrite as representatives of original dunite. In regard to the two former there can be no doubt, for both occur at Milford Sound, alongside of the dunite. I have long believed in the probability of the derivation of nephrite from dunite.

The North Island contains no large plutonic masses, but at Cabbage Bay and elsewhere in the Coromandel Peninsula there is a mica quartz diorite (tonalite) forming minor intrusions. (*c*)

(*a*) Recent analyses have shown that the isotropic matter is grossularite.

(*b*) Further researches by Mr. J. P. Smith have shown that a complete vogesite-camptonite-theralite series is represented in the boulders, and there is also a highly-interesting rock—a spherulite porphyry with much riebeckite.

(*c*) A recent expedition by the author showed that there is a large mass of diorite at Mongonui, and another large mass of olivine norite with Ahipara as a centre. This rock is very fresh, but contains little hypersthene, and olivine is usually abundant and unweathered.

Granites and granophyres, with various types of volcanic rocks, are abundant as pebbles in conglomerates of Maitai (Carboniferous) and Triassic age throughout the colony, from the North Cape to Waipapapa Point. In almost every instance it has so far been found impossible to trace them to their origin.

So far as known, dyke rocks are relatively uncommon throughout the country, and true sills are almost unknown. Exceptions to this statement are to be found in many of the volcanic districts, notably Dunedin; but they will be described when the volcanic areas are dealt with.

There is a well-defined system of dyke rocks of the camptonite-monchiquite series, which extends along the Southern Alps from the Taramakau to the Shotover. Dr. Bell has mentioned several of these at the camptonitic end of the series in his bulletin of the Hokitika quadrangle recently issued. In that area the dykes penetrate granitic rocks. Mr. J. P. Smith has sent me specimens of similar dykes penetrating granite near Lake Brunner, as well as a vogesite from gravels in the same locality. I have obtained similar rocks near the Big Wanganui, further south, and from the Shotover gravels specimens of true monchiquite can be obtained in quantity; but I have found none further south, though to the east they extend some distance down the Kawarau Valley, according to Professor Park. Except that the date of intrusion of these rocks is subsequent to the age of the granite, there is no information as to their age.

There is a porphyrite dyke at the Nuggets, and numerous diabase dykes at Reefton and at Moeraki, and dykes of quartz porphyry at Brunner.

In the South Island there is at Nelson and at Orepuke, as well as several intermediate places, a well-defined lava of Maitai age. In hand specimens the rock is green, and in thin section the coloring is found to be due to chloritic and serpentinous matter evolved during the changes that the rocks have undergone. The felspar is much decomposed, and is apparently labradorite. Augite (idiomorphic) is abundant in large crystals of a very pale yellow color and pseudomorphs of serpentine after olivine. The rock is often vesicular. The substantial identity of this rock throughout the South Island causes me to class it everywhere as a melaphyre, though in two different exposures Hutton classed it as leucophyre and diabase, and Sir J. Hector and his officers called it aphanite.

Later volcanic rocks occur in the Clent Hills and further north. The largest development is in the Mount Somers area; but there is a nearly continuous outcrop from the Waimakariri to the Rangitata. The most characteristic rock is a white rhyolite, with abundant quartz and usually a good deal of almandine. Glassy varieties are also common, and typical pitchstones are frequent. No spherulitic structure or development of crystallites other than globulites occur, and the glass is therefore particularly transparent. A white rhyolite, similar to the one mentioned above, occurs also at the head of Lyttelton Harbor.

The other rocks of this volcanic district are andesites (mica, augite, and hypersthene varieties). They were called melaphyres by Haast, though Hutton afterwards described their true nature. In a few instances the hypersthene is replaced by enstatite. The ground mass of these rocks is hyalopilitic, but the felspar microlites seldom have a parallel arrangement and augite microlites are more abundant than felspar in the light-brown glass.

The period of eruption of these rocks appears to have been the later Jurassic, for the tertiary rocks rest on them unconformably, and the lavas have shared in the folding to which the underlying Jurassic sediments have been subjected. They constitute the quartz porphyry and melaphyre system of Van Haast.

Volcanic rocks of Post-Miocene date are common on both east and west coast districts. For the greater part these rocks are basalt. This is the case at Mount Pleasant, in Southland. At the Haast mouth and at Koiterangi, in Westland, the same is the case. Basalts are said by the geological survey to occur in the Awatere and Clarence Valleys. Basalts and dolerites are abundant near Palmerston and at Waihola. At Timaru and Oamaru there are similar rocks, but at the latter place much of the rock is glassy, and true tachylite is in great quantity. In associated tuffs at Kakanui, large masses of augite, hornblende, felspar, and peridotite occur. It is impossible to say exactly what is the age of this series of volcanic rocks. They are spoken of above as Post-Miocene. New Zealand geologists, as a body, would hardly assent to this statement. With the exception of the Oamaru occurrences the volcanics rest everywhere upon Cainozoic rocks, usually unconformably. The exact age of these sedimentaries has been a rich subject for argument and dispute. Sir J. Hector and the officers of his survey classed most of them as Cretaceo-Tertiary. Captain Hutton considered them Oligocene, and Professor Park thinks them Miocene, which agrees with the views of the present author.

The Oamaru occurrence is rather different, for here the dolerites and tachylites are interstratified with sediments to which these various ages have been assigned. They are, therefore, slightly older than the others.

The main volcanic areas of the South Island are Otago Peninsula and Banks' Peninsula. The former has clear relations to underlying sediments of the doubtful age referred to above. It is unconformable to them, and, in the author's opinion, must be late Miocene or even Pliocene. The rocks are of very varied and peculiar types. They have been described in the Q.J.G.S., 1906, and it is impossible in a general paper of this kind to do more than indicate the nature of the variations.

Nepheline syenites occur sparingly. Tinguaites are abundant, and show connection with camptonites, teschenites, and bostonites.

A very large series of true volcanic rocks is present. It includes trachytes, which differ from the bostonites only in geological occurrence. Phonolites are in great quantity and variety; trachytoid and nephelinitoid types being represented. Cossyrite is frequent in the more alkaline types, and sodalite is abundant in one of them. Andesites of an alkaline type are well represented, and there are trachydolerites and basanites. One leucitophyre occurs sparingly. Basalts and dolerites are in alternating lava flows with the phonolites, and are subsequent to the trachytes.

Banks' Peninsula is composed chiefly of andesites, especially of a variety of olivine andesite, with very large porphyritic felspar and augite. Basalts and dolerites occur chiefly among the later lavas and in dykes. In addition, there is a trachyte, with large crystals of tridymite near Lyttelton. Two dykes of trachytoid phonolite only have been recognised at present, in one of which Mr. Speight has recognised arfvedsonite.

In the North Island volcanic activity has been almost continuous from early Cainozoic times to the present day.

The earlier volcanic eruptions appear to have been confined to the Coromandel Peninsula and the country to north of that area. Waitakerei, Great Barrier Island, Little Barrier Island, Whangerei Heads, Whangaroa Heads and numerous other places, including Hen and Chicken Islands, have rocks of similar nature and appear from their stratigraphical position and extent of decomposition to be of similar age. The commonest rock is hypersthene augite andesite. In the Coromandel area the hypersthene has been greatly chloritised, especially in those portions bordering on the quartz veins, and it has been supposed that hydrothermal action has caused the change, and that one of the results has been the removal of supposed metallic matter in the hypersthene and a subsequent concentration of the metal in the quartz veins.

These andesites have been fully described by Professor Sollas, in a work lately published by the New Zealand Government. Unfortunately, no attempt has been made in that work to define the area over which each rock occurs. A chronological classification of the rocks by Mr. McKay is given. Each division appears to include rhyolites, with andesites, and the age varies from Eocene to Pliocene. No attempt is made to indicate the areas of different rock types within each group. Professor Park classed the andesites as the older rocks of Eocene age, and this arrangement has been provisionally accepted, though it is not improbable that the rocks are younger than this.

Associated with the hypersthene andesites are other types, probably of the same age. Professor Sollas has recognised hornblende andesite, dacite and various glassy types, while the structure of the ground mass is widely different in different samples. Outside of the Thames and Coromandel region Capt. Hutton recognised hypersthene augite andesite at Whangarei Heads, while I have found a similar type abundant at Waitakerei. At Little Barrier Island a hypersthene andesite without augite appears to be the prevailing rock, judging from specimens forwarded to me by Mr. T. Cheeseman. At the Hen and Chickens Islands dacite and hornblende andesite is the characteristic type, so far as I can judge from specimens given me by Mr. C. N. Boult.

Hochstetter mentions many occurrences of breccia as similar to those of Waitakerei and Whangarei Heads, and the probability is that they contain the same rock—hypersthene augite andesite ; but I have had no opportunity of examining them, and no work has been published on them at present. At Whangaroa this rock occurs in the breccia, with hypersthene hornblende andesite.

There is in the Coromandel Peninsula another series of volcanic rocks widely developed that has generally been regarded as much younger. It consists of rhyolitic rocks of very variable structure and appearance. Quartz is relatively rare in these rocks, and the felspar is often of a triclinic variety. In many instances the excess of silica is in the form of tridymite. The structure is very variable. At Paku Island, in particular, but in many other localities as well, spherulites of a very large size—not infrequently 1in. in diameter—constitute the main mass of the rock. The spherulites have the pseudopodial form of Rosenbusch. They have been described by Rutley and by Sollas, who speaks of them as cerviform. Rutley thinks they are due to devitrification. Sollas says they are the result of decomposition. They have been well figured by Rutley, and McKay has made good photographs of them, which have been published with the notes of Professor Sollas on the rocks. To me, the spherulites appear to be the original structures, though I cannot at present offer any explanation of their formation.

Amongst the larger spherulites, and between their arms, are numberless microscopic ones. In many rocks these occur without the large ones, and may be arranged in rows or layers, when they give a very prominent banded appearance to the whole rock, and under the microscope they merge into axiolites. In addition, there is a third type of spherulite of intermediate size and opaque, except in very thin sections. They are always perfectly spherical, and the size usually is that of a pea. The causes that have resulted in these different structures appear to me to be beyond discovery by microscopic observations. Very careful chemical work seems more likely to give a clue to the origin than any study with the microscope. So far as I have seen, the rhyolites with coarse spherulites have little glassy residue. This appears to be the case also in the rocks composed of the spherulites of microscopic dimensions. In the third type of spherulitic rhyolite there is usually a large amount of glassy base, and the rock becomes a spherulitic pitchstone, and varies into a true obsidian, like that at Mayor Island. The glass is usually filled with trichites, which are clearly curved rows of globulites.

The rocks with pseudopodial spherulites are usually destitute of crystals of any mineral except quartz, in small nests of irregular grains. The others usually have crystals of trichinic felspar, hypersthene, and, less frequently, hornblende or biotite.

From the Coromandel Peninsula rhyolites extend over a very large area to the south and west, but the spherulitic character is less developed than in the Coromandel, though examples are not infrequently found.

On the west the rhyolite rocks extend to Taumaranui. On the south to the Kaimanawa Range. In general, there are huge nearly horizontal lava flows resting upon Upper Miocene rock. The rock is generally white, with phenocrysts of felspar rather abundant. In section the base is very glassy, yet with a structure related to a flow structure producing a pattern not unlike the damascened appearance of a gun barrel. The felspar is usually andesine. Hypersthene is usually common, but other minerals rare. Everywhere the rocks are covered with a thick mantle of pumice. The pumice has been distributed in some measure by water, and is often hundreds of feet thick. It is mingled with charred wood, evidently carried down in the flood with the pumice. In places several old soils can be distinguished between successive layers of pumice. The pumice contains the same minerals as the rhyolite, and on the shores of Lake Taupo, where it has been triturated by the waves, crystals of hypersthene can be gathered in large numbers, as noted long ago by Hutton. These crystals in some cases give a good interference figure. The dispersion and opticaxial angle are those characteristic of hypersthene.

Throughout this district there are no cones from which it can be said that the flows of rhyolite proceeded. There are several rhyolitic mountains, *e.g.*, Tarawera Ngongotaha, but in them, as elsewhere, the rhyolitic lavas appear but little inclined. It is probable that the tremendous emissions of pumice have levelled up the contours of the country and obscured the cones.

Through the rhyolite plateau there are several projecting cones, often of large dimensions—Ruapehu, Ngauruhoe, Tongoriro, Kakepuke, and many others. In nearly all cases where these have been examined they have been found to consist of andesitic rock. The fact that their more recent lavas have a surface free from pumice shows that their emission was subsequent to the eruption of pumice. On the other hand, the fact that their older lavas are covered by pumice does not prove that any eruptions of pumice succeeded their emission. It must always be borne in mind that the light pumice is always being redistributed by running waters, and at the eruption of Tarawera there was a striking illustration of the manner in which pumice might be scattered far and wide by an andesitic eruption, for augite andesite was, so far as known, the only fused rock matter that accompanied that eruption.

All the rocks of these cones that I have seen are hypersthene andesites. (*d*) Seeing that Hill has mentioned phonolites as occurring on Ruapehu, and Hutton has mentioned hornblende andesites, and Thomas augite andesites from Ngauruhoe and Tongariro, I revisited these mountains to find out whether my previous collections had been representative. On the south, south-west, and east sides of Ruapehu I found nothing but hypersthene augite andesites, and the same is true of the other mountains. I also carefully examined the gravels of the

(*d*) Specimens recently sent to me by the Rev. W. Fletcher, of Taupo, show that Tauhara is an exception to this statement. The rocks of which it is composed are different textural forms of dacite, with large quartz and reddish-brown hornblende.

Wanganui at Pipiriki, for the river and its tributaries drain the western side of the mountains. Here again I found nothing but hypersthene andesites, so I am forced to think that the other identifications are due to mistakes of some kind. On Ruapehu, at 6,500ft. on the south-west, a spur is composed of an exceedingly fissile light-grey andesite, with distinct grains of olivine. Under the microscope these grains are found to be surrounded by small crystals of hypersthene. This fact appears to confirm Professor Sollas' statement that in some of the Thames andesites hypersthene seems to replace olivine. Hutton has described hypersthene andesites from many of the other cones. It may, therefore, generally be stated that the cones that project from the rhyolite plateau are composed of hypersthene andesites. It will be remembered, on the other hand, that the rock expelled as banks from Mount Tarawera was described by Thomas as an augite andesite. My specimens of this rock are highly vesicular fine-grained hypersthene augite andesites.

In the region of the large volcanoes some of the lava flows have been completely eroded, especially in Tongariro, where the valleys are sometimes 500ft. deep in the gently sloping lava flows. Into these valleys recent lavas have flowed from Ngauruhoe. This seems to indicate a period of relative quiescence of considerable duration. The formation of the cone of Ngauruhoe, and of some craters in Tongariro, are the result of recrudescence of activity.

Outside of the main volcanic plateau there are isolated centres of activity. Mount Egmont is one of these. The specimens given me by Mr. R. Browne, from all parts of the mountain, are hornblende augite andesites, with a hyalopilitic ground mass. The rock is quite similar to that of the Sugar Loaves at New Plymouth. It has been described by Hutton. The specimen of this type of rock described by Hutton from Mount Ruapehu was probably wrongly labelled, for he describes a hypersthene andesite from the Sugar Loaves which, from the description, appears to be a Ruapehu rock. After careful search in these two localities for the rocks described, the author has come to the conclusion that Hutton's labels were mixed.

Two other isolated centres are at Pirongia and Karioi. The rocks, in common with those of Ruapehu, and of other andesitic cones, have been called trachydolerites My specimens are all dolerites, with large grains of olivine and augite. Hochstetter mentioned the former as a basaltic cone.

From the basin of the Waikato, almost as far south as Drury, to Auckland, in the north, there is a plateau of basalt. Its complete continuity is interrupted a little south of Auckland ; but the numerous cones on the Auckland isthmus supply a continuation. In its southern extension the surface of the basalt is very much weathered, while the surface of the lava flows from many of the Auckland cones is still absolutely fresh. Notwithstanding this apparent difference in age, the microscope shows that the rocks are essentially identical. In all cases that I have tested, the rock powder gelatinises with acid, and the evaporated solution yields crystals of sodium chloride. This indication of the presence of a felspathoid mineral is supported by staining tests. The mineral is probably nepheline, but it is present in very small quantity. Its presence justifies the classification of the rock as a basanite. The basanite is extremely rich in olivine. Magnesia has a percentage of 10 in the bulk analysis.

In the crater that is now the Domain cricket ground, in Auckland, there are blocks of a coarse-grained rock that have evidently been expelled during an eruption. Microscopical examination shows that it is a basanite with doleritic structure. The nepheline is abundant; olivine in elongated crystals. The augite is ophitic, enclosing large crystals of andesine. In places it is intergrown with nepheline, producing a micrographic structure. Menaccanite is well developed. Except for the presence of felspar, the rock closely resembles the nephelinite of the Lobauer Berg.

In the peninsula to the north of Auckland comparatively recent basaltic rocks cover a large area. The cones still retain a perfect form in many cases, and the lava flows are but slightly decomposed on the surface. Sections show a complete identity of the rocks with those of Auckland. They belong to the same class, and probably to the same period of activity.

From this rapid and general survey it will be noticed that the order of events in the volcanic history of the North Island appears to me to have been as follows:—

1. Eruption of andesitic rocks at Coromandel Peninsula, Waitakerei, Barrier Island, Whangarei, and elsewhere in the north.

2. Extensive eruptions of rhyolitic rocks over a wide area.

3. Eruptions of andesitic rocks in the central area and perhaps at Mount Egmont.

4. Basaltic eruptions in the Waikato region and at Auckland.

5. Renewed activity in the Tongariro region, with fresh andesitic eruptions. Similar activity at White Island and at Tarawera.

In this summary I have omitted all reference to the eruptions which formed Pirongia and Kerioi, as I know of no criteria that give a clue as to the relative age of such eruptions, though the fact is perhaps suggestive that their composition and structure is very similar to some of the basic rocks of Post-Miocene age at Dunedin.

In this brief survey no reference has been made to occurrences of volcanic rocks at Hick's Bay, East Wellington, and some other localities. This is due to the fact that I have had no opportunities of examining rocks from these areas.

Recent collections made by Mr. R. Speight on the north side of Ruapehu have included specimens of hornblende hypersthene andesite. The hornblende is abundant, and much browner and more pleochroic than in the Mount Egmont rock, and the hypersthene is very abundant. A similar rock occurs at A Taura, a hill 5,000ft. high, between Ruapehu and Ngauruhoe. This is possibly the rock referred to by Hutton.

SURVEYOR GENERAL'S OFFICE ADELAIDE A Vaughan Photo-lithographer

2.—ON THE RELATIONSHIP OF THE GENUS *GIRVANELLA*, AND ITS OCCURRENCE IN THE SILURIAN LIMESTONES OF VICTORIA.

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[WITH THREE PLATES.]

INTRODUCTION AND DESCRIPTION OF THE GENUS.

The genus *Girvanella* was established by the late Professor H. A. Nicholson and Mr. R. Etheridge, jun., in 1880, to include certain minute tubular organisms, which had also been noticed by Dr. H. B. Brady, occurring with some frequency in the Craighead limestone (Ordovician) of Girvan, Ayrshire. Similar nodule-forming organisms have since been met with in limestones of various ages, ranging from the Cambrian to the Jurassic; and others, no doubt allied to fossil forms, exist at the present day. As a rock-forming agent *Girvanella* has played a very important part in Palæozoic and Mesozoic times, and it has been shown in detail by Wethered and other investigators that many of the oolitic rocks of Jurassic and Carboniferous ages partly owe their origin to this microscopic fossil.

The question of the nature of this tubular organism, whether a form of animal or plant life, has not yet been satisfactorily answered, but the general consensus of opinion is in favor of the latter view. Some authors believed it to be of animal origin, and one of the foraminifera, or even a sponge, although there seems to be no evidence to support the latter view, whilst others equally held it to be a form of the calcareous algæ. Any fresh evidence, therefore, bearing on this question, which may help to settle the relationship of *Girvanella*, is of scientific value, and in view of this the following notes have been written.

The original description of the genus *Girvanella* is as follows (*a*):—"Microscopic tubuli, with arenaceous or calcareous (?) walls, flexuous or contorted, circular in section, forming loosely compacted masses. The tubes, apparently simple cylinders, without perforations in their sides, and destitute of internal partitions or other structures of a similar kind."

The first-described species was thus defined (*b*)—"*Girvanella problematica*, Nich. and Eth., jun., sp. nov. Spec. Char.—Tubes from 1-600th to 1-700th of an inch in diameter, not observed to taper, twisted together in loosely reticulate or vermiculate aggregations of a rounded or irregular shape, which seem to be mostly from 1-20th to 1-10th of an inch across."

OUTLINE OF RECORDED OCCURRENCES.

After the discovery of *Girvanella* in the Upper Ordovician limestone of Scotland by Nicholson and Etheridge, jun., Mr. S. A. Miller,

(*a*) Nicholson and Etheridge, jun. ('80), p. 23.
(*b*) Nich. and Eth. ('80), p. 23, pl. IX., fig. 24.

in 1882, described (*c*) a nodular organism found in great abundance in the limestones of Indiana, belonging to the Cincinnati group (Upper Ordovician). The nodules described by Miller have an average diameter of about a centimetre, and consist of "numerous irregularly concentric, more or less wrinkled, calcareous laminæ, separated by interlaminar spaces filled with minute vertical tubes." These fossils had already been noticed by Dr. J. T. Plummer, who, in a communication to the *American Journal of Science*, referred to them as "pisolitic balls embedded in the solid rock," and stated that the pisolite stratum varied from 2ft. to 10ft. in depth. To these nodules Miller gave the name *Stromatocerium richmondense*, believing it to be a stromatoporoid referable to J. Hall's genus. Some years later Professor Nicholson received examples of fossils regarded as "*S. richmondense*" from Mr. E. O. Ulrich, and, from a microscopical examination of these, concluded that they belonged partly to the genus *Girvanella*, but of a species distinct from *G. problematica*, as shown by their smaller tubules (*d*). At the same time Nicholson pointed out that some of the associated nodules were of an entirely different character, being of a more compact and uniform structure, and referable to *Solenopora compacta*, Billings.

Dr. G. J. Hinde, in 1887, (*e*) drew attention to the identity with *Girvanella* of the supposed calcareous sponge described by Professor H. M. Seeley,(*f*) in 1885, as *Strephochetus ocellatus*, which occurs in the Chazy limestone (Lower Ordovician) of North America. Nicholson also was satisfied as to the *Girvanella* relationship of this organism, and expressed the opinion that it may probably be specifically distinct from *G. problematica*.(*g*) Hinde further showed (*loc. cit.*) that Dr. Bornemann's then recently described genus *Siphonema*, represented by small rounded masses like nullipores, and consisting of a bundle of minute curved tubes, is likewise identical with *Girvanella*. These little nodular bodies, occurring in some abundance both in the Gotlandian (Silurian) limestones of the Baltic and in the Cambrian limestones of Sardinia, were regarded by Bornemann as calcareous algæ, and allied to living, subærial forms. Nicholson, in 1888,(*h*) further noticed some organic remains in the Carboniferous limestone of the North of England, which, although ill-preserved, were thought to be referable to *Girvanella*.

The Jurassic beds of England yielded very interesting results with regard to *Girvanella* in the hands of Mr. E. Wethered, for he showed, in 1889,(*i*) that certain pea-grits in the Corallian and Inferior Oolite were largely due to the encrusting tubules of that little organism enveloping detrital organic fragments derived from echinus spines, polyzoa, crinoids, molluscan shells, and foraminifera. One of the most characteristic forms Wethered named *G. pisolitica*. In another paper, read before the Geological Society in 1889,(*j*) the same author brought forward further interesting evidence as to the occurrence of

(*c*) Miller ('82), pp. 41, 42, pl. II., figs. 1, 1*a*, *b*. (*d*) Nicholson ('88), p. 24.
(*e*) Hinde ('87), p. 227. (*f*) Seeley ('85), p. 355. (*g*) Nicholson ('88), p. 24.
(*h*) Nicholson ('88), p. 24. (*i*) Wethered ('89), p. 196. (*j*) Wethered ('90), p. 270.

the genus in oolitic rocks of both Carboniferous and Jurassic ages, and he also described several new forms. Another paper by Wethered (k) dealt with the Inferior Oolite of the Cotteswolds, and *Girvanella* was recorded generally throughout the beds, but especially in the pea-grit series. In the Devonian limestones of England *Girvanella* appears to be exceedingly rare, so far as Wethered's observations extended; (l) however, he has recorded and figured (*loc. cit.* pl. IX., fig. 3) a fasciculate tubular organism, which he considered suggestive of an alga, from the limestone of Hopes Nose, Devonshire. The diameter of the tubes in this form are comparable with some of those found in the Victorian limestones, and the fossil is no doubt referable to *Girvanella*. Wethered described other occurrences of *Girvanella* in the Wenlock limestone of May Hill, West Malvern, and Ledbury, (m) and showed it to be of considerable importance as a rock-forming organism in that formation. In the Wenlock limestone *Girvanella* generally encrusts detrital organic fragments, and two kinds of tubules, large and small, are often associated in the same aggregate.(n)

In Australia the remains of *Girvanella* have been previously described from South Australian rocks of Cambrian age by R. Etheridge, jun.,(o) from the Carboniferous oolite of Lion Creek, Stanwell, near Rockhampton, Queensland, and in oolitic rock from County Murchison, New South Wales, by Messrs. R. Etheridge, jun., and G. W. Card.(p)

PUBLISHED VIEWS OF THE RELATIONSHIP OF *GIRVANELLA*.

Rhizopoda.—The original authors of the genus, Messrs. Nicholson and Etheridge, jun., were of the opinion that *Girvanella* found its nearest alliance with the Rhizopoda, and especially with the genus *Hyperammina*, Brady.(q) This view was also taken by Dr. H. B. Brady, who supported it by making a critical comparison with the recent *H. vagans*; (r) and, in again referring to *Girvanella* in his Report on the *Challenger* Foraminifera, he says (s)—"It is more than probable that the Silurian organism to which the provisional name *Girvanella* has been given by Nicholson and Etheridge may be a somewhat minute variety of the type closely allied to *Hyperammina vagans*; and similar forms more distinctly characterised have been found by Dr. Haeusler in the Jurassic rocks of Switzerland." Brady further expresses the opinion (*loc. cit.*, p. 261) that Nicholson and Etheridge's "description applies in every particular to such specimens of *Hyperammina vagans* as are represented in figures 7 and 8 [Rep. *Chall.*]: and the specific

(k) Wethered ('91), p. 550. (l) Wethered ('92), p. 378.

(m) Wethered ('93), p. 236.

(n) The present writer has found, however, a pellet-forming *Girvanella* in the Wenlock limestone of Dudley—see *postea*, p. 384.

(o) Etheridge, jun. ('90), pp. 19, 20.

(p) Etheridge, jun., and Card ('00), pp. 26, 27, 32.

(q) Nich. and Eth., jun. ('80), p. 24.

(r) Nich and Eth. jun. ('80), p. 23. (s) Brady ('84), p. 257.

characters which follow agree equally well, except in a single point, namely, that the diameter of the tubes in *Girvanella* is from 1-700th to 1-600th of an inch, whereas those of the present species range from 1-500th to 1-120th of an inch. Some latitude must be allowed in estimating the characters of a minute fossil belonging to so very remote an age, but it seems scarcely worth while to recognise these trifling differences as a basis of generic distinction."

Subsequent to the publication of the original description of *Girvanella*, Nicholson was inclined to regard *Syringammina fragillisima*, Brady, as the form of rhizopod more closely allied to *Girvanella*; (*t*) and a similar tendency was shown by that author in his "Manual of Palæontology" published a year later,(*u*) for there he refers to *Girvanella* in the following words:—"The most probable view of the relationships of this singular fossil is that it is an arenaceous foraminifer, allied to the recent genera *Syringammina* and *Hyperammina*." From Rothpletz,(*v*) however, we learn that Nicholson, writing to that author in July, 1890, expresses himself as not averse to the opinion of the algal origin of *Girvanella*, since he had observed it, as did also Rothpletz and Wethered, to show a branching habit.

Prior to 1893 Wethered accepted the rhizopodal relationship of *Girvanella*, but since the renewed work by Rothpletz and others, who upheld its vegetable origin, he seems to have been almost won over to the side of the algologists, for he then writes,(*w*) "I certainly think that the forms which I have discovered in the Wenlock limestone seem more favorable to the vegetable theory of the origin of this fossil than those described in my former paper, and possibly it may be allied to the calcareous algæ; more than this, however, I cannot say. Further investigation may throw light on this interesting question; but, whether it be a vegetable or animal, it is certainly a very low form of life, perhaps the lowest of which we have knowledge in a fossil state."

Other Animal Groups.—The fossil erroneously referred by Miller to the somewhat indefinite stromatoporoid genus *Stromatocerium*, J. Hall, as *S. richmondense*, is synonymous with *Girvanella*, as was pointed out by Nicholson.

Strephochetes, another synonymous genus, was regarded by Seeley as "a free calcareous sponge showing in structure concentric layers composed of minute twining cells." (*x*)

Algæ.—Bornemann, (*y*) in 1887, described his genus *Siphonema*, now identified with *Girvanella*, as an alga.

Rothpletz (*z*) examined typical examples of *G. problematica* which he had received from Nicholson, and concluded that they were structurally related to the algæ; and in comparing them with *Sphærocodium*, a somewhat similar nodule-forming organism from the Trias and Rhætic of the Eastern Alps, remarked on the absence of sporangia

(*t*) Nicholson ('88), p. 23. (*u*) Nicholson and Lydekker ('89), p. 128.
(*v*) Rothpletz ('91), p, 302. (*w*) Wethered ('93), p. 246.
(*x*) Seeley ('85), p. 355. (*y*) Bornemann ('87), pl. II.
(*z*) Rothpletz ('91), p. 301, pl. XVII., figs. 8, 9.

in *Girvanella* which appear to be present in the former genus. Whether the structures now met with in the Victorian limestones are at all comparable with those seen in *Sphærocodium* remains to be proved by additional and better-preserved specimens.

Whilst discussing the algoid affinities of *Solenopora*, Dr. A. Brown(*a*) expressed his opinion that the relationships of *Girvanella* lie with the *Siphoneæ verticillatæ*. A valuable and interesting resumé of the investigations upon organisms related to algæ which perform the work of rock-formation, was given by Mr. A. C. Seward in 1894.(*b*) The subject was again discussed and summarised by the same author in 1898,(*c*) who was then inclined to provisionally place *Girvanella* in the *Cyanophyceæ*. The present writer (*d*) also has recently expressed his view as to the probable algoid nature of *Girvanella*, derived from an early acquaintance with these organisms in the slides prepared by Mr. Wethered, and from several other examples since collected.

THE EVIDENCE FOR THE RHIZOPODAL NATURE OF *GIRVANELLA*.

Although it may appear to be somewhat belated to bring forward evidence against the view that *Girvanella* may belong to the foraminifera, this part of the subject has never been carefully criticised or refuted.

With regard to the supposed alliance of *Girvanella* with *Syringammina* it may be briefly pointed out that, beyond the fact the latter is a tubular arenaceous organism, no further comparison can be safely made. *Syringammina* (*e*) possesses a test composed of loosely aggregated sand grains, and is built up to form a series of branching, radiating, and inosculating tubes. The morphology of the test does not easily recall *Girvanella*, with its finely calcareo-granular tube, which rarely branches, but often reverts or coils upon itself. The large size of the tubes in *Syringammina* (averaging nearly 1 mm. across) is an additional distinctive character.

ITS ALLIANCE TO *HYPERAMMINA VAGANS* CONSIDERED.

The genus *Hyperammina* (Brady, 1898) comprises several species, most of which are remarkable for their relatively large size, having arenaceous tubes of a coarse texture. The only species of this genus with which a comparison can be made is *H. vagans*, Brady,(*f*) and there is no doubt of the striking and mimetic resemblance which that species bears to *Girvanella*. A closer examination, however, will show that there are certain characters borne by *Girvanella*, apart from size, which forbid our placing it with *Hyperammina*, or any other known rhizopod. As regards dimensions, the tubular shell of the smallest examples of *Hyperammina vagans* is slightly larger than the largest known form of *Girvanella*, and much larger than the type form *G. problematica*. In

(*a*) Brown ('94), p. 203. (*b*) Seward ('94), see especially pp. 12-16.
(*c*) Seward '98), pp. 124-6, p. 160. (*d*) Chapman ('02), p. 125.
(*e*) Brady ('84), p. 242. (*f*) Brady ('84), p. 260.

Hyperammina vagans the tube normally commences with a bulbous or drop-shaped primordial chamber; in *Girvanella*, in one species at least, it commences with a long segmented series (*g*) of ovoid and somewhat irregular chambers or cells, which are doubtfully calcareous, and probably originally of the nature of cellulose. The evenness of the granular structure of the walls of the tube-cell in *Girvanella* is not characteristic of the tests of the rhizopoda, which, in the arenaceous group, are formed of adventitious sand-grains. The branching of the tube as seen in *Girvanella* is unknown in the group of rhizopods to which *Hyperammina* belongs. The oblique septation of the early cells in *Girvanella* is also quite at variance with that seen in the foraminiferal genus in question; and the irregularity in the shape and size of the cells or segments is practically unknown in that group of organisms.

EVIDENCE FOR THE RELATIONSHIP OF *GIRVANELLA* WITH THE *THALLOPHYTES*.

In the examples of *Girvanella*, which possess fine tubes of an indefinite length, it has been difficult to discover the earlier stages of the organism; but in a more coarsely tubular form, found in some abundance in the Victorian limestones, and which is evidently more or less allied to *G. pisolitica*, Wethered, there seems invariably to be a somewhat extended series of ovoid cells, generally repent upon crinoid fragments, which at first sight the writer was inclined to regard as a minute modification of the foraminifer known as *Gypsina*. On closer examination under the higher powers of the microscope, it was seen that the cell-walls of this organic structure were non-perforate, thick-walled, chitinous in appearance, and peculiarly wrinkled or cracked along the diagonals of the subquadrate cells, reminding one of the aspect of certain modern vegetable cell-structures when undergoing shrinkage. A similar system of shrinkage cracks may also be observed in the cell walls of "macrospores" or sporangia found in spore-coals, which also seem to be produced by the drying of the original vegetable structure. This phenomenon lends strong support to the conjecture that these cells of the initial stages in certain *Girvanellæ* are, like the macrospores, of vegetable origin. The diagonal shrinkage of the cell-walls in the *Girvanella* above described further reminds one of a similar structure seen in Rothpletz's figures of "Schlauche mit Sporangien" in *Sphærocodium*.(*h*) The initial series of ovoid cells has already been figured by Wethered,(*i*) but not alluded to by that author: they occur in a section of a pisolitic granule formed principally of the tubes of *G. pisolitica* from the Inferior Oolite of Cheltenham, England. One of the series of cells of an example from the Tyers River, Victoria, measures a little over a millimetre in length, whilst the average maximum and minimum axes of the cells themselves measure .089 mm. and .055 mm. respectively. Frequently the initial series appears arrested in its further growth: but where this continues it shows a passage into more and

(*g*) An exception to this, however, is shown in Wethered's figure of the bulbous commencement in an example of *G. pisolitica* (Wethered, '90, pl. XI., fig. 3).

(*h*) Rothpletz ('91), pl. XVI., figs. 4, 5. (*i*) Wethered ('89), pl. VI., fig. 10.

more elongated cells, at first fusiform and obliquely partitioned, finally passing into a simple tube of the appearance of a typical *Girvanella*, but not produced to so great a length as in the finer-tubed species. In one instance at least, the earliest cell is seen lying within the axial canal of a crinoid arm-ossicle, and bears numerous papilliform outgrowths near its free extremity (see pl. I., figs. 5, 6.)

The larger tubed forms of *Girvanella* are strongly suggestive of a relationship with the siphoneous algæ, and possibly, when their structure is better understood they may have to be separated from the finer-tubed organisms as a distinct group represented by *G. problematica*. The latter group, including Wethered's *G. incrustans*, a species name, by the way, which is preoccupied by Bornemann's,(*j*) seems to show more affinity towards the cyanophyceous or blue-green algæ, as Seward, (*k*) in his excellent summary of the subject, is inclined to believe ; and if that be the case they are not calcareous algæ in the strictest sense of the term, on account of the sheaths enclosing the filaments being merely encrusted, as distinguished from an actual deposition of carbonate of lime within the tissues of plants like the siphoneæ, and other calcareous algæ.(*l*)

FORMS OF *GIRVANELLA* OBSERVED IN THE VICTORIAN SILURIAN LIMESTONES, AND THE SOUTH AUSTRALIAN CAMBRIAN LIMESTONE.

One of the commonest forms of *Girvanella*, occurring in both the Cave Hill, Lilydale, and the Tyers River Limestones, is nearly related, if not identical with, the *G. incrustans* of Wethered.(*m*) This specific name should be changed, however, for the reason previously mentioned, and the name *G. wetheredii* is now suggested. Wethered described the original specimens from the Carboniferous limestone of Clifton, England. The diameter of the tubes in our examples measures .014 mm., being slightly larger than those described by Wethered. The pellets formed by the aggregation of tortuous tubes sometimes attain a length of .7 mm.

Another form of *Girvanella* frequently met with in the Victorian limestone is a new species which the author has named *G. conferta*.(*n*) This species is distinguished by its short, fasciculate masses of tubules, with a parallel or sinuous habit of growth, rather than a continuously tortuous one ; and it generally forms pellets entirely composed of its own tubules, without any apparent enclosed nucleus or granule of attachment, although that may be present, but of small size. The

(*j*) The *Siphonema incrustans* of Bornemann ('87, p. 18, pl. II., figs. 1, 2) has been pointed out by Hinde to be a true *Girvanella*, and as such would be referred to as *G. incrustans*, Born. sp. Bornemann's species, however, is identical with the earlier described *G. problematica*, Nich. and Eth., jun. The still later described *G. incrustans* of Wethered ('90, p. 280), is a species distinct from Bornemann's, and by the rule of "once a synonym always a synonym," it must be given a new name. I would therefore suggest for this species *Girvanella wetheredii*, sp. nov.

(*k*) Seward ('98), p. 124. (*l*) Seward ('94), p. 15.

(*m*) Wethered ('90), p. 280, pl. XI., figs. 1*a*, *b*. (*n*) Chapman ('06), p. 74.

tubes in *G. conferta* measure about .017 mm. in diameter; the pellets are often as much as 3 mm. in length. This species also occurs in the Wenlock limestone of Dudley, England (*o*) (pl. III., fig. 2).

The third Victorian form noticed is in all probability referable to *G. pisolitica*, Wethered.(*p*) A detailed description of this larger-tubed form as it occurs in the Victorian limestones has already been given (see ante, p. 382).

In a thin slice of the Lower Cambrian limestone of Ardrossan, South Australia, for which I am indebted to Mr. Douglas Mawson, B.E., there is a form of *Girvanella* without doubt referable to *G. problematica*(*q*), as shown by its loosely aggregated and contorted tubules. The diameter of these tubes (about 1-500in.) is, however, only half that of the typical species from Girvan. There is so much variation in the size of the tubules, even in the same limestone specimens, as originally recorded by Nicholson and Etheridge, that this slenderness is not of primary importance.

SUMMARY AND CONCLUSIONS.

1. The tubular organisms included under the name of *Girvanella* which have already been recorded from other countries in strata of Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and Jurassic ages, as well as in the L. Cambrian of South Australia and the Carboniferous of Queensland and New South Wales, occur as important rock-formers in the limestones of Victoria, of Silurian (Yeringian) age.

2. There appear to be at least three forms of the genus present in the Victorian limestones, viz., *G. conferta*, Chapman.; *G. cf. Wetheredii*, Chapm. (= *G. incrustans*, Wethered, non Bornemann); and *G.*(?)*pisolitica*, Wethered.

3. The genus *Girvanella*, which has been variously assigned to the foraminifera, sponges, stromatoporoids, and calcareous or encrusted algæ, is here shown to have no claim to be regarded as one of the foraminifera, but to have strong affinity with the algæ, and especially with the *Cyanophyceæ* or blue-green algæ.

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(*o*) Examples in the author's collections.

(*p*) Wethered ('89), p. 200, pl. vi., figs. 8, 10, 11. Also ('90) pl. xi., fig. 3.

(*q*) The *Girvanella* figured by Etheridge from S. Australia appears to resemble more closely the form described by Bornemann from the Cambrian of Sardinia (cf. Etheridge, jun., '90).

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DESCRIPTION OF PLATES.

Plate I.

Fig. 1.—*Girvanella* (?) *pisolitica*, Wethered. An example showing both ovoid cells and tube cells. Silurian, Tyers River. x 56.

Fig. 2.—An enlargement of four cells of the same specimen showing the fractured wall. x 220.

Fig. 3.—*G.*(?) *pisolitica*, Weth. Example showing ovoid cells passing into tube cells. Tyers River, Gippsland. x 56.

Fig. 4.—*G.*(?) *pisolitica*, Weth. A series of cells with the earlier segments resting within, and apparently having produced corrosion of, a crinoid arm-ossicle. Tyers River, Gippsland. x 56.

Fig. 5.—*G.*(?) *pisolitica*, Weth. A series of ovoid segments nestling within axial canal of a crinoid arm-ossicle. Tyers River, Gippsland. x 56.

Fig. 6.—The same specimen with initial cell more highly magnified, showing papilliform outgrowths. x 230.

Plate II.

Fig. 1.—*Girvanella* cf. *wetheredii*, sp. nov. Tyers River, Gippsland. x 175.

Fig. 2.—A pellet of the same form. Tyers River, Gippsland. x 35.

Fig. 3.—*Girvanella conferta*, Chapman. Tyers River, Gippsland. x 175.

Fig. 4.—A pellet of the same species. Tyers River, Gippsland. x 35.

Plate III.

Fig. 1.—*Girvanella problematica*, Nich. and Eth., L. Cambrian. Ardrossan, S.A. x 35.

Fig. 2.—*G. conferta*, Chapm. Wenlock limestone, Dudley. x 35.

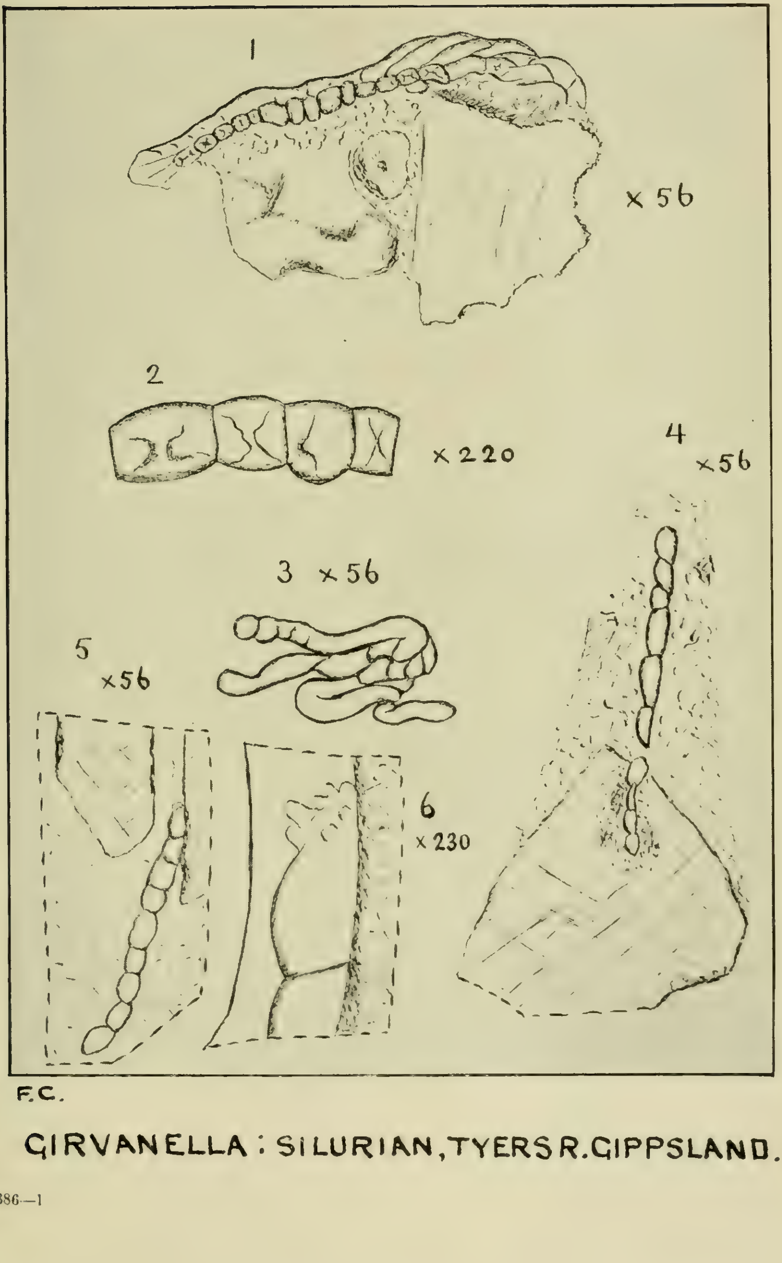
Fig. 3.—*G. wetheredii*, Chapm. Silurian (Yeringian) Cave Hill, Lilydale. x 35.

3.—NOTES ON THE SCHISTOSE ROCKS EAST OF THE MOUNT LOFTY RANGES.

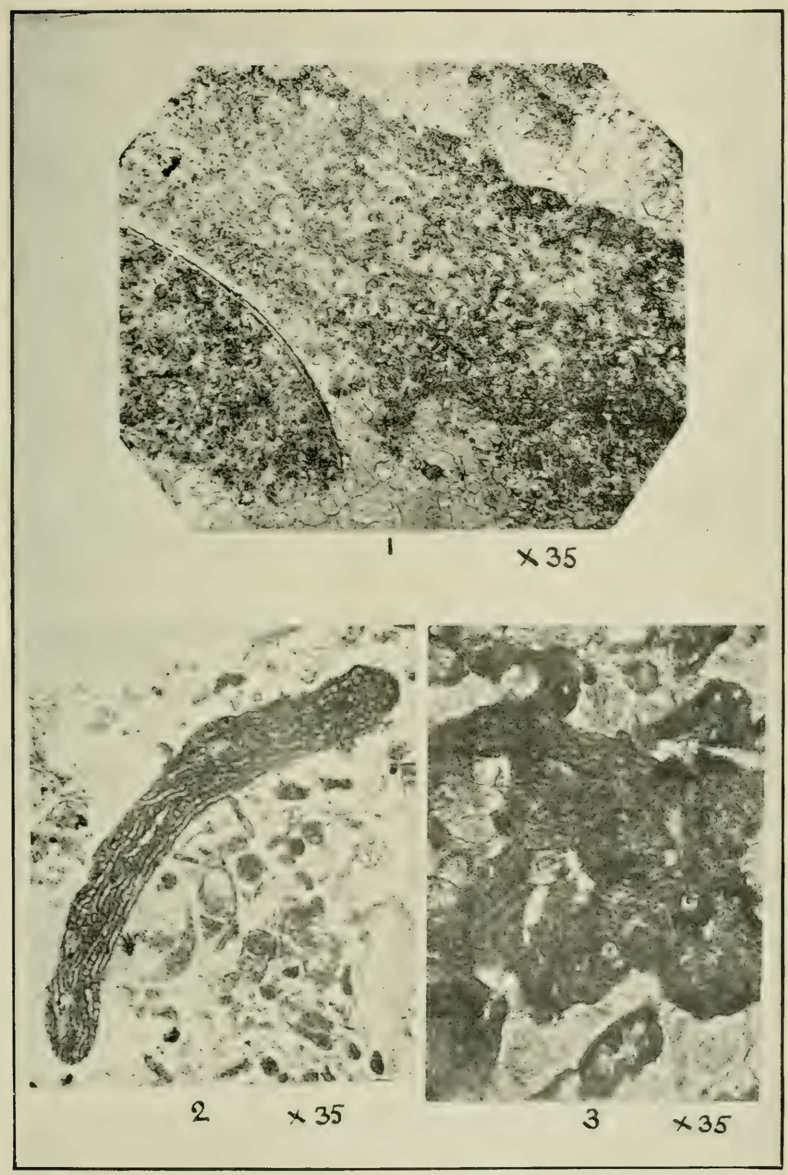
By W. G. WOOLNOUGH, D.Sc.

4.—ROCK PHOSPHATES IN THE HUNDRED OF BRIGHT, SOUTH AUSTRALIA.

By W. G. WOOLNOUGH. D,Sc.



GIRVANELLA: SILURIAN, TYERS R. GIPPSLAND.



F.C. phot.

GIRVANELLA: FROM THE CAMBRIAN & SILURIAN.

5.—NOTES ON THE GEOLOGY OF THE YOU YANGS, VICTORIA.

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[WITH THREE PLATES.]

INTRODUCTION.

About 30 miles from Melbourne, in a direction a little south of west, a bold line of hills, known as the Youangs or You Yangs, rises abruptly from the level surface of the volcanic plains. The railway line between Melbourne and Geelong passes within a short distance of them, and the culminating point, marked on the Government map as Wurdi Youang, or Station Peak (1,154 ft.), is clearly visible from Melbourne and from Geelong (12 miles). To those entering Port Philip by boat the clear-cut ridge forms the most conspicuous object during the passage up the harbor. The highest point—Station Peak—provides a magnificent and extended view over the Melbourne Basin and the Western District of Victoria, and this hill was the first on which a white man set foot in Victoria, Captain Flinders making the ascent in April, 1802.

I can find no written description of the geology of the rocks of the You Yangs. The general geological relations of the area are, however, clearly shown in the maps of the Geological Survey of Victoria, quarter-sheets 19 and 20. The area was mapped by Daintree and C. S. Wilkinson in 1861, under the direction of Selwyn, the Government Geologist, and the maps were published in 1863.

PHYSICAL GEOGRAPHY AND GENERAL GEOLOGICAL RELATIONS.

The physical geography of the district is simple, for one is concerned mainly with two features—the hills and the plains. The hills are entirely granitic. From the southern extremity the exposed area of granite stretches northwards for about three miles, and then divides, one narrow outcrop continuing northwards for about another three miles, while the main mass extends in a north-west direction for about seven miles. Outlying masses which occur beyond this extremity, and others to the north and to the west-south-west of the main mass, are no doubt connected beneath the basalt plain. The age of the granite cannot be definitely fixed. It is probably Post Ordovician, since it has altered rocks which are probably of that age. Denudation subsequent to the intrusion has now exposed the granite at the surface, and only at the south-west extremity of the area are any of the altered Palæozoic sediments preserved. These are shown on the geological survey map as a narrow fringe of highly metamorphosed sandstones and mudstones, forming the south-west margin of a small low-lying projecting part of the southern end of the granite. The present hill is, therefore, a residual mass or monadnock, which owes its preservation to the superior power of resisting atmospheric erosion which characterises the granite compared with the sediments. Station Peak (1,154ft.), at the southern end of the hills, is the highest point of the You Yangs and the level falls to the north. The surrounding plain is at a low elevation. Lara and Little River, the two railway stations nearest the hills, are only 52ft. and 108ft. respectively above sea-level. As a result, the steep-sided southern end of the You Yangs, in spite of its comparatively low altitude, has, as Professor Gregory remarks, (*a*) " all the impressiveness of a true mountain."

The Plain forms part of the large south-western plain of Victoria, extending from Melbourne on the east westwards through the Western District. For the most part, near the You Yangs it is fairly level, and is broken by only a few features. The Little River—a stream draining the area north and east of the You Yangs—has cut a gorge-like valley through the plain. On a smaller scale a stream called the Duckponds, or Hovell's Creek, rising in the western part of the granite hills, runs southwards in a similar steep-sided valley. Two or three volcanic hills, from which part of the basalt of the plain has been derived, rise above the general surface about seven or eight miles west of Station Peak. Going westwards over the volcanic plain for about five miles a ridge about 50ft. to 100ft. high, running west-north-west, has to be surmounted. This proves to be the edge of a plateau of similar volcanic rock to the plain below. The ridge may be due to faulting before or during the volcanic eruptions, or the lava may have flowed over a pre-existing escarpment. The plain, however, is not entirely composed of basalt. Considerable irregularities of surface were no doubt produced by continued erosion of the Ordovicians and of the granite, and in the depressions in Mid-Kainozoic times freshwater limestones were deposited. These contain freshwater shells, and are now exposed in and near the valley of the Duck Ponds Creek. Later still came the volcanic activity by which the basalt of the south-western plains was poured out, filling up all irregularities of surface and, consequently, varying greatly in thickness. The geological map also shows some patches of older drift, consisting of ferruginous sandstones. Since then a thin capping of a later superficial deposit has masked the basalt over part of the area, and recent alluvium occupies the present stream valleys and local depressions in the granite.

THE GRANITE OF THE YOU YANGS.

Effects of Erosion.—Outline.—The granite mass of the You Yangs, viewed either from Lara or Little River, has at first the appearance of the outline of stratified rocks, presenting a short steep slope on one side, resembling an escarpment, and a long, gentle slope on the other, resembling a dip slope. This appearance arises from the presence of two sets of prominent joints which traverse the granite and determine the nature of the outline produced by surface erosion.

(*a*) " Geography of Victoria," p. 59.

Tors and Boulders.—Besides these master joints, less prominent ones, arranged more or less rectangularly, have served to concentrate the atmospheric attack along these directions, producing cuboidal blocks. The attack proceeds most rapidly at the solid angles, where a maximum surface for a given mass is presented, less rapidly at the edges, and scarcely at all on the faces of the blocks. The cuboidal, therefore, gradually approaches the spheroidal shape, and all stages in this process in the production of "tors" and isolated boulders can be seen on the surface in this area. The granite of the You Yangs appears to be very vulnerable to the chemical attack of atmospheric water, and a further stage, resulting in the excavation of an already formed spheroidal mass occurs. Water finding its way to the heart of the mass along minor joints has decomposed the whole mass, and brought some of the iron and silicates into solution. Evaporation from the surface has caused the water charged with salts in solution to be sucked up to the surface of the mass where those salts are left behind as a deposit impregnating and indurating the outer crust and forming a resistant skin to further attack.

On the under side of the boulder this skin has either not been formed or has been removed, and wind and water erosion has scooped out the inner decomposed granite, leaving a dissected spheroid.

Rock Basins.—At the south-west end of Station Peak there is marked on the geological map what is described as a large projecting mass of granite. It appears to be an early stage in the production of a gigantic tor. The granite originally surrounding this isolated mass has been removed by denudation, and the sub-circular outline of the mass has been determined by the directions of several joint planes. The highest point of the mass is at an altitude of about 440ft. (aneroid reading), and the southern wall is very steep and about 80ft. high. The outer circumference of the rock mass is about 600yds. The north and north-east edge of the mass is only raised a few feet above the level of the general surface of the granite, and on ascending from this side the most interesting feature of the structure is seen. The central part of the upper surface is seen to be depressed, and constitutes a rock basin, partially filled with soil from the decomposition of the granite. The inner rim of this rock basin at its junction with the soil has a circumference of about 150yds. to 180yds., while the maximum and minimum diameters are 50yds. and 40yds. respectively. The basin is comparatively shallow, the outer rim being possibly 10ft. to 12ft. above the central soil cap, while the depth of soil in the centre of the basin may be 2ft. or 3ft. In most granite areas small rock basins, from a few inches to a few feet in diameter, are to be seen, and their origin is not difficult to explain. A minute depression in the granite surface causes rainwater to settle in it, and thus provides the means for the commencement of the disintegration of the granite. Vegetation gets a footing on the granite soil, and its decay provides acids for further chemical attack, and so the hollow is slowly widened and deepened. The interest of this granite rock basin on the south-west flank of the

You Yangs lies mainly in its dimensions, which are much larger than those of any basin having a similar origin which has come under my notice.

PETROLOGICAL DESCRIPTION OF THE GRANITIC AND ASSOCIATED METAMORPHIC ROCKS OF STATION PEAK.

The Granite.—Many of the rocks which have been called granites in Victoria have been shown to be in reality more basic in composition than true granites. Some of these have been described by Dr. Howitt as quartz-mica-diorites(*b*), while Professor Gregory, on account of the considerable proportion of alkali felspar, has suggested the name grano-diorite.(*c*) A short examination of rock sections of the You Yangs granite is sufficient to show that is does not belong to the grano-diorite division, but is an alkali granite. No detailed description of the rock has, I believe, been hitherto attempted. On the geological survey map it is described as " coarse-grained, with large crystals of felspar."

Megascopic Examination.—Its porphyritic character is certainly its most prominent characteristic, some of the felspar crystals being 3in. or 4in. in length. The base is also fairly coarse-grained, and consists to the eye of felspar, quartz, and biotite. The specific gravity of a specimen of the rock is 2.60. The granite shows the usual dark segregation patches, and is traversed by veins or dykes, some of which are more acid, others more basic, than the normal granite. The microscopical character of these will be described below.

MICROSCOPICAL EXAMINATION, SECTION 393 (*d*) (SEE PLATE I., FIG. 1).

The Structure of the rock is porphyritic, owing to the development of large early-formed felspars, while the structure of the later-formed ground mass is medium-grained and hypidiomorphic to panidiomorphic.

(*d*) These numbers refer to sections in the collections at the University of Melbourne.

The Minerals present, in order of relative abundance, are alkali felspar, quartz, oligoclase, biotite, hornblende, with small amounts of the accessory minerals, apatite and magnetite.

The Felspars: Alkali Felspar.—The phenocrysts consist of an alkali felspar which, for the most part, shows either no twinning, simple twinning, or an obscure and very fine twin lamellation. A perthite intergrowth, with albite, occurs in places. A blowpipe examination gave marked flame reactions for both sodium and potassium. The sections have been mounted in liquid balsam, with a refractive index of between 1.52 and 1.53. The refractive index of this felspar is in places equal to that of the balsam, and in places slighter higher. The optical and chemical evidence available makes it probable that the felspar is the soda-potash felspar anorthoclase, at least in part; while part is ordinary orthoclase. The felspar also shows a certain amount of undulose extinction—a common feature with anorthoclase; but, as the quartz in the rock behaves similarly, the effect may be due to strain.

(*b*) Roy. Soc., Vic., vol. xx., 1894, p. 31.
(*c*) Roy. Soc., Vict., vol. xiv. (New Series), 1902.

A determination in duplicate of the alkalies in the porphyritic felspar, kindly made for me by one of my senior students (Mr. A. J. Robertson) in the Chemical School, gave the following result :—

Na_2O	=	2·41
K_2O	=	11·85
Total alkalies	=	14·26 per cent.

This result confirms the microscopic determination, and shows that the bulk of the felspar is orthoclase, with some albite and probably some anorthoclase. The smaller alkali felspars are generally allotriomorphic, and moulded on the quartz.

Plagioclase.—The plagioclase crystals are much less abundant than those of the alkali felspars. They are generally idiomorphic, show well-defined narrow albite lamellæ in some sections (100), and exhibit, with respect to these lamellæ, symmetrical extinctions which range in different crystals from 4° to 14°, indicating oligoclase to andesine or albite oligoclase.

Some sections parallel to (010) show no lamellæ, but marked zoning in polarised light, and show extinction angles ranging from + 10° in the centre, + 5° in an intermediate zone, and — 16° at the boundary, indicating changes in composition from oligoclase-albite in the centre, through oligoclase (ab_4an_1) to albite or albite-oligoclase on the outside.

Biotite occurs in ragged crystals, with pleochroism, ranging from straw-yellow to nearly black. It has many enclosures of apatite, and a few of magnetite, and shows pleochroic halos round them.

The rock differs markedly from the normal Victorian grano-diorites in the large excess of alkali felspar over plagioclase and the almost complete absence of magnetite. It belongs, therefore, to the granite family. If the identification of anorthoclase is correct, it would be best described as a natron or soda granite, and in any case it may safely be described as an alkali-granite.

SEGREGATION IN GRANITE, SOUTH-WEST FLANK OF STATION PEAK, SECTION 390 (SEE PLATE II., FIG. 1).

Megascopic Examination.—The hand specimen containing more biotite is darker, and also finer and more even-grained, than the normal granite.

Microscopic Examination.—The structure of the rock is even-grained and panidiomorphic.

The minerals present, in order of abundance, are biotite, alkali felspar, plagioclase, quartz, hornblende, apatite,

Alkali Felspar.—Much is untwinned or simply twinned, and is probably orthoclase. Some shows very fine obscure lamellation, and may be anorthoclase. One or two porphyritic crystals are of this character, while others are oligoclase, with extinction angles of 15°, while (010) sections show zoning. The small amount of quartz is moulded on the felspars, while in places a small amount of a residual eutectic mixture has crystallised as a granophyric intergrowth of quartz and felspar. The very small proportion of quartz and the almost complete absence of magnetite are noteworthy.

SEGREGATION IN GRANITE FROM SUMMIT OF STATION PEAK, SECTION 361 (SEE PLATE I., FIG. 2).

Megascopic Examination.—This differs from the last rock in hand specimen mainly on account of the porphyritic structure produced by the development of large quartz and felspar aggregations.

Microscopic Examination.—The structure of the rock is hypidiomorphic. The minerals, in order of abundance, are alkali felspar, quartz, biotite, oligoclase (ab_8an_1), hornblende, apatite, zircon.

The felspars appear to be of three types—an alkali felspar, in large irregular crystals, and showing undulose extinction and either obscure lamellation, or none at all, and extinction angles from 0° up to 11°. Another type consists of smaller, sometimes idiomorphic alkali felspars; more often, however, allotriomorphic, untwinned or simply twinned; these are probably orthoclase. A third type is a plagioclase, probably oligoclase, in which symmetrical extinctions from twin lamellæ give angles of 9° and 15° in different crystals.

Quartz, both interstitial and also included in plagioclase, is more abundant than in section 390, and shows slight undulose extinction.

Biotite and Hornblende both occur as phenocrysts, and as smaller elongated crystals included in felspar and quartz. The hornblende has irregular boundaries, is of a pale-green color, and has colorless patches in the centres of the crystals; while the margins are in places altered to chlorite.

Apatite and zircon occur as small inclusions in the biotite and the felspar crystals.

SPECIMEN FROM BASE OF DYKE ON SOUTH-EAST SLOPE OF STATION PEAK, SECTION J. (SEE PLATE II., FIG. 2).

Megascopic Examination.—This is a dark-grey close-grained rock, with occasional phenocrysts occurring as a broad dyke 20ft. to 30ft. wide, and extending for some hundreds of feet up the south-east slope of Station Peak.

Microscopic Examination.—The structure is porphyritic, with a pan-idiomorphic even-grained ground mass. The minerals present, in order of abundance, are plagioclase, hornblende, biotite, alkali-felspar, quartz, uralite, magnetite or ilmenite.

Two or three large porphyritic kaolinised crystals of a plagioclase, probably a basic andesine occur with indistinct lamellæ extinguishing at 20°.

Another crystal shows lamellæ in one-half of an irregular twin and no lamellæ in the other half, and showing undulose extinction. The felspars of the ground mass are mainly idiomorphic, zoned, untwinned sections of plagoclase, the central zone extinguishing in one crystal at + 30°, diminishing in outer zones to 0°, and at the margin being — 7°. The central part is therefore labradorite, the middle parts andesine and oligoclase of various composition, while the margin is albite-oligoclase. The range of extinction angle and of composition in these zoned crystals is unusually large. A subordinate amount of clear untwinned alkali felspar occurs as allotriomorphic crystals in the ground mass.

Uralite.—Some of the hornblende is undoubtedly secondary after augite. This is well shown in one crystal of uralite, octagonal in section, having the crystal boundaries of augite and the cleavage and optical properties of hornblende. The paramorphic change has not been quite complete in the central part of the crystal, and is not quite truly paramorphic, as small quantities of secondary quartz and white mica have been produced.

Quartz.—Very little quartz is present in the rock. A little is included in the porphyritic felspars, but generally the quartz was the last mineral to crystallise, and is clearly moulded on the felspars. A slight tendency to a granophyric structure is observed in parts of the ground mass. The rock is clearly more basic than the granite, and may, perhaps, be best described as a hornblende porphyrite.

SAME DYKE AS J, BUT FROM UPPER PART, SECTION X.

Megascopic Examination.—In the hand specimen it differs from J mainly in being more definitely porphyritic, many of the phenocrysts being quartz.

Microscopic Examination.—The same minerals occur as in J (with the exception of uralite), but three points of difference are noticeable. First, the greater abundance of quartz, not only as phenocrysts, but also in the ground mass; second, the character of the plagioclase crystals showing lamellæ give extinction angles of only 2° or 3°, indicating an oligoclase, while sections parallel to 010, showing zoning, give extinction angles ranging from + 7° (acid oligoclase) to — 8°, (andesine). The plagioclases are, therefore, less basic than in J. Third, the structure of the ground mass, which is fine-grained and granular, and consists mainly of quartz and an alkali felspar. All the constituents occur in two generations, and since quartz is abundant the rock is perhaps best described as a granite-porphyry.

ACID DYKE IN COARSE GRANITE IN SADDLE BETWEEN THE TWO RIDGES OF STATION PEAK, SECTION 389.

Megascopic Examination.—It is an almost white granular rock, containing quartz, felspar, and a little biotite.

Microscopic Examination.—The structure is coarse-grained and hypidiomorphic. The most abundant mineral is quartz, showing slight undulose extinction. The quartz is frequently included in felspar, and includes biotite. Of the felspars, microcline, showing characteristic "grating" structure in polarised light and extinction angles of about 15° from lamellæ, is the most abundant. The specimen was not quite fresh, so the felspars are kaolinised. Some untwinned felspar—probably orthoclase—occurs, and a little plagioclase, showing albite-lamellæ, with extinction angles of 10°. Biotite occurs sparingly in elongated irregular crystals, with inclusions of apatite. The rock is an acid granite.

THE METAMORPHIC ROCKS OF STATION PEAK.

These have a very limited distribution at the surface, being confined to a small crescent-shaped area about 200yds. wide, from east to west, and half a mile long from north to south, flanking the extreme south-west exposure of the granite of the You Yangs. Their extent is indicated on quarter-sheet 19, S E of the Geological Survey of Victoria.

No doubt both granite and metamorphic rocks extend beneath the sheet of basalt which surrounds the You Yangs. The Metamorphic rocks which are exposed at the surface have been much denuded, and now form merely a thin coat overlying the granite. They consist of highly altered sediments, marked on the map as probably Silurian, while the legend on the map refers them to Lower Silurian—that is, Ordovician, as now understood. Their age cannot be fixed with certainty, but, since they lie 30 miles west of Melbourne and Ordovician rocks occur to the north and north-west along their line of strike, it is probable that these rocks are highly altered Ordovician sandstones and mudstones. For the most part they can be studied only from surface fragments lying in a plantation. The best exposure is seen in a ditch running east and west at the south end of the plantation, at the north extremity of the road from Lara, shown on quarter-sheet 19 S.E. In this shallow section the junction with the granite can be seen, and the strike of the metamorphosed sediments is here a little to the west of north, which agrees with the general strike of the Ordovician rocks in Victoria. It is almost impossible to get specimens of the rocks which are unweathered, but some fairly fresh pieces were obtained and sectioned. Along the line of contact fragments of tourmaline and tourmaline-bearing rocks were found, and an examination of rock sections of the altered rocks shows that the extreme metamorphism near the contact with the granite has been brought about not only as a result of thermal metamorphism, but, in addition, by the passage of hot gases and solutions containing boric acid, &c., through the sediments near the junction of the granite. The result has been, as an examination of the section shows, that the sandstones and mudstones have been metasomatically altered and completely recrystallised. All signs of clastic structure in the minerals and all traces of bedding are lost in the rock in contact with the granite, but one of the less altered rocks away from the contact shows traces of the original bedding, where layers of sand and clay have been converted into secondary quartz and micas.

DESCRIPTION OF THE METAMORPHIC ROCKS—LEAST ALTERED ROCK AWAY FROM THE GRANITE CONTACT, SECTION 392.

Megascopic Examination.—This rock was probably an argillaceous sandstone, with alternating laminæ of quartz and clay. It now has a spotted appearance, as the result of metamorphism, but the original bedding planes can still be traced.

Microscopic Examination.—Traces of the original bedding can be seen in the linear arrangement of quartz and micas. The quartz has been entirely recrystallised, and now consists of interlocking crystals. The mica is of two kinds. The most abundant is a clear white mica. Although colorless and free from pleochroism, it is neither muscovite nor zimwaldite, since it is distinctly uniaxial. It is like all the micas, negative in character, and occurs in elongated irregular crystals and in matted aggregates.

The other mica is brown-green in color, and is probably a variety of biotite, although not so strongly pleochroic. The brown-green mica frequently occurs in radial groups of crystals, and the junction of the two micas is generally sharp and distinct. In places along the cleavage planes of the white mica the brown-green mica is developed. It is possible that the white mica is bleached biotite, but the microscopic evidence rather points to the possibility that the brown-green mica has been formed after the white, as it is in places moulded on it, and along cleavage planes the brown-green appears to be developed at the expense of the white variety. A few crystals of tourmaline occur, showing pleochroism from pale straw-yellow to a dark greenish-brown, with occasional patches. The tourmaline sometimes encloses both quartz and the white mica. Some grains of hematite and of magnetite partially altered to hematite also occur.

ROCK NEAR THE CONTACT WITH THE GRANITE, SECTION 354 (SEE PLATE III., FIG. 1).

The rock is an altered argillaceous sandstone, in which no trace of bedding remains.

The constituent minerals, in order of abundance, are tourmaline, in irregular masses, which are yellow-brown to blue in color, and which enclose quartz and white mica; quartz, in interlocking crystals, some of which have dusky centres; white mica and brown-green biotite, similar to those in No. 392; hematite, in red specks scattered through the rock.

No. 387 (SEE PLATE III., FIG. 2).—MOST ALTERED ROCK IN CONTACT WITH THE GRANITE FROM A DITCH AT SOUTH END OF PLANTATION, SOUTH-WEST CORNER OF STATION PEAK.

Microscopic Examination.—The granite consists of quartz, with undulose extinction; very kaolinised alkali felspar, white uniaxial mica, and brown-green biotite. Since white mica does not occur in the main granite mass, it is clearly a product of alteration of the felspar, due to acid vapors and solutions at the margin of the granite—solutions and acids which caused the tourmalinisation of the sediments, and possibly the extreme kaolinisation of the felspar in the granite at the margin. The junction of the white and the brown-green mica is quite sharp. The white mica is possibly not bleached biotite, but may be a new white uniaxial mica.

METAMORPHIC PART OF SECTION 387.

The minerals and structure are similar to those in section 392, but tourmaline and quartz are rather less abundant, while the white and brown-green micas form the bulk of the rock.

DESCRIPTIONS OF PHOTO-MICROGRAPHS OF SECTIONS OF ROCKS FROM NEAR STATION PEAK, YOU YANGS.

Plate I.

Figure I.—No. 393. Granite of Station Peak × 13 diams. + Nicols.—On the upper left-hand side a large crystal of alkali felspar, possibly soda orthoclase, shows very fine lamellation. A small quantity of albite is intergrown with it. Just above the centre of the field is a porphyritic crystal of plagioclase showing albite twin-lamellæ. The lower left-hand side consists of biotite and quartz in a position of extinction, and the lower right-hand side consists of a big quartz crystal showing strain polarisation effects.

Figure II.—No. 361. Segregation in Granite, summit of Station Peak, × 24 diams. + Nicols.—A large rather embayed strained quartz crystal occupies the lower left-hand side of the figure. A porphyritic plagioclase occurs in the lower right-hand side, and the rest of the field consists of quartz and alkali felspars, with well-defined biotite crystals and a few sections of hornblende.

Plate II.

Figure I.—No. 390. Segregation in Granite, south-west flank of Station Peak. × 24 diams. + Nicols.—The figure shows a well-defined panidiomorphic structure. The minerals are mainly biotite and felspars, both plagioclase and an alkali felspar being represented. Only a little interstitial quartz is present.

Figure II.—No. J. Dyke in Granite, south-east slope of Station Peak, × 24 diams. + Nicols.—Most of the field consists of idiomorphic zoned crystals of plagioclase, some showing both albite and Carlsbad types of twinning. Hornblende and biotite altering to chlorite are also to be seen, and uralite also occurs.

Plate III.

Figure I.—No. 354. Metamorphic Rock, altered Ordovician (?), south-west corner of Station Peak, × 24 diams., ordinary light.—The sediment has been completely recrystallised. The dark areas are mainly tourmaline, with some biotite. The light areas are secondary quartz, with white mica, which may be bleached biotite.

Figure II.—No. 387. Metamorphic Rock at contact with Granite, south-west corner of Station Peak, × 24 diams, ordinary light.—Very little tourmaline is shown in this slice. The dark areas are brown-green crystals of biotite. The light areas are partly quartz, but mainly white mica intimately associated with the biotite.

6.—THE ASSOCIATION OF LAMINATED CLAYS, SHALES, AND SLATES WITH GLACIAL DEPOSITS: THEIR SIGNIFICANCE AND CHRONOLOGICAL VALUE.

By D. MAWSON, B.E., B.Sc.

PHOTO-MICROGRAPHS OF SECTIONS OF ROCKS FROM NEAR STATION PEAK, YOU YANGS.

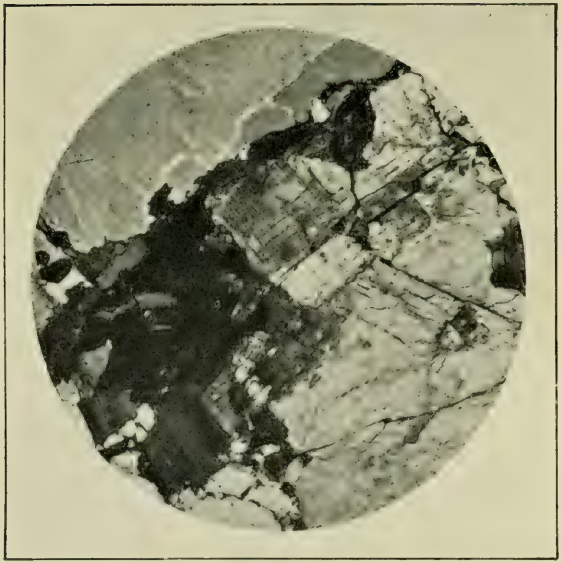


FIG 1.

No. 393.—GRANITE OF STATION PEAK.

× 13 *diams.* + *Nicols.*

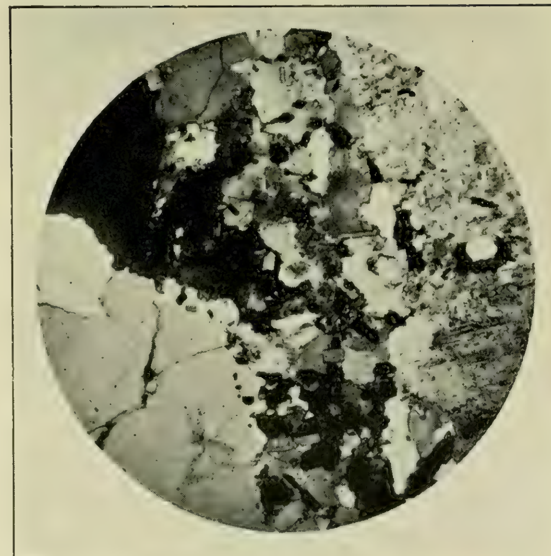


FIG. 2.

No. 361.—SEGREGATION IN GRANITE, SUMMIT OF STATION PEAK.

× 24 *diams.* + *Nicols.*

PHOTO-MICROGRAPHS OF SECTIONS OF ROCKS FROM NEAR STATION PEAK, YOU YANGS.

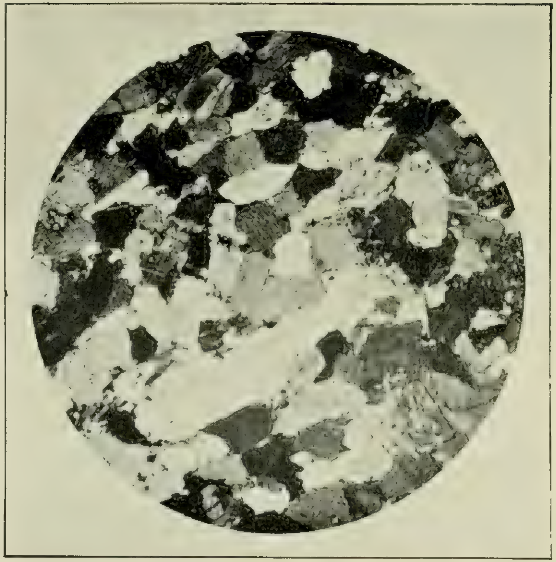


FIG. 1.

No. 390.—SEGREGATION IN GRANITE, SOUTH-WEST FLANK OF STATION PEAK.

× 24 *diams.* + *Nicols.*

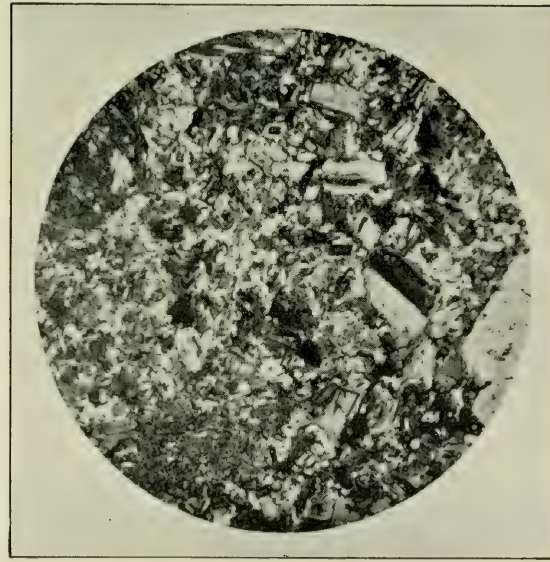


FIG. 2.

No. J.—DYKE IN GRANITE, SOUTH-EAST SLOPE OF STATION PEAK.

× 24 *diams.* + *Nicols.*

PHOTO-MICROGRAPHS OF SECTIONS OF ROCKS FROM NEAR STATION PEAK, YOU YANGS.

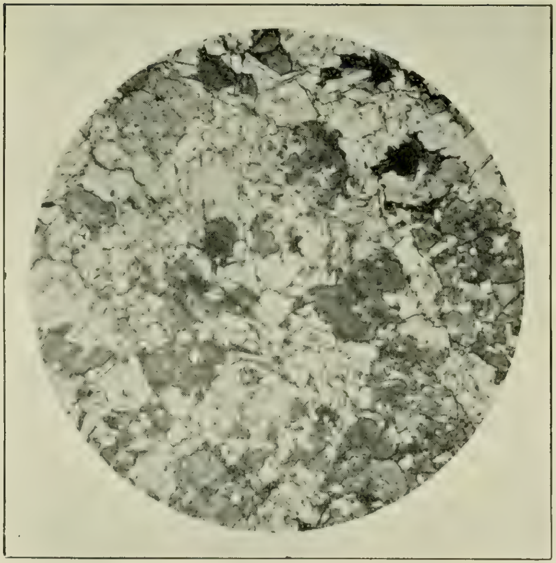


FIG. 1.

No. 354.—METAMORPHIC ROCK, ALTERED ORDOVICIAN (?), S.W. CORNER OF STATION PEAK.

× 24 *diams. Ordinary light.*

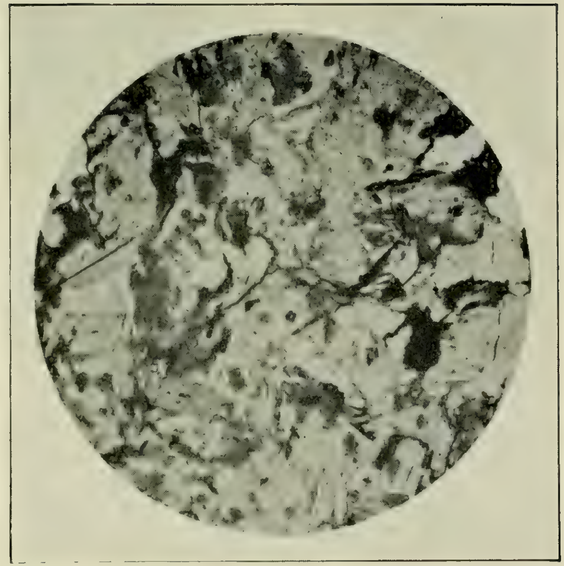


FIG. 2.

No. 387.—METAMORPHIC ROCK AT CONTACT WITH GRANITE, S.W. CORNER OF STATION PEAK.

× 24 *diams. Ordinary light.*

7.—CORAL REEFS OF THE GREAT BARRIER, QUEENSLAND: A STUDY OF THEIR STRUCTURE, LIFE-DISTRIBUTION, AND RELATION TO MAINLAND PHYSIOGRAPHY.

By C. HEDLEY, *F.L.S., Australian Museum, Sydney, and* T. GRIFFITH TAYLOR, *B.Sc., B.E., Geological Department, University of Sydney.*

[WITH SIX BLOCKS AND THREE PLATES.]

I. INTRODUCTION.

Unhappily for its subject, the controversy upon coral reefs has been mainly conducted in cities distant the world's breadth from the scene of investigation. Data compiled for other purposes are pressed into service, and opportunities of verifying facts are denied to authors. Some who discourse learnedly on coral geology have perhaps never touched a living coral. It is in harmony with this disconnected study that the grandest display of corals that the earth can show—the Great Barrier Reef—has received scanty attention; while the next finest reef—that of New Caledonia—is absolutely untouched by scientific observers.

On the occasion of its discovery the scientific staff of the *Endeavour* saw ruin and death in the Barrier Reef, rather than an interesting field for research.

The Barrier was fortunate in its first historian. During the survey of H.M.S. *Fly*, in 1842-6, Professor Beete Jukes served on board as naturalist, and enjoyed ample opportunities for examining what is now the coast of Queensland. Endowed with keen insight and uncommon literary ability, already trained in geology and zoology, he has placed before us vivid pictures of its scenery, an account of its entirety, and a solution of some of its problems.

Saville Kent, during his tenure of office as Commissioner for Fisheries in Queensland, visited most of the Barrier, and portrayed the reefs and their constituents.

In the course of his world-survey of coral reefs, Professor Alexander Agassiz traversed the whole length of the Barrier, and recorded his impressions of it.

Professor A. C. Haddon visited Torres Strait in 1888, and produced a valuable series of memoirs on the geology, fauna, and ethnology of that district.

A section of the Middle Barrier was examined in 1901 by Mr. E. C. Andrews, in company with one of us (H.). He has published a report on the section in detail and the reef as a whole (Proc. Linn. Soc., N.S.W., XXVII., 1902, pp. 146-185).(*a*) In his opinion the gradual subsidence

(*a*) The foraminifera collected on this trip were catalogued by Messrs. Goddard and Jensen (Proc. Linn. Soc., XXXII., 1907, pp. 296-300). Under the title of "A Day on the Great Barrier Reef," a collecting experience on Green Island is described (Hedley.—The Nautilus, XV., 1902, pp. 97-100).

which determined the present Barrier Reef dates from Pleistocene times, and was followed by a modern very slight uplift.

An island named Masthead, near the southern extremity of the Barrier, was searched in 1904 by a scientific party organised by one of us. A description of this island and part of its fauna has appeared (Hedley, Proc. Linn. Soc., N.S.W., xxxi., 1906, pp. 453-479, &c.).

Material for the present article was gathered by us in 1906 during a visit to the reefs near Cooktown. We are enabled to present definite traverses across three reefs in various and progressive stages of growth, showing the superficial geological structure and distribution of life along actual sectional lines. The ecology of coral reefs has been so little studied that we would draw attention to an interesting series of articles on the fauna of the Djibouti reefs in the Red Sea, by Professor H. Coutiere (Bull. du Museum, Paris, iv., 1898, pp. 38, 87, 155, 195, 238, 274).

II. (*a*) TRAVERSE—HOPE ISLAND REEF.

The Hope Islands were so called by Captain Cook, after the wreck of the *Endeavour*, because here he first took hope that he might save his ship and the lives of his company. A view of the reef flat at Hope Island is given by Mr. W. H. D. Le Souef ("Wild Life in Australia," 1907, p. 347).

Details of the traverse from north to south across the reef serve to show definitely the distribution of organic and inorganic structures on a typical reef integer of the Great Barrier Reef (see Plates I., II.). A cursory examination reveals the fact that the fauna of the coral reef —which is covered at every tide—mainly consists of various other families than the Madreporaria or true (stony) corals. Each of the three traverses was about a mile long, and it is interesting to note that the solid growth of living coral formed a fringe constituting some 20ft. or 30ft. at each end of the total of 5,000ft. or 6,000ft. representing the whole width of the reef.

Starting at the north edge of the reef (the leeward for the greater part of the year), at low spring tides the living rampart of dense massive corals such as *Goniastrea* and *Porites* project slightly above water for about an hour each day of such tides. This rampart is well defined all round the reefs, but is notched by channels some 4ft. deep (reaching to the foot of the rampart), in which more delicate branching madrepores and millepores flourish. The latter are being constantly broken off on the windward side, and driven up and over the edge of the reef, constituting, as we shall see, the "clinker embankment."

Within the rampart, and level with its cap, are to be found more accessible corals, forming a second zone about 30ft. wide. Here occur *Turbinaria*, *Coeloria*, *Fungia*, *Galaxea*, *Herpetolithes*, and many madrepores which, while not so delicate as those living at the foot of the huge blocks of *Porites*, &c., are too frail to withstand the full force of the surf. Here also occur many *Tridacnas* (clams)—the larger free, while the smaller are buried mouth uppermost in coral masses.

The third zone (see Plate I.) is somewhat shallower, about 5ft. of water covering it at high tide. Here we find a few corals, mostly *Favia* and *Mussa*, and allied forms, which form small isolated masses about the size of a cricket ball. But the *Alcyonaria* run riot. Huge green discs (*Sarcophyton*), 8ft. across, whose name—"flesh-plant"—well expresses their structure, are intermingled with *Spongodes* resembling a richly tasselled curtain of dull lilac hue flung on the rocks.

The next zone consists of an area covered by brown algæ, together with the calcareous green *Halimeda*. These grow to the foot of the sand beach around the island, the sand from which, drifting to leeward, seems to have prevented the growth of more delicate organisms.

We have now traversed 300yds. (*vide* fig. 1, Plate I.), and risen about 6ft. Ascending the rather steep beach, which consists (in order of abundance) of fragments of foraminifera, shells, and coral, we enter the thickly-crowded foliage which crowns the beach. *Pandanus*, *Scaevola*, *Sophora*, *Ipomea*, *Tournefortia*, various jasmins, dodders, and prickly-seeded grasses grow thickly together, so that it is difficult to force one's way through. No freshwater is found on these islands, though a brackish supply can be obtained by sinking wells for 10ft. or 12ft., and lining them to prevent infilling with sand.(*b*)

Emerging on the southern side of the islet, which is about 200yds. wide, we find, in the East Hope Island, a flat area some three-quarters of a mile long, extending out to the southern rampart on which the south-east wind is raising a a low surf. The southern beach rests on coral sand-rock, with a definite dip of 6° to the north. This pronounced dip is undoubtedly of the nature of current bedding; and, as will be seen later, the same structure is in process of formation at the outer edge of the present movement.

On leaving the beach sand, which is only 15yds. wide, one reaches a sandy level area with coral rock patches to which is attached a flourishing colony of the mollusc *Chama*. It forms a zone about 100yds. wide around the beach sand. The pseudo-lagoon (see Plate I.) of this reef commences about 200yds. from the islet, and gradually deepens to 3ft. or more at the outer edge. At the nearer border, in 6in. of water (at low tide), the sands are dotted with sponges, some cup-shaped (*Phyllospongia spiralis*)(*c*) and algæ, resembling nothing so much as a small green bundle of coarse wire netting (*Hydroclathrus*).(*d*). Here and there *Caulerpa uvulifera* presented its bunches of tiny green berries. With it is *Cymodocea*.

Seaweed helps to bind the sand together, and large beche-de-mer crawl sluggishly in the shallow water. At 300yds. from shore, the water gradually deepens, and beds of mussels appear. Emerging from the

(*b*) The similar fauna and flora of the Claremont Islands, a few degrees north of the Hope Islands, are described by G. F. Mathew (Proc. Linn. Soc. N.S.W., x., 1885, pp. 251-258).

(*c*) Kindly determined by Mr. Whitelegge, Aus. Museum.

(*d*) Kindly determined by Mr. E. J. Goddard, B.A., B.Sc.

sand are the characteristic flat rocks, about 2ft. across and 3in. deep, which are indurated corals, derived, possibly, from worn-down "negroheads," and under which a rich harvest of molluscs and ophiuroidea can be found.

The pseudo-lagoon gradually increases to a depth of several feet. Six hundred yards from the shore, and an equal distance from the surf, the first specimens of the blue coral (Heliopora) are met with. It reigns supreme in this area in the form of bushy radiating colonies, with flat, truncated upper surfaces never rising above the lowest tide mark.

The penultimate zone consists of the "clinker embankment," one of the most characteristic features of the reef.

Imagine a railway embankment parallel to the surf line 2ft. or 3ft. high and about 20ft. across. It is composed of the confusedly intermingled remains of madrepores and other corals of a similar habit, the most delicate and most massive not being represented in any great degree. In many places the long axes of the coral stems lie across the bank, indicating a sort of "flow structure." Long tongues of coral "clinker" radiate from this bank, projecting 40ft. or more towards the islet. One can see the half-buried corals dying along the edge of the advance wave of debris. The dip angle of the latter, due to the combined action of the wind and tide, is about 6°, as in the case with the coral sand-rock in the island beach. The structure indicates a prime factor in the building of a coral islet such as that under discussion. The "bank" has a front of 50yds. in this instance, and consists wholly of fragments of corals broken off by the surf and swept to leeward. No cementing action has yet taken place.

Outside the clinker zone appear the rough craggy pools which invariably lie just within the living coral. They extend over an area about 30yds. wide. Lastly, the visible living coral zone is reached, which is much less extensive—as noted by Kent and denied by Agassiz —than that on the northern shore.

Owing to the strong surf driven up by the constant south-easter it is dangerous to examine the windward edge closely. Alcyonaria (soft corals) are comparatively rare, while the main types visible are the strong spherical or pedestal-shaped masses of *Goniastrea* and *Porites*.

RESUMÉ OF ZONES (E. HOPE ISLE)

Commencing at north end of traverse.

1. Living coral rampart	10ft.
" (inner zone)	30ft.
2. Alcyonaria, &c.	100yds.
3. Algae (*Halimeda*, &c.)	200yds.
Islet—Coral sand beach	20yds.
Tree-clad Island	200yds.
Beach and coral rock	20yds.
1. *Chama* beds	100yds.

RESUMÉ OF ZONES (E. HOPE ISLE)—*continued.*

2. Pseudo-lagoon—(*a*) Sponges	100yds.
(*b*) Mussels, &c.	300yds.
(*c*) *Heliopora*	500yds.
3. Clinker embankment	10yds.
4. Rock pools	30yds.
5. Outer zone, massive living corals	10ft.

II. (*b*) TRAVERSE ACROSS CAIRNS REEF.

This reef lies to the east of Hope Island, and about 10 miles from the Queensland coast (see Plate II.). It has much the same shape as the East Hope Reef— *i.e.*, the form of a horseshoe, with the convexity to the south—but has ten times the extent and is wholly covered at high tide. At low water the main (west) arm of the horseshoe is exposed as an area 10 miles long and one mile wide. Standing on the inner edge and looking outwards, it has all the appearance of a huge sandy waste with a few scattered tussocks here and there. On the farther edge the jagged or rounded " negroheads " seem to lie at a higher elevation than is actually the case owing to refraction, while the white line of surf appears on the point of rushing over the " barrens " between.

RESUMÉ OF ZONES, COMMENCING AT NORTH.

1. Rampart of live coral fringing the ragged edge of the reef	10ft.
2. Zone of corals of less robust nature	30ft.
3. Alcyonaria zone (colonies more isolated than on Hope Island)	100yds.
4. Sandy lagoon, with scattered green *Astreid* coral colonies of size and shape of a cricket ball	200yds.
5. Pure *fine* coral sand (no organisms)	50yds.
6. Sand, with isolated frondose Alcyonaria, also few *Euspongia* (12in. diam.)	250yds.
7. Sand, with *Halimeda* growing fairly thickly, few *Tridacna* and *Zostera*	200yds.
8. Shallow sandy lagoon, with *Pinna*, *Zostera* and "net" algae (*Hydroclathrus*)	200yds.
9. Bare *coarse* sand, with molluscs	250yds.
10. Single isolated *Negrohead*, 5ft. high, oyster covered, followed by strong *Chama* beds	100yds.
11. Rough coral *slabs*, with much live *Orbitolites*, dwarf *Porites* growing on lee side	300yds.
12. *Negroheads* fairly numerous, coral slabs and rocky pools; isolated *Porites* and green *Astreids*, also *Orbitolites*	350yds.
13. Loose *dead corals* in angular and cylindrical fragments, larger *Astreids* on lee of big boulders	50yds.
14. *Live coral* zone covered by surf and reaching to rampart	20ft.

II. (*c*) TRAVERSE ALONG BEE (*b*) REEF.

In this reef the horseshoe shape does not obtain, but the "morphological axis" still runs north-west and south-east (see Plate II.). It is an elongated oval, somewhat over one mile long. The windward (south) end is surmounted by an immense "clinker embankment" rising several feet above high-water mark. The northern end consists of pure sand without live coral, but composed very largely of the tests of foraminifera and coral remains. It is half a mile wide.

The reef is extending rapidly to the north, being "pushed" along by the strong tidal currents sweeping along each side, which also tend to drop sediment at the jumble of cross currents just to leeward of the island.

RESUMÉ OF ZONES COMMENCING AT NORTH

(*Vide* PLATE I., FIG 3).

1.	Mound of pure sand, due largely to tidal action......	400yds.
2.	Shallow sandy "col" joining 1 to 3................	300yds.
3.	Flat sandy area, with coral fragments and coral slabs	500yds.
4.	Shallow pools becoming more rocky towards south; *Tubipora* plentiful..............................	200yds.
5.	Long tongue from "clinker" bank, 15ft. wide, rising to 4ft. high	300yds.
6.	"Clinker" bank, 12ft. high at the front south face and 40ft. wide	12ft.
7.	Bare coral rock pools, &c., to growing coral zone....	200yds.

The area to the south of this striking "clinker rampart," which had an abrupt windward face but was "stepped" on the lee side, had been swept clear of living coral apparently by the northward movement of the clinker over it. To the lee of the latter the growing *Tubipora* was being rapidly demolished by the long tongue of clinker sent out from the eastern end of the clinker bank. The "flow structure" of the "tongue" was very noticeable. Each succeeding layer terminated in a well-defined "step," such as lava flows of a viscous nature show at their limit of advance. The "step" and the angle of repose (6°) are indicated in the third figure on Plate I.

III. THE NEGROHEADS.

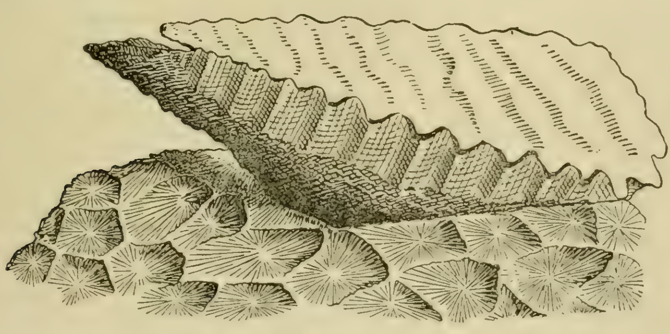
Sailing past almost any reef on the Barrier the traveller's attention is arrested by a row of crags, like huge milestones, irregularly disposed along the crest of the reef. Even when the bank is covered with high water they project above the surface of the sea. To these Flinders applied the name of "negroheads," converted in local parlance to "niggerheads." If the negroheads gathered on a steep and narrow shore they would compose a "hurricane beach."

The following description is based on those observed on Cairns Reef. At a distance of a mile or so, by optical illusion, perhaps partly mirage, partly lack of standards of comparison, the negroheads are accepted by the eye as being of far larger bulk than the reality. On near approach they resolve into masses of dead coral 5ft. or 6ft. in height and of nearly equal breadth.

The massive corals, *Porites*, *Astrea*, &c., of which they are composed, grow irregularly and circumferentially. It is impossible to orient them by any axis of growth or to tell by inspection of the polyp cells whether they are upright or upset. Once landed, a stranded block might be welded by chemical action to the floor on which it stood. No sign of coral breccia or superposed coral was noticed in connection with the Cairns negroheads.

No blocks occur on the central or leeward portion. The whole crop are confined to a zone 300yds. or 400yds. from the surf. Often the grit-armed surf has hollowed a pool around the boulder and undercut the base, leaving a stout stalk by which it is attached to the reef. (See fig. 2, plate I.). Above the block may be fantastically carved into pinnacles and hollows. All are obviously melting away under rapid erosion and possibly solution.

A time measure is afforded by encrusting oysters. These cluster thickly on the exterior of the negroheads, and may even completely sheath in armor a square foot of the surface. Single aged oysters project like spurs, their point of attachment being *not the umbo* but the ventral margin.



Oyster on Denuded Coral Block, showing how the Original Base under the Umbo has vanished.

Their history clearly is that the oyster was first fastened as usual by the umbo, and that as soon as a fresh grip was gained in front so the earlier support behind was removed. During the brief span of the bivalve's life (say four or five years) a layer as much as 2in. thick of the rock crust may have vanished. At this rate of erosion no great antiquity can be ascribed to the negroheads.

Both Kent and Agassiz have illustrated and described the Queensland negroheads, but offer opposing explanations of their origin. The former regards them as jetsam flung up by hurricanes ; the latter considers them as a residue of elevated reefs cut down by erosion to present level. The verdict is a matter of some geological importance, for if the view of Agassiz be adopted a direct proof of recent alteration of level is established.

We were fortunate in surveying Cairns Reef because it is quoted by Agassiz (*op. cit.*, p. 116) as showing, *better than any other*, the remnants of an old elevated reef.

The hypothesis of Kent is preferred by us on the following grounds:—Positively—The negroheads do not continue down into the ground but are perched as morainic blocks might be. Jetsam would accumulate on the weather side of the reefs (where the negroheads are) not on the lee side (where they are absent). Negatively—An elevated reef in course of denudation would commence to wear on the windward side, where the attack is fiercest; the last surviving remnants should be on the leeward shore. Supposing that the negroheads are such remnants, why do they survive only where they ought earliest to disappear? The central portions, more than half a mile from either edge, might naturally be expected to remain as more or less solid "mesas" long after the rest had been ground to sand. Such is not the case on Cairns Reef. Again, a former elevated reef should have remained intact beneath the wooded islets like Hope Island; whereas the only rock there is coral-sand rock.

IV. THE ISLANDS.

Contrasting the inter-tropical with the extra-tropical coast of East Australia, the northern part is seen to be profusely beset with islands while the southern is left unusually bare.

In New South Wales the general trend of the coastal ranges (*e.g.*, Macpherson, Hastings, Hunter, and Cambewarra) is at right angles to the coast. Here subsidence on a large scale would result, not in the formation of islands but in the appearance of bold promontories like those of the south of Greece. But the subsidence which did occur fell short of this, and merely produced a series of drowned valleys within a remarkably linear coast line.

But the main trend of the coastal ranges of Queensland is meridional, or roughly parallel to the sea, and here the larger subsidence has carved the coast into a series of bays such as Shoalwater Bay. Broad Sound, and Edgecombe Bay—all on the way to island-making. A step farther has resulted in such severances as the Whitsunday, Hinchinbrook, and Albany Passages.

The dissection of the Queensland coast being greater than that of New South Wales, indicates greater subsidence.

Two types of islands occur along the Queensland coast. One, a *flat wooded* island, which the practised eye recognises as a vegitated sandbank of coral origin. In literature they have been described as "cays," but that term is not colloquially used in Queensland. These range from Anchor Cay, in Torres Strait, where the influence of the Fly River terminates coral growth, south to Lady Elliot Island off Bundaberg. It is curious that Captain Cook, when he sighted and named Green and Low Woody Isles, should not have marked them as danger signals informing him of the proximity of coral reefs. He had previously observed such islands in the Paumotus, but seems not to have been sufficiently familiar with them to appreciate their significance and profit by the warning they conveyed.

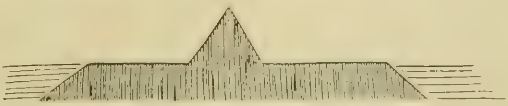
The other type appears as a long array of *hilly timbered* islands standing like sentinels off the Queensland coast. Here and there in ones and twos, but often clustered in archipelagoes, they stretch from Thursday Island, or, more accurately, Mount Cornwallis, in the north to the Keppel Islands in the south. Rarely does a coaster lose sight of one before another rises into view. Each island is associated with the mainland nearest to it by identity not only of rock structure, but also of fauna and flora. They impress a casual observer as being a part severed from the main. We may dispense with arguments that they are aught else and consider the manner of their severance.

In other regions of the world—for example the Chilian coast—a long stream of off-shore islands is held to indicate subsidence. This is the first explanation, and we hold the true one, which these islands suggested to geologists. Like a conflagration subsidence destroys its own history, but a couple of hundred feet would be a moderate estimate of the descent which isolated these rock masses. Such a movement would suffice to build much of the Barrier Reef on Darwinian lines.

Professor Agassiz, who avoids this deduction, regards the high islands as separated from the main, not by subsidence but by "erosion and denudation." We cruised along the Barrier with his memoir in hand and studied it in sight of the subject. Though impressed by his vast experience and knowledge, we are unable to accept his interpretation of this crucial point.

Denudation fails before reaching base level; it could not reduce a cape to an island. Marine erosion only takes effect upon a coast fronting the open sea; it could not excavate tortuous sheltered channels. A well-known beauty spot of the Queensland coast is the Whitsunday Passage. On either side extend an intricate dissection of mountainous land seamed by waterways 100ft. deep. To this archipelago we especially point as a characteristic product of subsidence; we submit that its features could not be evolved by erosion and denudation.

Professor Agassiz, if we understand him aright, traces the history of the Barrier Reef without the intervention of subsidence. He considers that this region has been stationary since the Cretaceous era, that numerous continental islands similar to those which now fringe



the coast have been cut down by marine erosion, and that on their bases have spread as a "thin veneer" the reefs now existing. The unfinished product of marine erosion might be imagined as a flat cake, with a median or lateral undenuded residue, as shown in figure. Instead of being a usual form of island, this type is rare or absent. Indeed marine erosion seems to us to play a paltry part in the moulding of the Queensland coast, the main features of which we ascribe to subsidence. Though Jukes probably exaggerated the mass of coral in the Great Barrier, yet Agassiz certainly went to the opposite extreme and underestimated it as a thin veneer " of at most 20 fathoms " (p. 139).

It may be allowed—though Darwin deprecated the idea—that the continental shelf was ready prepared with numerous banks representing eroded islands, just reaching to within the required distance of the surface, when the first coral builders came.

V. THE BUILDING OF A CAY.

This hypothetical history of a Barrier Reef islet, as deduced from the Hope Islands and Cairns Reef, commenced when the coast of Queensland stood at a higher level than it does now. Or it would equally suit our purpose to consider that the sea lay then at a lower level. Queensland had not remained at that height sufficiently long for the sea-board to have been reduced to a peneplain.

The high islands, then a part of the main, commenced to sink. No evidence is available, but it is as likely that the descending cycle was advanced, that the movement had already made much progress, and that it had swallowed a coastal plain, as that it began with the attack on the high islands.

Invasion of the sea has parted the high islands from the main by channels 15 to 20 fathoms deep. No sediment from the Queensland rivers escapes to the open sea beyond the Barrier. All is deposited in the channel along the coast. Therefore the present sea-floor as shown by the soundings on the chart, would not represent the original bed of the sunken valleys. And 200ft. may be assumed as a moderate estimate of the depth to which the islands have been submerged.

The subsidence that isolated the high islands has also left its mark on the mainland. Mourilyan Harbor is a good example of a drowned land valley. As instanced later, all the rivers of north-east Queensland debouch through estuaries filled with sediment and lying in troughs too deep for excavation at present level.

An exchange of flora and fauna between Australia and New Guinea points to a time when an isthmus occupied the place of Torres Straits.(*e*) The alteration in level needed to restore this isthmus corresponds to the alteration which would restore the high islands to the main. Since the time when communication by land was held across Torres Strait, the fauna has undergone some specific change. This affords us a time index, and we date the isthmus as Pleiocene.

When the sea had so far overrun the land as to submerge the position of the Cairns Reef, the corals would not at once occupy it. The mud brought down by the streams renders the immediate vicinity of the land too turbid for reef growth. Not till the coast had retreated further would colonists from the seaward reefs settle there.

(*e*) Hedley.—Proc. Linn. Soc., N.S. Wales, xxiv., 1899, p. 396.

Spreading from a central nucleus in round or linear form, the budding reef rises towards the surface. If the axis of a linear reef is parallel to the south-east trade its shape persists; but if it lies across the wind, then, as it comes within the influence of the waves, the prevailing south-easter moulds it to a crescent, with the convexity to windward. By a continuation of the crescent horns to leeward, the

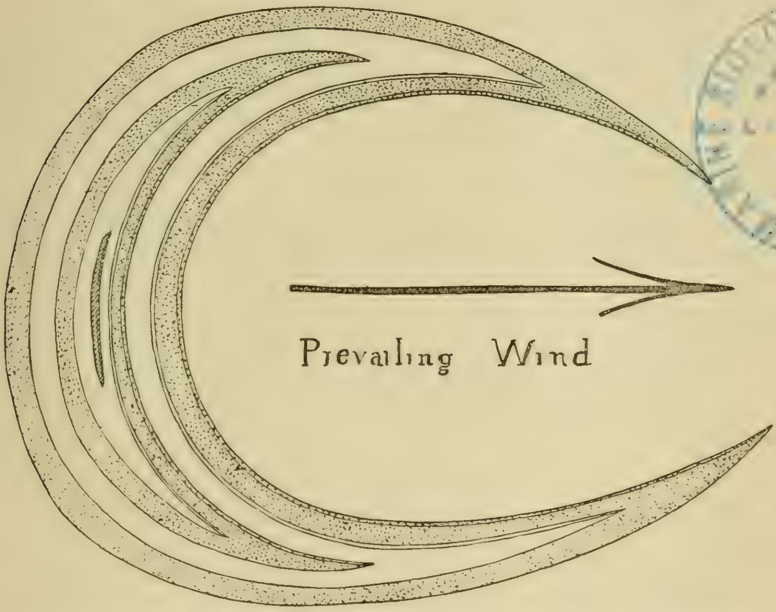


Diagram to show how a Linear Reef lying across the Wind is formed into a Horseshoe.

characteristic horseshoe shape is attained. As elevation would affect a river so submergence, at the present stage, would rejuvenate the reef. Conversely, maturity or senility in a reef imply quiescence.

This explanation differs from that of Sir J. Murray, who considers the atoll form to be assumed by abundant growth of well-fed corals on the margin and solution of dead coral rock in the interior. But if solution be so destructive, how can a reef form at all?

In its next stage the horseshoe reef reaches the surface as a ridge of growing coral. On this summit the corals die, and the crest is rubbed down level by the surf. The top of the reef then resembles a roadway, with borders of living coral for the side-walks. With age each arm of the horseshoe broadens indefinitely; the fringes of living coral on either side remain, but an expanse of a mile or more of dead coral intervenes. The broadening of reefs in the central Pacific has been described by one of us.(*f*) Erosion and solution destroy much material, but the loss is at once made good by fresh matter thrown upon the reef.

(*f*) Hedley.—Natural Science, XII., 1898, pp. 174–178.

It cannot be insisted upon too strongly that all over the reef, wherever water moves, there we find a perpetual swirl of grit. This rasps the negroheads, and planes down inequalities on the reef crest. But any hollow calm acts as a trap to arrest and retain this grit. The larger the area of ground between tide marks the more room there is to produce foraminifera, corals, and shells, which in turn supply building and eroding material.

It is a geological axiom that as the source of a stream is approached its burden consists of larger fragments. So approaching the weather edge of a reef we pass from finer to coarser debris, for here is the main source of building material. Under the high pressure of the hurricane, the factory turns out the huge masses we call negroheads. The output of a lesser gale is coral clinkers; while ordinary weather throws up sand and broken shells.

As soon as the reef reaches the dead crest stage, the matter transported by the water commences to be washed across the reef into the area enclosed by the horseshoe, here called the lagoon. Everywhere in

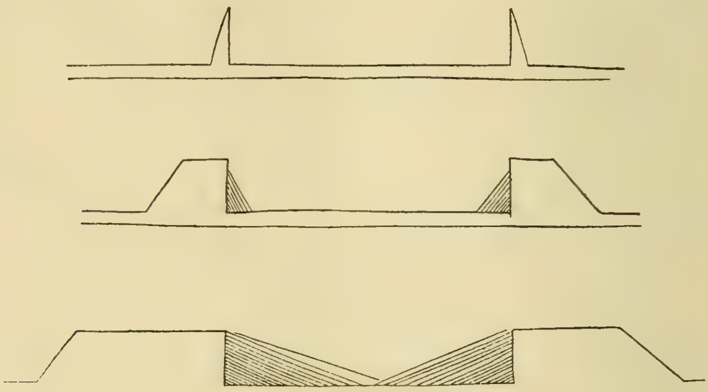


Diagram showing Progressive Stages in the Broadening of the Lagoon Walls and the Infilling of the Lagoon Itself.

the lagoon of Cairns Reef our dredge brought up a load of weed, shells, foraminifera, sand, and broken coral. The borings of Mr. G. H. Halligan showed the floor of Funafuti Lagoon to be composed of like material.(*g*) From this stage onwards the lagoon is like a lake in process of being choked with sediment by brooks. If there is a gap or gutter in the reef, the stream which spurts from it into the lagoon tends to build a jetty. Such are shown on the west side of Captain Hore's model of Funafuti.(*h*) Here and there, at a distance from the reef, there may be an odd clump or two of coral, but such plays a slight part in the infilling of the lagoon. The sediment in the lagoon is apt to smother

(*g*) "Nature," LXX., 1904, p. 319.

(*h*) David and Sweet: "The Atoll of Funafuti," 1904, p. 62, plate B.

the coral clusters. When deposition has advanced a short way, a map (*vide* Plate II., Cairn's Reef Lagoon) will show patches towards the centre, where the original floor is still bare. Thence to the reef wall stretches a talus slope. Given a sufficient period of quiescence, the lagoon will fill up solid and be obliterated. Masthead Reef offers a case where the lagoon is in the last phase of disappearance.

Late in the development of a reef occurs the inception of the islet. Some of the sand and shingle that perpetually drift across the reef is caught by a chance obstruction (as in Bee Reef, Plate I). Round this nucleus more and more sand is packed. Saville Kent has well figured this stage as "the birthplace of a coral island."(*i*)

When the sand has piled up enough to be dry at high water, it is soon possessed by drift seeds, and grows green with shrubs and herbage. The vegetation binds and protects the sandbank, so that dunes rarely, if ever form on these cays. However far the periphery may advance, the land does not gain in height. Torres Straits pilots have informed us that certain islets have considerably enlarged their borders within their recollection. Percolation of water through the sand of the cays forms coral sand rock by solution and deposition of lime. Such rock is generally visible where any temporary denudation of the beach has occurred. In the phrase of physiographers describing the history of rivers, the cay is now "mature.' The "senile" stage might be represented by a reef entirely overspread by a vegetated sandbank.

VI. EVIDENCE OF THE MAINLAND.

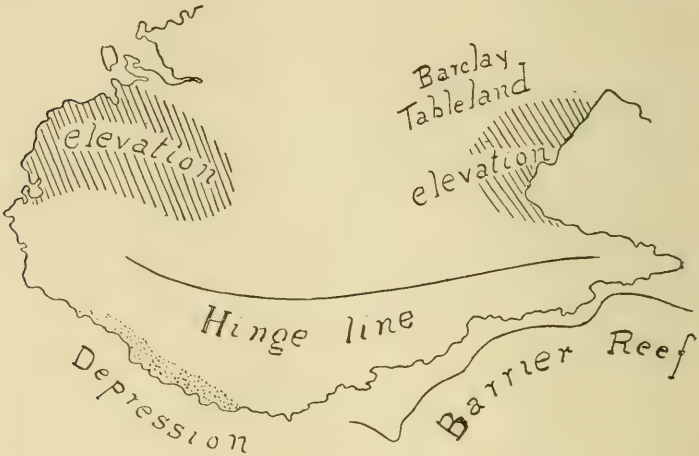
The present section is an attempt to correlate the broad geological features of Eastern Australia with movements affecting the origin of the Great Barrier Reef.

In New South Wales the present drowned coastline is of comparatively recent date. The old river courses ran north and south (*vide* Shoalhaven, Wollondilly, and Clarence), and hence more or less parallel to the present coastline. Rivers flowing directly to the coast—whose mouths are in many cases in the form of *drowned* valleys—are most probably of late Tertiary age. Hence one may refer an important portion of the subsidence of the New South Wales coast to late Tertiary times. It is significant that the western portion of the State (the lower Darling and Murray, see Plate III.) exhibits an elevation of somewhat the same period. This gave rise to the engrafting of the Murray tributaries and to the exposure of wonderfully rich Tertiary fossil beds.

It seems probable, therefore, that a "tectonic rocking" about the main mountain axis (north and south) of the State obtained at the close of the Tertiary, leading to depression in the east and elevation in the west.

(*i*) Saville Kent: "Naturalist in Australia," 1897, p. 147, text figure.

In Queensland the axes have a direction like those of New South Wales, the chief mountain ranges running north and south. Here are also shown on the geological ma› huge areas of Tertiary deposits extending for more than 200 miles from the Gulf of Carpentaria.



Sketch showing Relation of Area of Elevation to Area of Depression.

Mr. L. C. Green (late of the Queensland Geological Survey) informs us that he is of the opinion that the Barclay tableland south of the Gulf is probably the last relic of the old inland sea of Australia. The Post Pliocene limestone constituting such tableland has an elevation of some 500ft., pointing to a considerable rise of land surface in recent geological time. To this elevation we may refer the extraordinary shallowness and even shore line of the Gulf of Carpentaria. The s me movement may have influenced Lake Eyre.

Across the Papuan Gulf are evidences of a recent uplift. One of us (H.) has observed a raised barrier reef behind the village of Maiva. At Yule Island this barrier is breached by the St. Joseph River. The plain between the Mount Yule Range and the coast, through which the St. Joseph River winds, is obviously the former bed of a broad lagoon channel. This interesting feature has not, we believe, been hitherto noticed in literature, though some of the fossils from the raised barrier were discussed by Mr. Etheridge (Rec. Geol. Survey, N.S.W., II., 1889, p. 177). This movement was probably synchronous and possibly an effect of the same crustal heave that depressed the Queensland coast.

If, as Professor Agassiz considers, the Queensland coast had remained stationary since the Cretaceous it would have now presented a very different appearance. Long-continued denudation would have levelled the coastal ranges to a uniform peneplain. The rivers, especially active silt-carriers when swollen by the wet cycle of Tertiary times, would have formed deltas, coastal plains, and that even monotonous shore line characteristic of old rivers uninterrupted by earth movements.

The east coast of Queensland is free from such features; almost the only attempt at a delta that we can recall is that of the Burdekin River. Most of the rivers flow directly into gulfs or bays, whose outlines have hardly yet been softened by their sediment.

Subsidence, however, seems to have been less active in recent times, and to have permitted the inception of alluvial plains. Thus the Endeavour River enters the sea at the head of a bay (which it will possibly in the course of ages fill up), and for some miles back flows through low country undoubtedly formed of its own alluvial (see map). The Annan River (south of Cooktown) has a similar wide valley, with its mouth also at the head of a bay. The river flats extend to the foot of rather *steep* hills bounding the former, as if the river had gradually filled up its older valley since the latter subsided.

The Bloomfield River (20 miles south of Cooktown) has a relatively huge flow of water considering the small extent of its basin. Its falls line reaches within 10 miles of the coast, implying some warping action or allied phenomena within a geologically late period; at any rate absolutely opposed to the idea of a *long-continued* era of geological quiescence.

An apparent exception to the pattern of the coastal streams are a group of rivers south of Cooktown—the Bloomfield, Daintree, Barron, etc. From one view-point on the Cairns railway there may be seen

Sketch to show the Position of the Head Water of the Barron and the (possibly beheaded) Mitchell River.

in the east the cay of Green Island and below the gorge of the Barron. While the former disproves elevation and suggests subsidence or quiescence, the foaming cataracts now carving out the gorge of a youthful and vigorous stream appear to demand great and recent elevation. To harmonise the apparent contradiction we suggest that a capture of the headwaters of the Mitchell by the Barron has lately occurred; in which transfer the stream would shorten its journey to the sea from 300 miles westerly to 30 miles easterly, and the steepness of its fall would imitate a stream rejuvenated by elevation. The situation reminded one of us (T.) of the Shoalhaven capture lately studied and described in conjunction with Dr. Woolnough (*j*)

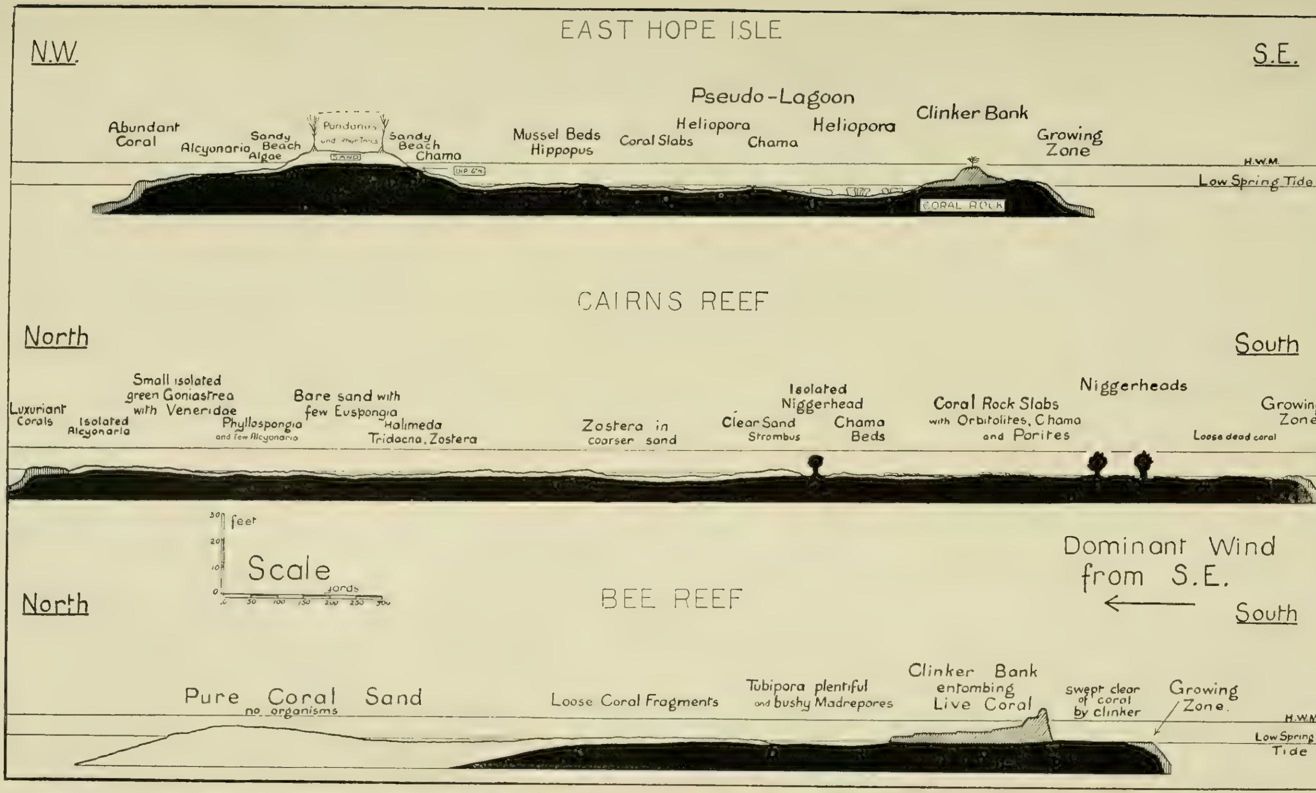
Such a capture would be assisted if not determined by a downward movement east of the Divide. As chronological estimates of the end of the Ice Period have been based on the rate the Niagara excavates its gorge, so the rate at which the Barron digs its valley might provide an estimate of the time of the local subsidence.

Were the coral crust of the Great Barrier merely a thin veneer, then at its border it should scarcely break the natural curve of the continental shelf. So Professor Agassiz writes (*loc. cit.*, p. 141)—"There is nothing to show that the slope of the continental plateau has been modified by the growth of the Great Barrier Reef, and that we have a steep pitch (almost a vertical rise, due to the growth of corals) . . . . on the sea-face of the living Barrier Reef." But the precipitous submarine slope of Raine Island and the adjacent Barrier—a tower beyond a wall—as developed by the *Challenger* survey (Narrative *Chall.* Rep. p. 530, inset map 27, opp. p. 464) is comparable to the submarine cliff of Funafuti, and may be cited as evidence in favor of Darwin. Recent Admiralty surveys abreast of the Hope Islands show the seaward face of the barrier to rise there even more abruptly. At one and a half miles outside the reef the depth is 312 fathoms, and at three and a half miles it is 600 fathoms. There is not in all Australia a declivity to match this; but those who know the mountain towering over Monaco may realise how the Great Barrier would appear if uplifted in the air. Part of this slope is probably talus.

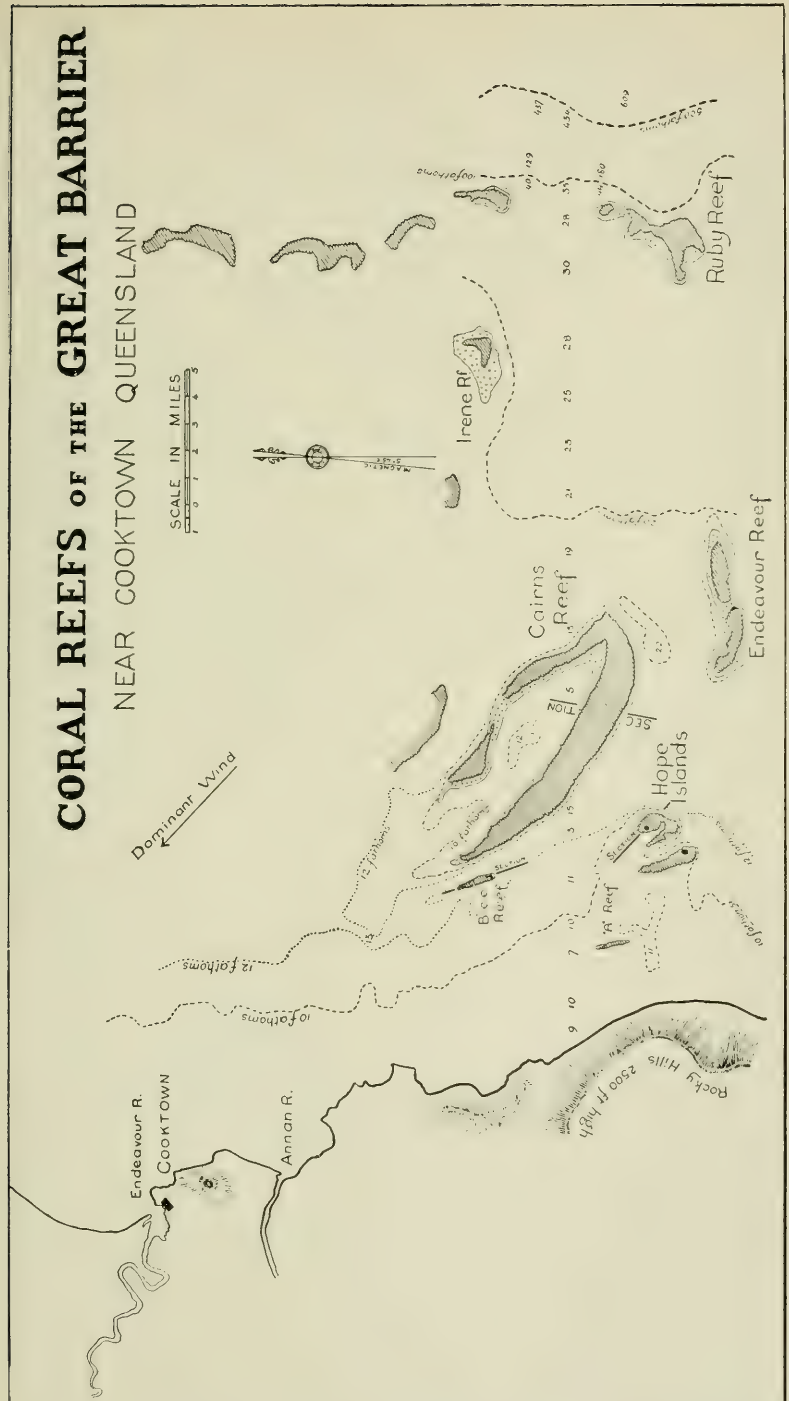
One of the chief gains to science in the investigation of Funafuti was the generalisation that crystallised dolomite characterised the strata below 638ft., but was unknown above that horizon (Cullis—"Atoll of Funafuti," 1904, p. 405). Now large blocks of dolomitic coral were observed to have been ejected by the extinct crater of Mer, Murray Islands, north end of the Great Barrier, by Professor A. C. Haddon (Trans. Roy. Irish Acad. xxx., 1894, p. 433). These blocks have been examined *in situ* by one of us (H.). This shows that the volcanic pipe burst through an underlying coral reef. It seems a fair deduction to conclude that at this spot sunken reefs exist below the 100-fathom level.

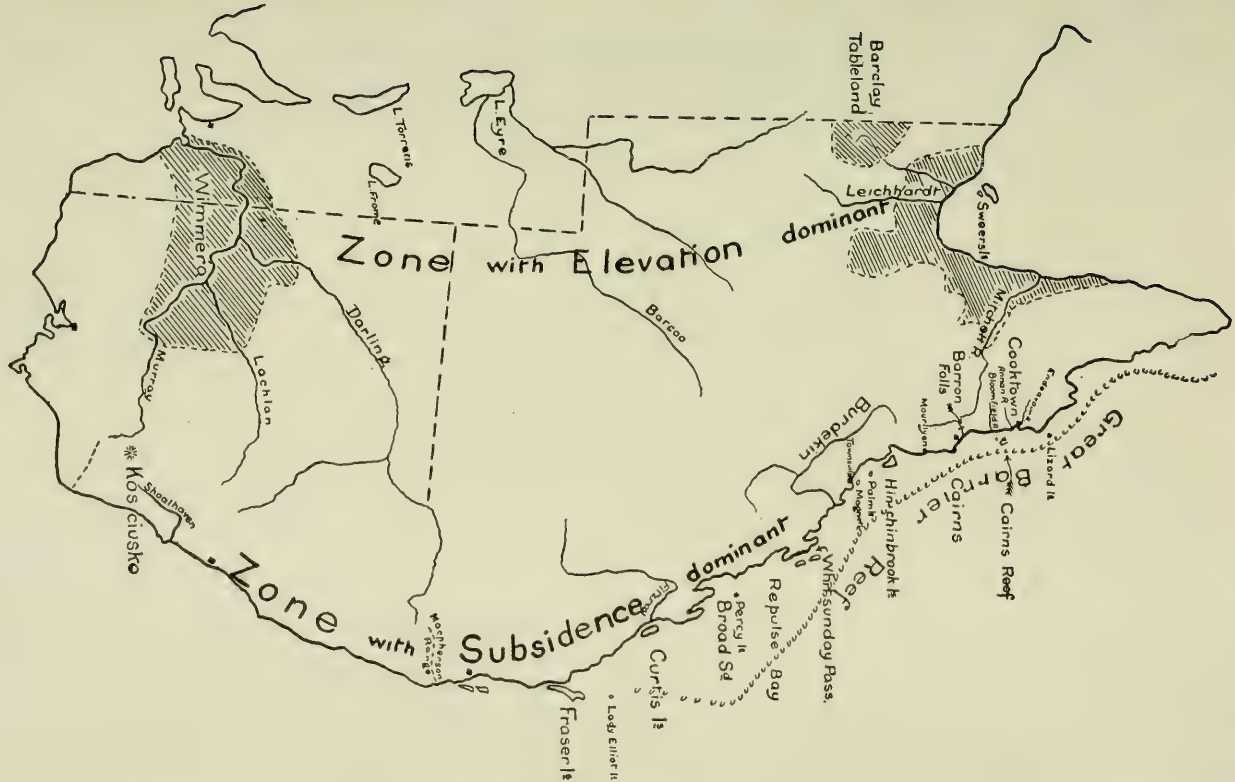
The last upward vibration of Andrews was not observed by us; possibly it does not extend along the whole coast. A slight elevation

(*j*) Woolnough and Taylor: Proc. Linn. Soc., N.S.W., xxxi., 1906, pp. 546-554.



Sections across typical Coral Reefs (see Map, Plate II), illustrating the Physiography of the Great Barrier Reef.


CORAL REEFS OF THE GREAT BARRIER
NEAR COOKTOWN QUEENSLAND
SCALE IN MILES
MAGNETIC
Dominant Wind
Irene Rf
Ruby Reef
Cairns Reef
Endeavour Reef
Hope Islands
Bee Reef
'A' Reef
Section
Endeavour R.
COOKTOWN
Annan R.
Rocky Hills 2500 ft high
12 fathoms
10 fathoms
100 fathoms
500 fathoms



Locality Map of Eastern Australia, showing the Great Barrier Reef and Adjacent Coast, also Zones of Late Post Tertiary "Tectonic Rocking."

at Magnetic Island was recorded by W. S. Kent (Proc. Roy. Soc., Qland. VII., 1891, p. 39); but Haddon, Sollas, and Cole consider that no elevation has occurred in Torres Strait (Trans. Roy. Irish Acad., XXX., 1894, pp. 460, 472).

Whatever the history of the Great Barrier was, the reefs of the Coral Sea, such as the Lihou Reefs, Flinders Reefs, and the Herald Cays, shared in it.

VII. SUMMARY.

The growth of an individual reef is shown to proceed in a regular cycle. If the reef reaches the surface with its axis along the wind, then its shape endures; but if across the wind, then its extremities are produced backward, forming first a crescent, later a horseshoe, and lastly an oval, thus enclosing a lagoon. Descent at this stage arrests development or rejuvenates the reef. In quiesence the lagoon walls broaden, the lagoon is obliterated with sediment, a vegitated sand-bank spreads on the summit, and the atoll, grown to a cay, has arrived at maturity.

It is argued that the negroheads are not, as has been advanced, relics of former raised reefs, but are tossed up by hurricanes.

Not every writer on the Barrier Reef region has expressed an opinion on the question of formation during subsidence. On the Darwinian side are ranged Jukes, Kent, and Andrews, and opposed to it is Agassiz. The present observers find a verdict for the Darwinian view on these grounds:—That the mainland of Queensland shows subsidence in (1) drowned river mouths, (2) the formation of its bays and islands, and (3) the sinking of an isthmus that once continued the Cape York Peninsula to Papua. That the sinking of the Queensland coast is part of a general movement which affected the whole of Eastern Australia and Tasmania; probably correlated with an upward movement in the Australian interior between the 135th and 140th meridians, and perhaps on the north shore of the Papuan Gulf; the Barrier trough thus ending in the valley of the Fly River. That the Barrier *does* present (which has been denied) a steep outward face agreeable to the Darwinian hypothesis. That ejections from the Murray volcano show coral formation to occur there at considerable depths; and that the maturity (a term here introduced into coral geology) of the northern reefs indicates slow subsidence followed by quiesence.

DESCRIPTION OF PLATES.

Plate I. Sections across three typical coral reefs showing the physiography of the same.

Plate II. Map of the reefs near Cooktown, from the Admiralty chart, showing direction of traverses and contour of sea-floor and reefs.

Plate III. Sketch map to show position of reefs studied and relation of areas of elevation to those of depression.

8.—A GENERAL DESCRIPTION OF THE CAMBRIAN SERIES OF SOUTH AUSTRALIA.

By WALTER HOWCHIN, F.G.S., Lecturer in Geology and Palæontology in the University of Adelaide.

For some time great uncertainty existed as to the geological age of the Mount Lofty and associated ranges. The late Professor Tate regarded them as exclusively Archæan, limiting the Cambrian areas to an outcrop near Ardrossan, Yorke Peninsula, and certain portions of the Flinders Ranges, indicated by the presence of *Archæocyathinæ.* Mr. H. Y. L. Brown, in his Geological Map of South Australia (1899), indicates in descending order from west to east—(1) Cambrian and Lower Silurian (?), (2) Cambrian, &c. (Metamorphic), (3) Metamorphic and Plutonic. Until recently the data at command were insufficient to define the Cambrian areas in their true extent, or the recognition of a Cambrian base level.

Sufficient detailed work has now been done to give a generalised description of the great Cambrian system of South Australia, which, so far as the south-central highlands of Australia are concerned (including the Mount Lofty, Barossa, Flinders, and other ranges), is by far the dominant geological feature of the country. No other Palæozoic formations occur within the areas indicated, unless we take into account the glacial beds of the Inman Valley and Hallett's Cove, which are probably of Permo-Carboniferous age ; and the Pre-Cambrian exposures are of limited extent, mostly lineal and following the main axis of the ranges.

The Cambrian series is of very great thickness, probably not less than 30,000ft. to 40,000ft., or even more. So far as known, the beds are conformable throughout. The most clearly marked lithological distinction in the series occurs about the horizon of the Brighton limestone. Above this horizon the typical characteristic is that of red-colored rocks, chiefly purple slates, quartzites, and sandstones. Below the Brighton limestone the rocks consist principally of slates, siliceous quartzites, phyllites, and one or two limestones. In this lower part of the system there are no purple slates, and the rocks are not colored red. The transition at the Brighton horizon is certainly somewhat sudden and strongly marked ; but it is not clear that an unconformity exists. There seems, indeed, to be a transition zone of color, for the upper bed of the Brighton limestone is reddish and is locally known as the "pink limestone."

Upper Cambrian.

The close of the Cambrian period was marked by a great elevatory movement that initiated the main physiographical features which have, in a measure, persisted to the present day. The evidence (so far as we are able to test it) goes to show that the old Cambrian mountains of southern Australia, in their greater heights, have not been submerged from the time when they were first raised above sea-level. From the great waste they have suffered in the interval, it is reasonable to conclude that the top beds, which would be particularly exposed to the denuding agents, have entirely disappeared, so that we speak of the top of the Cambrian series only in a relative sense. On the other hand, the base of the system is well defined, and will be dealt with in the sequel.

The age of the beds is determined mainly on palæontological grounds. With the exception of a few obscure remains of Radiolaria in the Brighton beds, the fossiliferous horizons, so far as known, are limited to two limestones very high in the series. These occur at Ardrossan, Yorke Peninsula ; Sellick's Hill, 20 miles south of Adelaide ; and at many places in the Flinders Ranges. The most striking group of fossils belong to the *Archæocyathinæ*, which must have formed coral reefs in the Cambrian seas of great geographical extent and from 100ft. to 200ft. in thickness, in addition to which are the typically Cambrian forms of *Obolella*, *Stenotheca*, *Hyolites*, *Salterella*, and some Cambrian trilobites (*Microdiscus*, *Olenellus*, *Ptychoparia*, &c.), which unfortunately, are mostly in a very fragmentary condition. This strongly marked Cambrian fauna, occurring near the top of the series, fixes the latest geological age that can be assigned to all the inferior beds in the same series. As a matter of convenience, the beds above the Brighton horizon, which include about two-thirds of the whole, may be called Upper Cambrian (or Purple Slates series), whilst the beds below that line may be designated Lower Cambrian. The former are best seen in the Flinders Ranges and the latter in the Mount Lofty, Barossa, and Petersburg Ranges.

The physiographical features of the Flinders Ranges differ greatly from those of the Mount Lofty. This arises partly from the different climatic conditions of the respective areas, the southern districts having a relatively moist climate and the northern districts an arid one. In the latter case the stratification over great areas is as sharply defined as when drawn on the blackboard : the hills have jagged crests and peaks, and the limestones, instead of passing into solution, stand out as prominent ridges.

Another point of contrast arises from the variation which has occurred in the folding force in the respective areas. In the Mount Lofty and other southern districts the tectonic forces operated on a grander scale, the axis of elevation reached a higher altitude, the crush was correspondingly greater, and an anticlinorium of great intensity was developed with numerous contortions, overfoldings, and thrust planes. In the Flinders Ranges and in the country between Petersburg and the New South Wales borders, whilst there has been much crush, producing in places vertical and contorted stratification, the country has not been contracted under pressure to the same extent as in the case of the Mount Lofty Ranges. I am not aware of any place in the Flinders Ranges where the base level is exposed, but the Cambrian beds spread over a great extent of country in broad anticlinal and synclinal foldings. In these northern districts there is not that definite thrust from east to west which is so evident in the Mount Lofty Ranges, and the contractions operating north and south (on the strike), appear to have almost equalled that produced in an east and west direction. The effect has been to produce periclinal folding, taking the form of vast domes and basins, the latter producing the remarkable saucer-shaped areas to which the name of "Pounds" has been given, as in the case of the Wilpena Pound, the Illinawortina Pound, and others. Where these features are imperfectly developed the strike follows curves rather than straight lines, and is frequently helicoidal. This curvature of the strike has produced in many places differential movement in the mass, with the attendant features of blatter and horizontal slickensides; and not unfrequently an exceedingly complex system of faulting and disturbance.

A good illustration of the dome-structure, as well as presenting one of the most complete sections of the upper beds of the Cambrian series with which I am acquainted, occurs near Blinman. One line of section across this vast dome may be taken from the Parachilna Plains, near Lake Torrens, on the west, to the Grindstone Range, on the eastern side of the Flinders Range overlooking the Lake Frome Plains, on the east. The mining township of Blinman, which is about 2,000ft. above sea-level, forms the centre of elevation in the dome structure, with the beds dipping away from this centre in all directions. The broken edges of these beds standing out prominently as mural cliffs, present striking features in the landscape. Geographically, the section (*a*) represents an east and west line of 40 miles; geologically (making allowances for curvatures and other irregularities of strike), it is supposed to represent about 20 miles across the strike, and includes, approximately, the full diameter of the dome. The symmetry of the dome is broken by an adjoining basin which is developed on the south-east of Erungundah Creek.

The great western escarpment, which makes a striking feature from the railway line, rises abruptly from the plains to about 1,000ft. in height, and forms an impassable rock face for many miles both on its eastern and western sides. The angle of dip is high, and the wall of rock on its western face probably represents a fault-scarp connected with the great meridional fault indicated by the central valley of Gulf St. Vincent, Gulf Spencer, and Lake Torrens. The rock consists, in the main, of a very close-grained, siliceous quartzite, and is overlain by a thick series of limestones, largely oolitic or dolomitic in the lower members, and an *Archæocyathinæ* coral reef in the upper portions. These are amongst the highest beds of the Cambrian series exposed on the western side. On the eastern side of the ranges we have a set of beds, superior to the *Archæocyathinæ* limestone, including *Obolella* and *Girvanella* limestones, which are not seen on the western side.

(*a*) This refers to a sketch-section which was exhibited at the meeting in a diagram, showing the dome structure and succession of beds across the Flinders Ranges in the direction mentioned.

An inner escarpment runs for many miles parallel with the outer, and is but little inferior to the latter in height and impressiveness. In descending order, there follow very characteristic purple slates, which, in part, are in vertical position ; and then a series of oolitic, dolomitic, and siliceous limestones, interbedded with flags and slates, representing several thousands of feet in thickness. A lower set of flags, slates, and limestones complete the section to Blinman. On the western side of Blinman the beds (allowing for a certain amount of curvature in the strike) have a uniform dip to the west. On the eastern side of Blinman the beds are repeated with a uniform dip to the east, until the Eringundah Creek is reached, 10 miles from Blinman, when the *Archæocyathinæ* limestones again appear in the section, and the folding becomes synclinal of a roughly periclinal type.

Near the Eringundah Creek the *Archæocyathinæ* limestone bifurcates; one limb runs north-easterly to Wirrialpa Old Station and the Mount Lyall Range ; the other trends south-easterly to the Balcoracana Creek. This periclinal basin brings into view a set of beds which are superior in position to the *Archæocyathinæ* horizon. They consist mainly of a series of red, softish, sandy flagstones, with purple slates, and a few small limestones. One of the latter is highly fossiliferous in a narrow horizon. Shells of *Obolella*, *Orthis*, *Hyolithes*, *Girvanella* nodules, and other remains are sometimes matted together in a confused mass. *Archæocyathinæ* are also sparingly represented in this bed, and there is an horizon of sandy limestone which carries undoubted evidences of annelid burrows. This fossiliferous horizon can be traced for miles in the Wirrialpa and Balcoracana country. A marked topographical feature of this upper series of beds is the presence of thin-bedded quartzites or flags, which form a group of jagged peaks, five miles from Wirrialpa Station, and are known as the Grindstone Range, or the "Little Bunkers." These hills die away to the plains on the east, and are the highest horizon of the Cambrian rocks known to me.

There are two points of special interest which should be mentioned in this generalised review of the geology of the Flinders Ranges. One of these has reference to the conditions of deposition. It is usually admitted that red rocks indicate subærial deposits, either æolian, or shallow water in combination with the latter. The upper (that is the Flinders series) is characteristically of a red color, especially in the higher members ; the beds largely consist of loosely cemented, reddish sand grains, and are frequently false-bedded, of a kind which suggests wind action. Further, the limestones, other than the dolomites, are usually under three kinds of structure : (*a*) finely oolitic, (*b*) coarsely concretionery, or (*c*) finely laminated. Observations made in the south-east of this State have led to the discovery of an oolitic rock now under formation. In this case concretionery granules of carbonate of lime are forming on calcareous flats where the sand is saturated with water but still exposed to the air. Where this occurs the surface appears dry, but on scraping away the oolitic sand the deposit is found in a wet condition. Oolitic concretions, I assume, are most likely to form when evaporation of shallow waters containing calcium carbonate in solution is continued to saturation or dryness, as in the case of the recent oolitic deposits referred to. If this be so, then the extensive development of the oolitic structure in the Upper Cambrian beds of this State would suggest that they were formed (at least in part) under practically subærial conditions. Again, the *coarsely concretionary* limestones bear an exact resemblance (differences of age being taken into account) with our concretionary travertine limestones, which form over the surface of calcareous soils in all the drier parts of Australia. The concretionary, or nodular, Cambrian limestones break up readily into rounded fragments in a similar manner to this nodular travertine limestone of recent origin, and can best be explained, I think, when referred to a similar origin. The *finely laminated* limestones in the Cambrian series also bear a likeness to such travertines as are laid down from slow-moving surface waters when charged with calcium carbonate in solution in an arid climate. A microscopical examination of these interesting limestones is in progress, which may possibly throw further light on the nature of their origin. The whole of these facts taken together make, I think, a strong presumption that at certain intervals of the Cambrian Period in these latitudes arid, if not desert, conditions prevailed, and that much of the material laid down in Cambrian deposits was of terrestrial origin.

The second point referred to as of special interest in the Flinders series is the great volcanic field which was developed in Post-Cambrian time, chiefly at or near Blinman, forming the central part of the elevated dome. The country is riddled with basic dykes, which have a general east and west direction, but are not continuous for long distances, and are sometimes circular, which suggests that some of them may be old volcanic necks. Two considerations seem to point in the direction that the volcanic activity belonged to a late stage of the elevation of the dome, and that the dykes were formed at no great depth from the present surface, viz., the lava of the supposed necks is often vesicular in structure ; and, secondly, whilst the slate and other rocks which have been penetrated and reduced to breccia by the intrusive dykes show contact effects, they have undergone no secondary metamorphic changes in the mass, which might be expected to occur had they been brecciated at considerable depths.

As these observations have only recently been made, time has not permitted a petrological examination of the intrusive rocks. These dykes often run parallel with or intersect the dolomitic limestones of the district, and it is in the zone of junction of the limestones with the intrusive rock that the mineral deposits of the neighborhood chiefly occur.

The lowest beds of this section comprise slates, flags, and dolomites, but do not expose the base of the purple slates series. In other parts of the Flinders Ranges the lower members—as low as the glacial till beds—are at the surface. These have a general strike from south-west to north-east.

The Cambrians thin out on the western side against the Pre-Cambrian *massif* of the western plateaux, as in the case of the Tent

Hills west of Port Augusta, or rest unconformably on the older series, as at Ardrossan, Yorke Peninsula. This marks approximately the western margin of the old Cambrian Sea, or at least its shallows, and the beds of these districts were laid down by overlap and transgression. At Ardrossan the *Archæocyathinæ* limestones and accompanying dolomites (which in the Flinders Ranges are underlain by a great thickness of Cambrian deposits) are here only separated from the Pre-Cambrian by basal grits.

Lower Cambrian.

The lower beds of the Cambrian system are reckoned from the horizon of the Brighton limestones, not, as has already been stated, from the occurrence of any distinct unconformability in the series, but conventionally on their lithological differences and color. This lower series may be roughly estimated as comprising about one-third of the total thickness of the Cambrian beds as developed in South Australia.

In the Mount Lofty series there are three well-marked limestone horizons—(*a*) A *Lower Limestone*, which is within a few hundred feet of the base and about 150ft. in thickness, varying from a blue limestone to marble or dolomite. (*b*) A *Carbo-argillaceous Limestone*, situated near the centre of the series, forms a calcareous zone about 100ft. in thickness. The stronger and more calcareous beds of these outcrops are locally known as "blue metal" and are extensively used for roads. These dark-colored calcareous beds are particularly useful to the field geologist as supplying a datum for the determination of the order of succession in a much-faulted district. (*c*) The Brighton or *Upper Limestone*, which in its highest beds is a very pure oolitic limestone capped by a yellow dolomite, but passes down to argillo-siliceous limestones and calcareous slates, which merge into the Tapley's Hill banded or ribbon slates. The latter (estimated at about 1,500ft. in thickness) are composed of exceedingly fine clayey material, laid down in very thin laminæ, and marked by colored bands, which are brought out strongly under weathering. The bed varies from a laminated shale to a slate which splits readily at a high angle to the bedding plane, but not sufficiently thin for roofing slate. Near Adelaide it has a slaty structure, but further north it becomes a shale and splits up into thin slabs. It is sometimes of a very dark color, which is discharged by heat, indicating the presence of carbon.

By far the greater portion of the Mount Lofty beds consists of quartzites, slates, and phyllites, which make a very uniform succession in the lower half of the series. The quartzites are characteristically highly siliceous by infiltration of silica and the secondary development of quartz. Most of the quartzites in this part of the series have a macroscopic, granular, felspar constituent, which may be estimated at about 30 per cent. of the whole. The felspar clastic material was probably derived from the granitic Pre-Cambrians, which carry a high proportion of felspar, and would form the land surfaces from which the fragmental beds would derive their material. Dr. Woolnough, my late colleague in the Adelaide University, has made a study of these quartzites, and published in the Trans. Royal Society of South Australia an interesting description of a large number of specimens collected from the Mount Lofty Ranges. The main quartzite in this series, which reaches a thickness of 1,000ft., has been broken up by block-faulting and forms the disconnected fragments of the Black Hill, Stonyfell, Mount Lofty, and others. The Glen Osmond and Mitcham quartzite is 100ft. in thickness, and occupies a higher position in the series than the last named.

The slates and phyllites, which are interbedded with the quartzites, supply the preponderating geological features of the foothills of the Mount Lofty Ranges near Adelaide, and by their decomposition form the rich soils of our agricultural fields, vineyards, and gardens of the lesser slopes and gullies of these ranges.

Between the Mitcham quartzites on the one side and the Tapley's Hill banded slates on the other there occurs a formation which exhibits strongly contrasted features from either. It forms in its essential characteristics a typical till bed, unstratified, and thickly charged with erratics, many of which are conspicuously striated by ice action. The beds near Adelaide form the southern extension of the great Cambrian glacial formation which covers a vast area northwards of Adelaide, reaching within a few degrees of the Tropics. As these beds have received special reference from me in another paper, which has already been placed before the Association through the medium of the Glacial Research Committee, further comment on this subject is unnecessary here.

The *basal beds* of the Cambrian consist of white felspathic grits, arkose grits, and coarse conglomerates, with clastic ilmenite, averaging from 150ft. to 200ft. or more in thickness. They rest on an Archæan complex of highly altered schists and quartzites which have been penetrated by granitic batholiths, aplites, and pegmatites of various ages, and unitedly are intimately foliated, constituting a very intricate and difficult series for determination. The eroding agents of early Cambrian times operated on this old Archæan floor, and the basal grits and conglomerates of the overlying Cambrian represent the waste and redistribution of these older rocks.

The line of junction between the Cambrian and Pre-Cambrian, whilst sufficiently distinct in its broader features, is not always easy to discriminate in particular sections. This follows from the fact that the basal Cambrians are composed of the clastic material gathered from the rocks on which they rest, whilst a subsequent pegmatisation has included both Cambrians and Pre-Cambrians in one and the same conditions of alteration and intrusion. When the great thickness of the Cambrian system of South Australia is taken into account, and the consequent depth to which the beds must have sunk to receive such a weight of material, it is not to be wondered at that the lower members should have reached an isogeotherm where pegmatisation was active. In places the basal beds exhibit flowage in a remarkable degree. Some striking effects of this kind are seen in the coarse conglomerates, especially in the Grey Spur outcrop of Inman Valley. In the upper and middle portions of this conglomerate bed the pebbles occur in their normal shapes as they were rounded by water action, but towards the lower parts they gradually become compressed and elongated, as though rolled out, and finally pass into quartz veins parallel with the bedding planes, which have also become planes of thrust and flowage.

These basal beds follow an axis of elevation which, intermittently, exposes the Pre-Cambrian floor in a north by east direction, from Inman Valley in the south, across the Onkaparinga (near Mylor), Aldgate, Stirling East, Carey's Gully, Forest Range, River Torrens, Houghton, the South Para, Barossa, and Tanunda

The Eastern Side of the Mount Lofty Ranges.

There still remains the question as to the age and succession of the beds which occur on the eastern side of the Pre-Cambrian axis.

A prominent feature of the eastern slopes of the Mount Lofty and related ranges is the development of a great plutonic and igneous area, which takes in not only the eastern side of the highlands, but extends over the Murray Plains and much of the continental shelf of the southern coast. It forms a plutonic area of great complexity, and along its western margin numerous basic dykes and pegmatitic areas intersect sedimentary beds that show a prevailing easterly dip. A regional metamorphism, of a high degree of intensity, sets in gradually a few miles east of Mount Lofty (and also of the Pre-Cambrian axis), and reaches its climax in near association with the great granitic region on the east. But little detailed work has been done on this much-altered and difficult tract of country. There is reason to believe that the beds on the eastern side are the equivalents of those that outcrop on the western side of the Pre-Cambrian axis. The chief considerations which have led to the adoption of this view are :—

(1) The dip on either side of the Pre-Cambrian axis of elevation is complemental in its direction. The prevailing dip of the beds on the western side of the axis is toward the west, and on the eastern side towards the east, forming together a great anticlinorium, which requires, for stratigraphical consistency, that there should be a repetition of beds on the opposite limb of the fold, not necessarily maintaining a lithological resemblance, but as equivalents in the order of succession.

(2) The basal conglomerates and ilmenite grits of the Inman Valley have a dip to the east, and exhibit in superposition a series of quartzites and slates, which become more schistose in their upper members as they approach the great granitic zone of the coast, at a distance of seven miles from the base. In this instance it seems clear that the beds, which are superior to the basal conglomerates, must be the equivalents of those that overlie the same basal beds on the western side of the Pre-Cambrian ridge, and their occurrence can be traced uninterruptedly to the region of intrusion.

(3) In other instances known horizons of the Cambrian rocks can be traced from their unaltered condition into the region of contact, where they are powerfully affected and altered. This has been noted in the case of the Cambrian glacial beds and equivalents of the Tapley's Hill slates, at Umberatana, on the eastern side of the Flinders Ranges, and at Olary, on the Petersburg and Cockburn railway line, not far from the New South Wales border. In the Kapunda district a 10-mile section can be followed, where it includes the Mitcham quartzites and the till beds, in the Camel's Hump Range, four miles north-west of Kapunda; the Tapley's Hill slates, in the neighborhood of Kapunda; and the Brighton limestone series, in the Kapunda marbles, in a position where the igneous zone is not far distant.

(4) The most distinctive horizons of the lower beds of the Cambrian on the western side are, in ascending order—(*a*) Felspathic and ilmenite grits and sandstones (= Aldgate beds); (*b*) the lower limestone (= River Torrens limestone); (*c*) the thick quartzite (= Black Hill and Mount Lofty quartzite). These respective horizons are separated by phyllites and lesser quartzites. The three divisions mentioned are well defined in their lithological characteristics and stratigraphical relationships. Similar beds in the same order of succession have been determined by cross-sections on the eastern side of the axis in the following localities, (*b*) viz., Philcox Hill, between Mount Barker and Strathalbyn; Mount Barker Springs, near Mount Barker; Reefton, near Woodside; Mount Torrens, near the head of the Onkaparinga Valley; and Springfield, near Williamstown. The interstratified phyllites of the western side are represented mostly by fine-grained mica schists or micaceous flags on the eastern.

(5) The highly altered character of the beds on the eastern side can be satisfactorily explained by the very great extent of the igneous zone, and the corresponding potentiality for effecting metamorphic results. The great development of plutonic rocks on that side indicates that the associated sedimentary rocks were at one time deep-seated, and under geothermal conditions which must have been equal to the production of regional metamorphism on a grand scale. On the assumption that the beds thus metamorphosed are of Cambrian age, it will follow that the intruding granitic veins and bosses of the eastern side are Post-Cambrian. At the same time, it is highly probable that some of the igneous outcrops, especially on the western side of the State, are of Pre-Cambrian age.

b Detailed descriptions of these sections are in course of preparation.

9.—PRELIMINARY NOTE ON ARCHÆOCYATHINÆ FROM THE CAMBRIAN "CORAL REEFS" OF SOUTH AUSTRALIA.

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[WITH EIGHT FIGURES AND TWO PLATES.]

INTRODUCTION.

During February, 1906, the Author made a journey to South Australia for the purpose of collecting specimens of the Cambrian organisms, provisionally classed with the corals, belonging to the family Archæocyathinæ. The fossils occur in a limestone belt extending some 400 miles in a northerly direction from Port Victor to Lake Eyre. They constitute probably the largest fossiliferous deposit of Cambrian age in the world, and this fact alone renders them of the highest palæontological interest. When it is recognised that practically no other members of the Cœlenterata have been recorded from pre-Ordovician rocks, it is evident that the ancestry of the whole phylum may very reasonably be involved in a study of these fossils. Moreover, if the Porifera be taken as a separate phylum, it is not impossible that the Archæocyathinæ represent a link connecting the Cœlenterata and Porifera. Thus light may be thrown on the evolution of two out of the eight subdivisions of the Animal Kingdom. Hence the investigation is of fundamental importance in the great scheme of biogenesis.

In 1861 Billings described the first specimens from Labrador, gave them the name of Archæocyathus, or "ancient cup," and classed them with the siliceous sponges. In 1865, Dawson declared that Archæocyathus was a giant foraminifer allied to *Eozoon*. In 1880, Professor Römer referred the whole group to the same family as *Receptaculites*—another doubtful "missing link" of invertebrate biology. Hinde, however, placed them with the sponges, and in 1886 they were classed as Hexactinellids. In 1886 appeared a comprehensive work on the Cambrian fossils of Canalgrande, in Sardinia, which treats largely of this family, and later the same author (Professor Bornemann) concluded that they constitute a special group of Cœlenterata midway between Porifera and Anthozoa. In 1900, Zittel places them with the perforate corals. Finally may be mentioned the revolutionary theory of Von Toll. This Russian scientist, from an examination of Siberian specimens, relegates the Archæocyathinæ to the Vegetabilia, and allies them to the calcareous algæ. It may be stated that the Australian specimens do not seem to bear out this idea in the least.

The only noteworthy Australian account was published in 1889 by Mr. R. Etheridge. He describes some South Australian specimens (*Ethmophyllum Hindei*, *Protopharetra Scoulari*, and *Coscinocyathus Tatei*), but the character of the specimens precluded a very detailed account, and practically no attempt was made to investigate the classification or biology of the group as a whole.

The stratigraphy of the Archæocyathinæ horizon is engaging the attention of that indefatigable South Australian geologist, Mr. W. Howchin, F.G.S.; but a few words as to the extent of the "Cambrian Reef" may not be out of place.

The magnitude of this old reef will be appreciated when it is stated that at the Ajax Mine—10 miles north of Beltana—its width (with a dip of 68°) approaches 300yds. There is little doubt that as the local geology of South Australia is worked out more and more localities will be discovered at intermediate points over this 400-mile belt, and that, in addition to the most magnificent modern reef (the Great Barrier), Australia will be found to possess the greatest paleozoic reef in the world.

A factor rendering the South Australian specimens of especial value is that most of the Ajax specimens have undergone silicification to a most wonderful extent. By acting on the matrix with hydrochloric acid, and carefully coating delicate structures with paraffin as they appear, it is possible to etch to a depth of four or five millimetres without destroying the meshwork of which walls, septa, and tabulæ are composed. So far as I am aware, no other Archæocyathinæ specimens admit of this treatment. There is, however, little doubt that the original skeleton was calcareous and not siliceous. The organisms from Sellick's Hill consist entirely of calcareous matter; while the Ajax specimens are sometimes only replaced by silica in the peripheral portion of the matrix in which they are preserved. Thus, in some instances, one side of a cup will resist the acid while the other is entirely dissolved.

NOMENCLATURE.

In the following descriptions the terms septa, calyx, tabulæ will be used to denote structures similar in appearance to, but probably not homologous with, corresponding structures in the corals. The outer wall and inner wall do not resemble very closely the thecal elements of the corals. In the flabellate genera the lower proximal wall (from which proceed the rhizoids) and upper distal wall are analogous to the outer and inner walls respectively of the turbinate and bell-shaped genera. The term septum (denoting simply a partition) can still be used for the vertical plates connecting the two walls at regular and frequent intervals in the flabellate (or expanded) genera. The rectangular chambers bounded by the adjoining septa and the walls will be termed "loculi." The latter will be cuboid (isometric) or brick-shaped, according as the tabulæ are numerous or remote.

The above terms are illustrated and more fully defined in the sequel.

MORPHOLOGY.

The original Archæocyathus of Billings—on which the family was founded—is described as follows:—

"Turbinate, simple or aggregate, cup deep. Internal structure, so far as can be made out, consists of an inner wall, constituting the inner surface of the cup, and an external wall, or epitheca, enveloping the whole. Between the two walls there are numerous radiating septa, the interseptal spaces being filled with poriferous or septal tissue."

As will be seen, many of the South Australian species differ enormously from the above type, but connecting links uniting the extremes are not uncommon.

In the present short paper I propose to describe briefly the structures present in half a dozen specimens, illustrating the gradual change from a conical, or almost cylindrical, shape through those of a bell-shaped habit, with spreading rims, to the extreme flabellate type, which possesses nothing comparable to a calice (*vide* fig. 5).

One of the simplest types of the family is illustrated in longitudinal section in fig. 1, which is drawn from an etched specimen from Ajax Hill (Beltana). The calice (to use a term borrowed from the Anthozoa) is about 2 c.m. long, and gradually increases in width from 3 m.m to 8 m.m. at the distal end. Judging from the small cross section and the

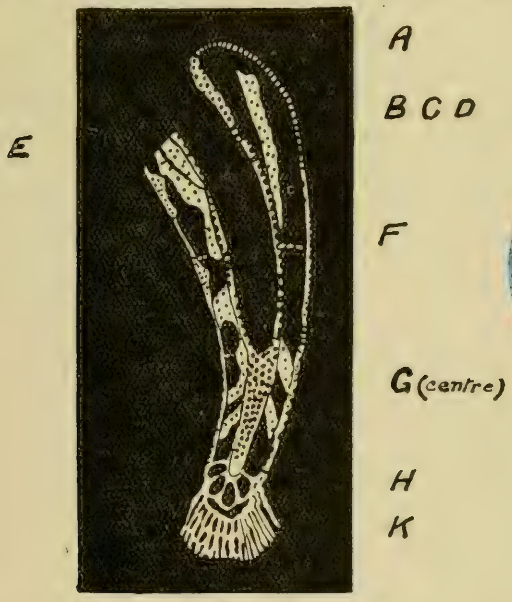


FIG. 1.

Longitudinal etched section of small Cup (2 *cm. long*), *cutting through Outer Wall* (A *and* D), *Inner Wall* (B *and* G), *Septa* (C *and* E), *Tabulæ* (F), *Initial Loculi* (H), *and Rhizoids* (K).

fewness of the septa, it is a young specimen. At the lower end appear the lamellar attaching structures for which I suggest the name *rhizoid.* In most specimens there is evidence of a more or less concentric growth of these rhizoid lamellæ, as if the plates grew out freely from the lower end of the calyx for some time and then the free ends fused to form a platform (*vide* fig. 2). Then the lamellar growth continued, forming another zone of plates normal to the outer wall of the calyx, and so on. Probably this lamellar structure was occupied by sarcode consisting of lime-secreting cells, as in other sections (fig. 3), a very luxuriant growth is evident. The earliest stage of the individual is represented by a few more or less globular loculi (H), seen immediately above the rhizoid tissue. Cross sections of small calices usually show a similar arrangement of a few globular loculi separated by septa, and occupying the space between a coarsely perforate inner wall (G) and a more highly perforate outer wall.

A cross section half way along the cup would show that the septa have become more numerous and the loculi are rectangular. Tabulæ are present, though somewhat remote, in the younger (and possibly faster growing) types. The septa, cut somewhat obliquely, are clearly represented in fig. 1. It will be noticed that they are rather solid, the pores being smaller and further apart than in the walls.

The upper portion of the inter-mural space is completely closed by the curved perforate plate (at A). This is the growing point of the organism, and probably represents the latest tabula connecting the outer and inner walls. It is improbable that the inter-mural sarcode in the older loculi was in the form of a definite zooid, since we should then reasonably expect the tabulæ to show some well-defined central orifice (as in many tabulata), whereas it is uniformly perforate. Reasons will be given later for the theory that the Archæocyathinæ were compound organisms, and not simple zooids like *Zaphrentis*, &c., though one is at first tempted to place them among the simple corals from close morphological resemblance of the main structures to those Rugosa provided with a (somewhat indefinite) inner wall, as for example *Campophyllum*.

Probably the relation between the Rugosa and the Archæocyathinæ is of the same type as that between the mollusca and brachiopoda—a sort of parallelism of development as regards skeleton on the part of the two phyla, which is not in the least accompanied by a biological kinship.

Reverting now to the second specimen (see Plate I., fig. 1), a more advanced stage of the turbinate calice than that in fig. 1 is represented in longitudinal section. This photograph gives a very good idea of the matrix of many of the Beltana specimens. On the left may be seen siliceous replacements of indefinite tubes, which have been regarded as *Girvanella*—but which are probably in some cases simple Sycon-like sponges. On the right occurs a triangular patch of "concentric" calcite, with a curious "Stromatoporoid" appearance, but which is almost certainly of inorganic origin.

The turbinate calice (28 m.m. long) has been sectioned medially and then etched rather deeply with acid. Almost the whole structure typical of the simple Archæocyathinæ is revealed at a glance. The most prominent feature is undoubtedly the symmetrical arrangement of the convex tabulæ. These "sieve-like platforms" appear to be present in all the Archæocyathinæ examined, and are not peculiar, it would appear, to the genus *Coscinocyathus*, as claimed by Bornemann and Hinde. The arrangement of the pores in the radiating septa is very clearly shown, and also the intercalation of a septum is recognisable in the upper left of the calice.

The inner wall, as usual, is coarsely perforated, each pore being sunk at the bottom of a "dimple," giving a rugged appearance to the surface. The outer wall can be made out in the lower right hand portion of the calice, and the pores are seen to be smaller than in the inner wall.

The rhizoids are not apparent in the photograph, but can be discerned faintly in the specimen, though they have not undergone silicification to such an extent as the rest of the organism, and hence did not etch out with the acid.

In Plate I., fig. 2, on the left will be seen a cross section of a specimen similar to that illustrated in Plate I., fig. 1. It has been etched rather strongly, so that the septa and walls stand out in relief. Obviously, therefore, the original structure is here replaced by silica. The outer wall can be seen as a delicate porous investment connecting the outer ends of the septa. The latter are thickened where they join the outer wall, thus materially strengthening the whole structure. The septa are rather numerous, indicating that the section is taken through the upper and later developed portion of the calice. In the upper right hand portion—where the septa are cut obliquely—the pores can be made out in a few of the septa. The inner wall shows very clearly the rugged porous nature of this element of the calice. Stretching across the loculi can be seen (with a lens) the beautifully delicate meshwork of the tabulæ. In the central cavity of the calice appears a mass of crystalline calcite which has resisted the etching in some degree, but does not represent any organic structure. Some of the loculi also contain secondary infiltered material.

In fig. 2 (text) the longitudinal section of one of the Sellick's Hill (unsilicified) specimens is represented. It is drawn from a microphotograph, and shows very clearly the relation of the rhizoid lamellæ to the calice proper. As the section is somewhat oblique, it does not pass quite through the bottom of the cup. At I the inner wall is cut through, and the irregular projections between the pores of the former are indicated. They may be compared in position to the rugæ of the perforate corals. The pores of the inner wall are well represented between I and S. Crossing the loculi can be seen rudimentary dissepimental tissue. This is very delicate and does not appear to be preserved in etched specimens.

The septa consist microscopically of granular calcite, no sign of spicules being apparent. To the left of D are the pores of the outer wall, which latter will be seen to merge immediately into the rhizoid lamellæ. This curious structure—unparalleled, I believe, in other Cœlenterata—resembles the septa in microscopic appearance, but contains no pores. In some specimens the rhizoids seem to grow out directly from the outer end of the septa, and may perhaps, therefore, be compared to enormously developed costal ridges. The lamellæ are most numerous at the base of the cup, and often are not produced in the upper portions of the organism. It is noteworthy that this structure is almost universal in the southern (Normanville, Ardrossan, Sellick's Hill) specimens, while it is much less strongly developed in the Archæocyathinæ obtained 400 miles north of the latter localities, near Beltana.

In many of the Archæocyathinæ, however, an analogous lamellar structure persists as an exothecal investment over a large portion of the exterior of the cup. In Plate I., fig. 2, on the right will be seen a cross section of a calice with two zones of such investment. From the fact that all the buds appear to spring from a lamellar tissue of this nature it may be set down as subserving an asexual (?) reproductive function. It would appear to be antagonistic to that free passage (of water and food) from the interior cavity to the exterior, which all the other structures seem designed to allow. On many of the very large cups patches of this lamellar structure mark where a smaller individual is united to the larger. Hence the rhizoids may be set down

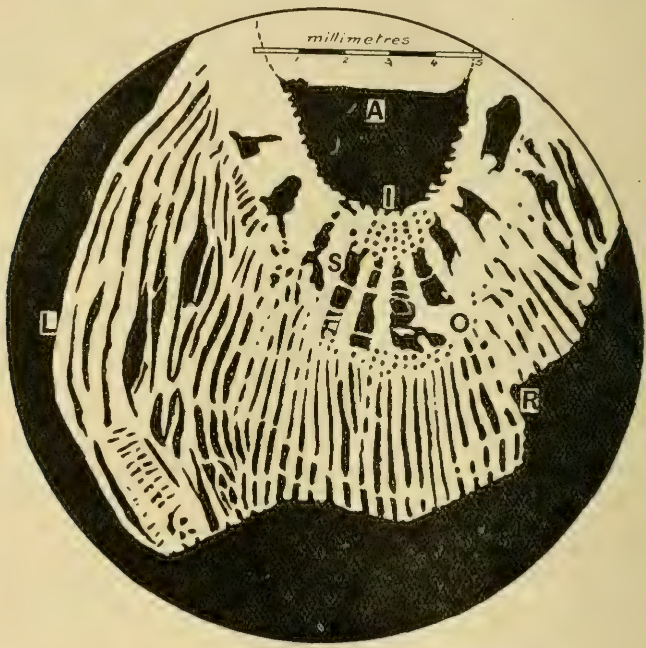


FIG. 2.

Slightly oblique vertical section through lower portion of a small Cup, cutting through the Central Cavity (A), *the Inner Perforate Wall* (I), *the "Septa" with Dissepiments* (S), *the Outer Perforate Wall* (O), *the Inner* (R) *and Outer* (L) *Rhizoid Lamellæ. (From microphotograph.)*

as an exothecal growth from the outer wall in the older portion of the organism, which may be analogous in part to the stolonal outgrowths of many modern Cœlenterata, serving for attachment and asexual reproduction.

In fig. 3 (text) is represented the relatively tremendous growth of the rhizoids around the base of the small cup A (cross section). Probably the lamellæ here also function protectively, as they may be noticed winding round the surface of the calice some distance from the point of attachment. It is of course possible that the young Archæocyathenoid has merely made use of the older individual—shown in the upper part of the figure—as an anchor; but serial sections seem to show that a more intimate relationship is present. In one of the loculi

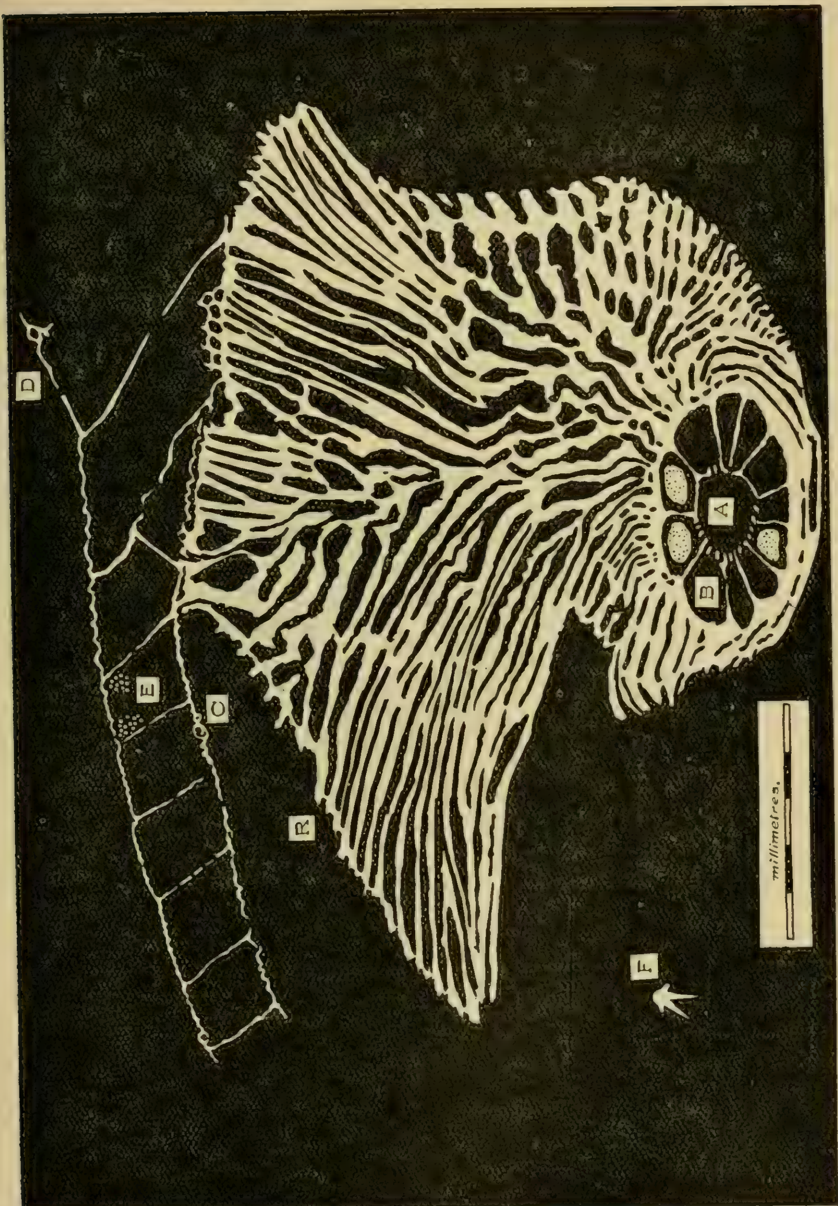


FIG. 3.

Cross section of a small Cup, showing relatively small area of Central Cavity (A) *and the rounded "Loculi"* (B), *some occupied by brownish infilling (dotted). The Rhizoid Tissue* (R) *connects the former Cup to portion of a larger individual, of which the Perforated Walls are indicated at* C *and* D. *Small strongly refractive bodies occur at* E. *At* F *a large isolated Sponge Spicule is seen in the matrix. (From a microphotograph.)*

of the larger individual (of which only a portion is represented) small spherical refractive bodies occur (E). As these have been noticed in similar positions in several other specimens it seems probable that they are organically important. They may be sexual products (gonads at a late stage), or possibly represent gemmules, as in the Porifera.

At F a large sponge spicule is apparent, lying quite isolated in the matrix. This throws some light on the question of relationship to the Porifera. If the septa and other skeletal elements of the Archæocyathinæ ever consisted of spicular bodies it seems strange that their internal structure—so perfectly preserved otherwise—should have entirely vanished, while within five millimetres distance an isolated sponge spicule is marvellously preserved!

This seems a strong argument against assigning the Archæocyathinæ to the Porifera, as none of the latter phylum are known to possess well-defined septa devoid of spicular elements.

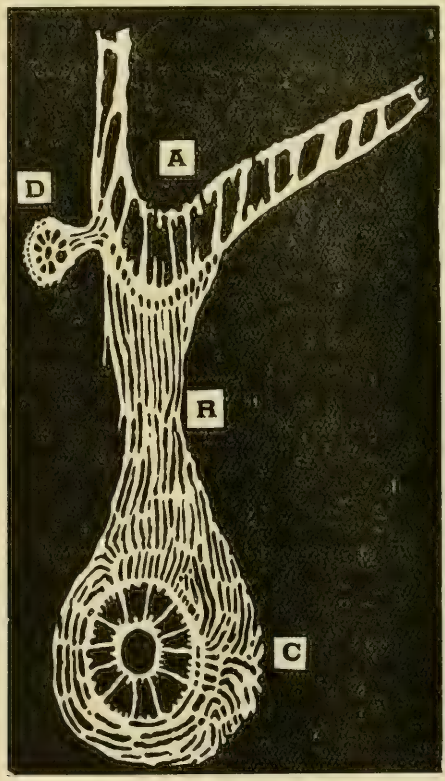


FIG. 4.

Section illustrating Budding among the Archæocyathinoids. Primary Cup (A) *shown in longitudinal section, Rhizoid Lamellæ at* R. *At* C *appears the cross section of a younger Cup arising from the Rhizoid growth. An oblique section of a very young Bud is seen at* D, *with the characteristically rounded Loculi.*

In fig. 4 (drawn from a section through specimen 46, Sellick's Hill) the method of a sexual reproduction by budding is well shown. The loculi exhibit a feature common to many individuals of rugæ projecting inwards, both from the inner and outer walls, reminding one of an internally-cogged gear wheel. In some cases these are contiguous with the rhizoid lamellæ on the outer side of the outer wall, and one has a curious inversion of the perforate coral structure, the ridges (rugæ) being inside and the lamellæ outside the thecal wall.

We may now leave the turbinate or conical type of Archæocyathinæ, and refer very briefly to the bell-shaped calice having an expanded rim. In Plate II., fig. 1, careful etching has resulted in revealing a calice of this type resembling in shape a convolvulus flower. A reference to the sketch (B in fig. 5) will make this clear. In the photograph the external wall (Plate II). has been preserved over the central portion of

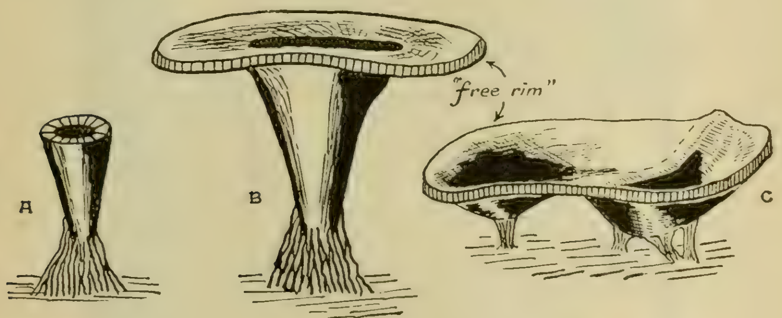


FIG. 5.

Sketch of three types of Body Form of Archæocyathinoids.—A, *the Conical or Turbinate;* B, *the Bell or Convolvulus Shape;* *and* C, *the Flabellate or Expanded Form. The absence of any well-defined Central Cavity is to be noticed in* C.

the calice. The inner wall shows in the lower portion, while the delicate vertical septa stand out admirably on the dark matrix. The expanded rim (in section) appears at the top right hand, and this portion is sketched separately in figure 6.

A noteworthy feature is the union of the outer and inner walls at the periphery (L), which tend to show, as stated elsewhere, that the outer and inner walls, and *not the open ends of the loculi at the rim*, were the scene of the "living zones" of the organism.

The last type to be considered in this preliminary paper is that roughly indicated in fig. 5, at C—the flabellate irregular expansion—which possesses nothing in the shape of a calice, and is anchored by bundles of rhizoid lamellæ proceeding from the lower (or proximal) surface. In Plate II., fig. 2, appears a photograph of a specimen of this type from, Ajax Mine (10 miles north of Beltana), while fig. 7 (text) is a drawing illustrative of the same specimen, and fig. 8 shows a cross section. It is only necessary to fold the warped surface (constituting the organism) into a cone—as one folds up paper for a ridged filter in the chemical laboratory—to arrive at the preceding types. The walls, septa, and tabulæ are practically identical, whether the shape be turbinate or flabellate, and it seems fair to suppose that *the central cavity or cup of the former fulfils no essential function in the economy of the animal.*

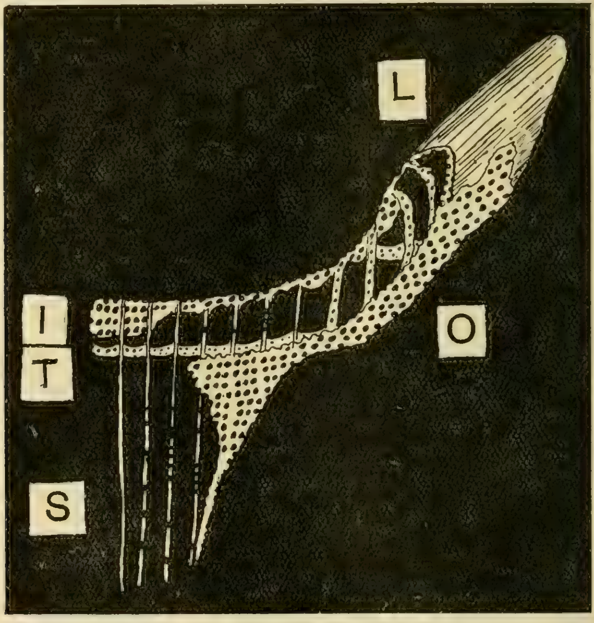


Fig. 6.

Etched section of portion of rim of Bell-shaped Calice, showing Outer (O) *and Inner* (I) *Walls, Septa* (S) *and Tabulæ* (T)*; and, in top right portion, a surface view of the Layer* (L) *investing the margin of the rim.* *(See also Plate* B, *Fig.* 1.*)*

It seems possible that cross sections of cylindrical rhizoids, such as are here represented, have been set down as separate organisms, as they resemble rather closely the *Protopharetra* of Bornemann—though the latter are, of course, a distinct genus, and can be distinguished readily from the former structures when well preserved.

Many of the flabellate types are of large dimensions, with an area of 30 or 40 square inches. The regularity in the distribution of the septa, and the warped character of the expansion, account for the meandering scalariform appearance of cross sections of the genus.

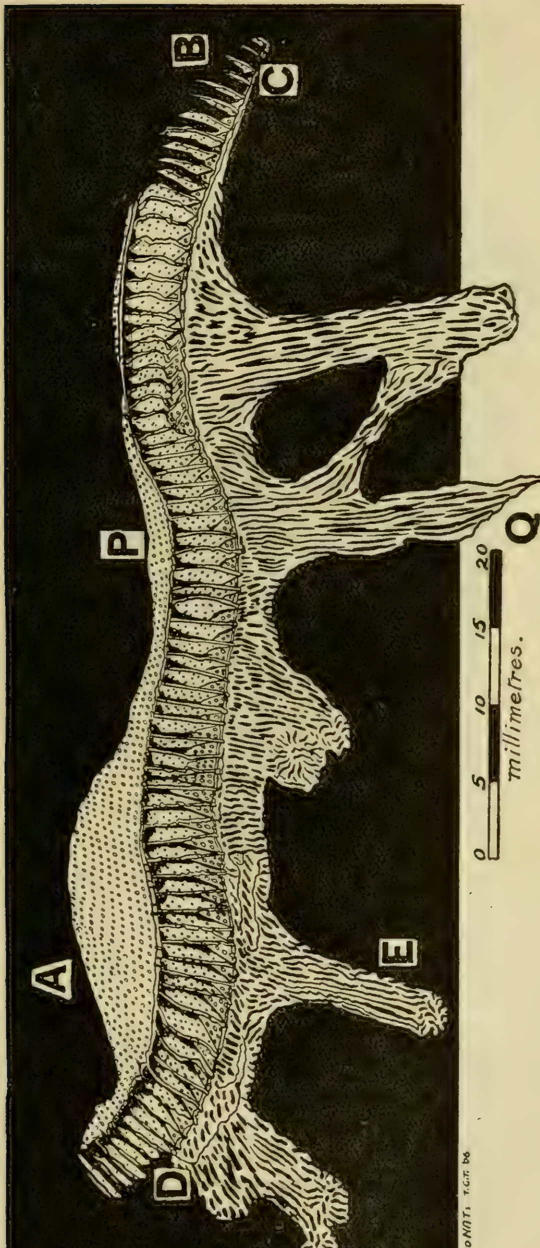


FIG. 7.

Strongly etched section of a Flabellate Archæocyathenoid, showing Upper Surface (A) *with fine pores, the Vertical "Septa"* (B) *remotely perforate, the coarsely perforate Lower Surface* (C), *the Proximal Rhizoid Zone* (D), *and the Cylindrical Rhizoids* (E). *Outer black portion is the Dark Matrix.*

In common with the other genera described, tabulæ are present (T in fig. 8). In several of the loculi spherical bodies—which may be sexual products resembling amphiblastulas or planulas, or possibly gemmules—occur, as noticed in a similar position in fig. 3.

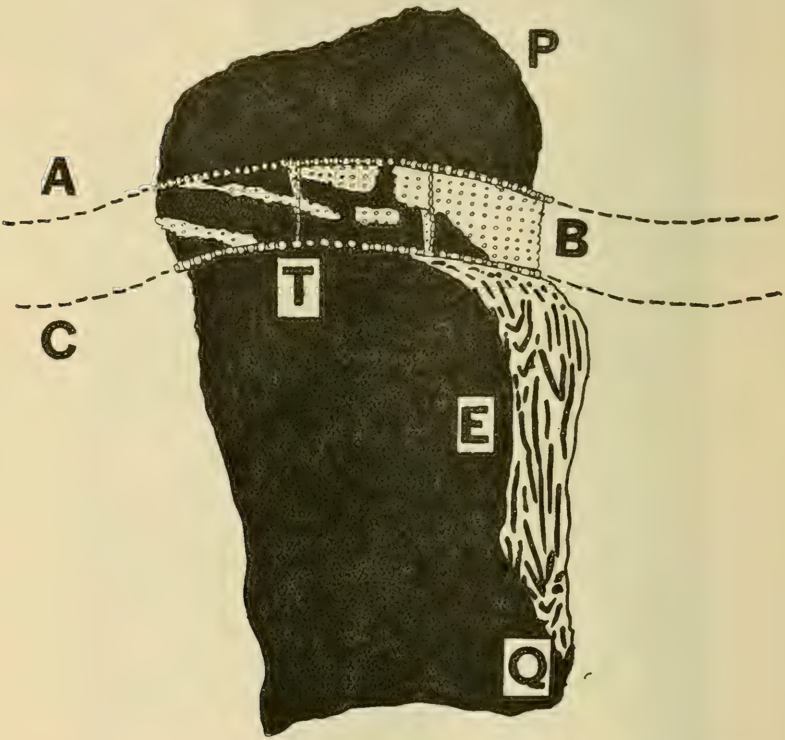


FIG. 8.

Lettering as in preceding figure. Slightly etched section (along line P Q) *perpendicular to view in Fig.* 7 *and nearly parallel to the "Septa," showing remote vertical "Tabulæ"* (T).

The importance of this latter (flabellate) morphological type as regards the classification of the Archæocyathinæ, will be referred to in the last section of this note.

AFFINITIES OF THE ARCHÆOCYATHINÆ.

In the present condition of my investigation it would be premature to go very fully into this question; but certain points of interest have developed already, and these will be briefly discussed.

As will have been seen in the preceding, the classification of this family is a question of great difficulty. Almost every structure of the Porifera and Anthozoa is represented in one genus or another.

As regards the general form, one sees turbinate specimens resembling closely many of the Rugosa, such as *Omphyma*. But on the other hand in some examples the rim of the calice spreads, as in the flower of the convolvulus. This recalls no coral—with the exception, perhaps, of *Sanidophyllum*—in which the corallites are united by a similar expansion; not, however, containing a complete septal system, as in the Archæocyathinæ. The restoration of the hexactinellid sponge *Ventriculites* (*a*) has a very close resemblance, however, to the form of calice under discussion.

A further development leads to the flabellate type of Archæocyathinæ. This (as shown in figs. 7 and 8) is a large irregular expansion, anchored by cylindrical bundles of rhizoid lamellæ, and such structure is unknown in the corals, so far as I am aware. On the other hand, there are many sponges with a very similar form, such as the tetractinellid *Phakellia* (*b*).

It is difficult to imagine that the two extreme types, turbinate and flabellate, belong to two distinct families, as they have the same fundamental structures of outer and inner perforate walls, connected by perforate septa and tabulæ. Considering the simple turbinate cup alone (figs. 1 and 2) it would be easy to suppose it the skeleton of a simple coral, uniting the outward form of the Rugosa with the septa of the Perforate Hexacoralla. This has apparently been the view of many earlier investigators.

Where, however, did the polyp animal live? One can imagine an organism resembling the coral polyp, the gastral portion occupying the central cup, and filamentous mesenteries penetrating into the loculi, between the septa, through the (invariably) perforate inner wall. But how can this hypothetical simple polyp be related to the sarcode of the flabellate types? The shape of the latter (*vide* C fig. 5) is highly irregular—though the internal structure of walls and septa is constant—and nothing resembling a cup or calice is present. One is led to assume that in this latter (flabellate) type of Archæocyathinæ the organism is of a compound nature; and if this is true for the flabellate form, it is most probably true for the infolded or turbinate type.

A glance over the general scheme of Anthozoan evolution seems to show a gradual advance from archaic solid dense types, such as those obtaining in the rugosa, towards the delicate, and often highly-elaborate trellised and trabeculate skeleton of the modern Madreporaria. It is somewhat like the advance from the solid strength of a Roman aqueduct to the equally strong but more economical (and, therefore, higher) type of the modern concrete-steel Monier equivalent. Some of the etched Archæocyathinæ from Beltana reveal structures more regularly arranged and more strongly braced than any Paleozoic or Mesozoic Anthozoan. Here, then, would be a striking example of retrograde development if the modern madrepore were directly descended from the Cambrian Archæocyathinæ.

Reverting again to the simple turbinate type, let us consider the "building construction" (to use a useful engineering term) of the

(*a*) Lankester—Zoology, Pt. II., Sponges, p. 16. (*b*) Ibid, p. 22.

skeleton. The outer wall may aptly be compared in structure, to an inverted incandescent mantle containing another (the inner wall) several sizes smaller, the two being united by fairly solid radiating septa somewhat sparsely perforate. Perforate tabulæ are almost invariably present also. One important function of the skeleton would, therefore, appear to be to allow extremely free communication between the central cavity and the exterior. The central cavity of the organism is apparently devoid of dissepimental tissue, in all the specimens I have examined, to the bottom of the cup—which fact seems to indicate a circulation of food and oxygen after the sponge type ; probably from the outside, through the walls to the inside, and out through the mouth of the cup.

At first glance one might compare the family to various compound Cœlenterata, such as *Halysites*, where the corallites are united linearly to form walls consisting of oval tubes. But it seems difficult to reconcile each parallel-sided loculus (fig. 7), in the Cambrian family with the calice of a polyp. Secondly, as shown in fig. 6, the free edges of the rims of the central cavity seem to show a fusion of outer and inner walls, and not the *open*, growing, portion of the coralites, as one would expect in an Anthozoan.

The microstructure of the organisms, where every pore is preserved apparently in the original lime, shows that the septa are built up of minute granules. No sign of true sponge spicules is so far apparent in the septa, though such spicules have been detected at some distance from the Archeocyathinæ. The dense lamellar uniform character of the perforate septa resembles much more closely the septa of a madreporarian than any similar structure in a sponge. The regular growth and strict parallelism of the septa, tabulæ, and walls respectively is quite antagonistic to a close relationship with the Porifera of Palæozoic age.

Yet the irregularity of the shape merging from a Pharetrone type to a flabellate Clathrina type is poriferate in character. The presence of anchoring rhizoids is suggestive, as such are very usual in many sponges. The budding of small individuals from the walls of the large ones is common to both coral and sponge, though the Archæocyathinæ habit resembles the latter more closely in this respect.

Serial sections through certain of the Sellick's Hill specimens show that in some genera the cavity of the calice is wider in the middle, and contracts to a small aperture at the upper end. This, also, is contrary to coral morphology.

From a consideration of the growth habit of the flabellate types (figs. 6 and 7), *i.e.*, with the rhizoids normal to the perforate wall, it would appear evident that the nutrition zone was represented by the upper perforated wall, and not by the free rim, as analogy with *Halysites* and other Anthozoa would require.

Further study of the small nepionic forms will undoubtedly assist greatly in determining the classification. They would appear to arise from a more or less globular cell, around which other cells are built, the

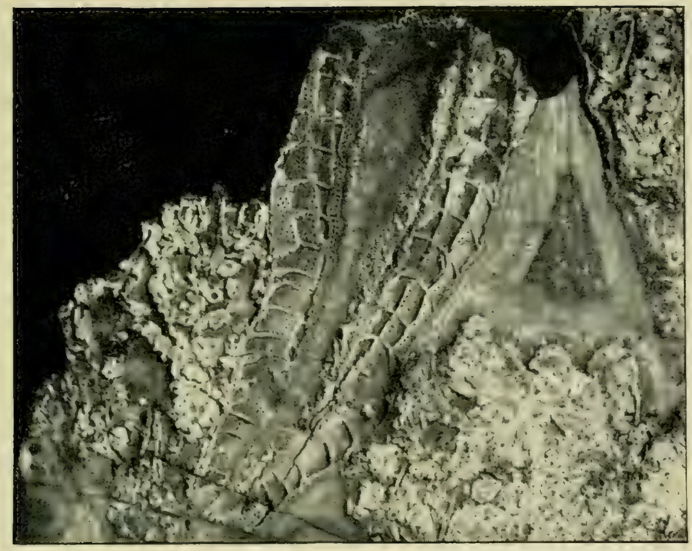


Fig. 1.

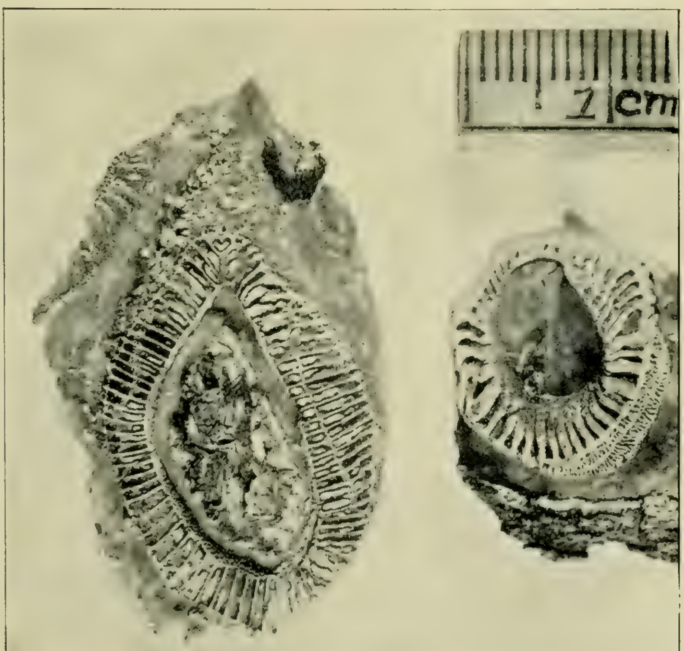


Fig. 2.

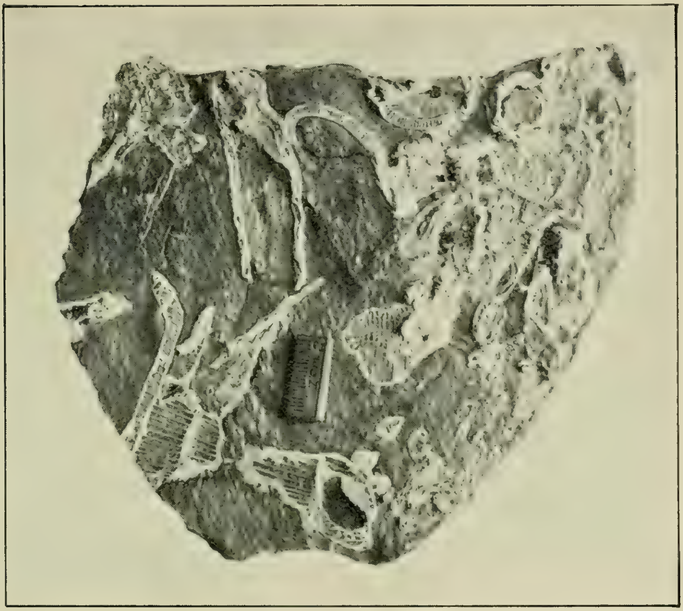


Fig. 1.

Fig. 2.

partitions constituting the septa. At a later stage the cells become parallel-sided, and the pseudo-septate structure is characteristic of the older growth.

As Man is in some respects intermediate between the Orang and the Chimpanzee—a study of their common features leading one to a knowledge of the primeval *Pithecanthropus*—may not the Archæocyathinæ be descendants of that Proto-cœlenterate from which also are derived the sponges and corals ? One can at all events hope for much for evolution from these fossils—by far the most elaborate and best preserved relics of the lower invertebrata from the oldest horizons of the Age of Life.

SUMMARY.

Evidence tends to show that the Archæocyathinæ were compound organisms, whose internal structure—both as regard composition and regularity—approximates to that of the Anthozoa, but whose general shape, protean forms, and methods of attachment are distinct from the Cœlenterates and resemble the Porifera. In conclusion it may be suggested that in this family we have a division of the Metazoa of equal rank with the Porifera and Cœlenterata, and possibly representing a missing link between these two phyla.

KEY TO PLATES.

Plate I., fig. 1.—Longitudinal section (strongly etched) of turbinate Archæocyathinoid, showing very clearly the outer and inner walls, septa, and tabulæ,. 28 mm. long.

Plate I., fig. 2.—Cross sections (strongly etched) of turbinate Archæocyathinoids showing tabulæ (on the left) and exothecal lamellæ (on the right).

Plate II., fig. 1-—Specimen of bell-shaped calice, showing outer wall, septa, and expanded rim. (See also fig. 6.)

Plate II., fig. 2.—Vertical section through flabellate type, showing cylindrical rhizoid bundles attached to lower wall. (See also figs. 7 and 8.)

10.—THE PHYSIOGRAPHY OF PORT NICHOLSON HARBOR, NEW ZEALAND.

By JAMES MACKINTOSH BELL, Director of the Geological Survey of New Zealand.

[WITH MAP.]

The harbor of Port Nicholson, on which Wellington, the capital of New Zealand, is situated, forms a prominent indentation in the southern coastline of the North Island. The harbor is a fine sheet of water, almost landlocked, about nine miles long by five miles wide, connected with the open water of Cook's Strait by a narrow channel of water about one and a half miles long and about one mile in width. The harbor is almost completely surrounded by high hills, which rise, in general, very abruptly from the water's edge. There are, however, several fair-sized areas and many small patches of level or gradually sloping land close to the edge of the harbor. By far the most extensive of these is that which forms the relatively wide valley of the Hutt River, extending north-eastwards from the north-eastern end of the harbor. This plain has a width of nearly two and a half miles near the harbor, and gradually narrows as it extends inland.

Westward from the narrow channel, connecting Port Nicholson Harbor with the sea, is a ridge of low rocky hills. West of this ridge of hills lies the area of low-lying country which separates Lyell Bay from Evans Bay, bordered to the westward by the Kilbirnie Hills, which have a maximum altitude at Mount Victoria of 648ft. above sea level. Westward of the Kilbirnie Hills lies another area of comparatively low country, on which is located the city of Wellington, having a slope on the northern side to Lambton Harbor and on the southern side to Island Bay. To the westward of the city of Wellington rise the Karori Hills. The northern continuation of the Karori Hills forms the precipitous country bordering Port Nicholson on the west and north-west and also the Hutt Valley further north. There is continuous high country from the entrance of the harbor along its eastern side up the Hutt Valley.

There are two small islands in Port Nicholson—Ward Island and Somes Island—which are approximately in line with the continuation of the hills lying west of the entrance to the harbor.

A view from any prominent part of the hills around Port Nicholson discloses an elevated country stretching in all directions, broken by narrow valleys and deep ravines. The most salient feature of the landscape is the generally uniform elevation to which the hills ascend, namely, between 700ft. and 800ft. This uniform elevation does not represent a plateau, and since it is quite independent of the structure of the country rocks (consisting of tremendously contorted and shattered argillites and grauwackes), it apparently exhibits, somewhat roughly, an elevated plain of erosion or peneplain. Above the general level of this peneplain a number of hills rise to altitudes of greater prominence, forming apparently residuals from an earlier cycle of erosion than that represented by the peneplain. These may be considered as monadnocks.

SURVEYOR GENERALS OFFICE, ADELAIDE. A. Vaughan, Photolithographer

Since the elevation of the peneplain, the spacious harbor of Port Nicholson has been formed. This has been produced by the down-faulting of an area of country, forming a graben extending from Cook Strait north-eastwards up the valley of the Hutt River. This graben apparently does not represent a single down-faulted block, but consists of several parallel and transverse blocks, not all of which have settled equally, either longitudinally or transversely. Thus it seems evident that the ridge of hills bordering the western side of the entrance to the harbor, with Ward Island and Somes Island, and also the Kilbirnie Hills, represent portions of the peneplain which have sunk but little or not at all ; their reduced elevation, as compared with the general height of the peneplain, being due to the more rapid denudation consequent on their isolated and exposed positions. In the same way, the low-lying areas of country between Lyell Bay and Evans Bay and between Island Bay and Lambton Harbor have apparently not subsided to the same depth as the floor of the main body of the harbor, though it is not improbable that both these areas were either originally below sea level or at least occupied a lower altitude than at present, their height above sea level and general surface area being increased by the advanced of wind-blown sand. As every student of New Zealand geology knows, the harbor of Port Nicholson underwent several comparatively slight changes of level during the past century, and Wellingtonians owe part of the flat land on which their city is built to one of these tectonic movements.

The plain along the valley of the Hutt River is but little elevated above sea level, and has been formed by the laying down in the graben of material brought down by the rapid-flowing Hutt River. This plain is rapidly advancing into the harbor.

The time of the maximum down-faulting of the country during which the harbor of Port Nicholson was formed was evidently not geologically remote, as shown by the even and abrupt coastline to the east and north-west of the harbor. These coastlines in general mark the planes of maximum faulting to which the many other planes are subsidiary or parallel.

The diastrophic history of the area of country in which Port Nicholson Harbor is situated may be briefly summed up as follows :—First were laid down a series of sedimentary rocks, which were uplifted and intricately folded, producing a mountainous country. Gradually, through long periods of time, these mountains were worn down almost to sea level, and a rough peneplain was produced. Then came the elevation of the peneplain, and later the sinking of the graben, which has given the beautiful land-locked harbor of Port Nicholson, on which New Zealand's capital is situated.

11.—THE PHYSIOGRAPHY OF WEST WANGANUI INLET, NEW ZEALAND.

By JAMES MACKINTOSH BELL, Director of the Geological Survey of New Zealand.

[With Map.]

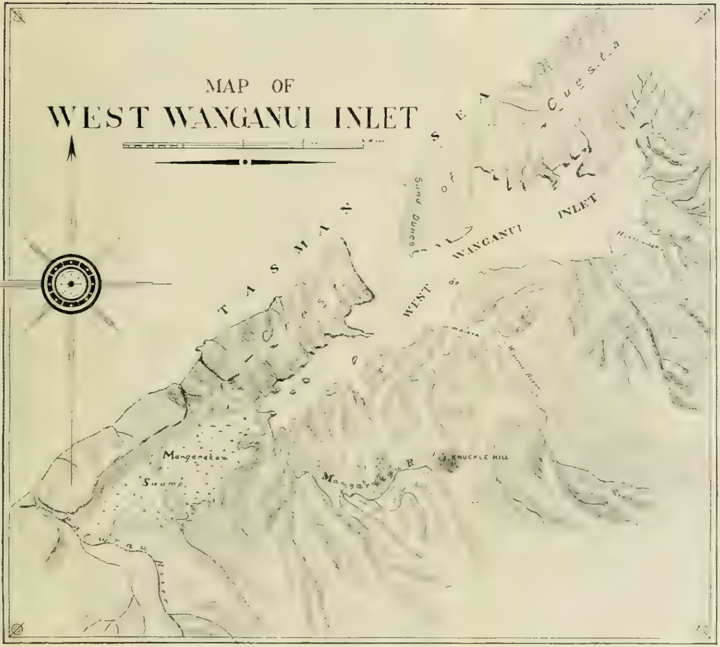
The Inlet of West Wanganui occupies a prominent bight in the western seashore of the extreme north-western corner of the South Island of New Zealand. It presents many physiographic features of interest, and exhibits a scenery of rare beauty and charm.

The inlet has an extreme length from north-east to south-west, in which direction its main axis lies, of about nine miles, and an extreme width in the opposite direction of rather less than three miles. It is connected with the open sea, about half-way along its western border, by a narrow strait of water, rather less than three-quarters of a mile in width at high tide, though only a few chains wide at low tide. The coast line of the inlet, with its numerous deep and irregular bays, is very intricate, and is said to be no less than 110 miles around.

The extreme rise of the tide at West Wanganui Inlet is about 16ft. At high tide the inlet is a beautiful sheet of water, almost completely landlocked, while at low tide the basin is occupied by a spacious mud flat, through which ramify the narrow tortuous channels from the numerous entering streams.

The stratigraphical geology of the country surrounding West Wanganui Inlet is simple, the rocks consisting entirely of strata, classified as Cretaceo-Tertiary by former New Zealand geologists. These strata have a gradual though decided inclination to the north-westward from the rugged eastern hinterland of Palæozoic rocks and intrusive granites. The Cretaceo-Tertiary rocks may be loosely divided into two series—a lower poorly consolidated and easily weathering series of shales, sandstones, and coal seams, and an upper more compact and more resistant series of calcareous sandstones and limestones. The shallow basin occupied by West Wanganui Inlet and the broad valley stretching south-west from that feature beyond the Patarau River indicate physiographically the location of the friable series, while the ridge of rugged bluffs rising abruptly close to the western margin of West Wanganui Inlet and the valley marking its south-western continuation show topographically the presence of the more resistant series. These bluffs form a typical cuesta, or ridge of rock, presenting a steep escarpment in a direction opposite to that of the dip of the strata and a gradual slope corresponding closely to the inclination of the strata in the contrary direction.

West Wanganui Inlet is probably but a portion of a more majestic feature, and formerly it seems to have stretched south-westward along the broad valley already mentioned beyond the Patarau River, as far south at least as Lake Otahie, or a distance of some 10 miles from its


MAP OF
WEST WANGANUI INLET
TASMAN SEA
Cuesta
Sand Dunes
WEST WANGANUI INLET
Mangarakau
Swamp
KNUCKLE HILL

present southern boundary. To-day a number of small ponds apparently remain as remnants of this former extension of the inlet, and a very slight depression would change the whole of Manga Rakau Swamp—an extensive area which lies just south-west of the inlet—into open water.

Wanganui Inlet is an excellent example of a depressed system of small stream valleys. Formerly a river flowed north-eastward along the south-eastern base of the cuesta above described, and receiving a number of tributaries from the south-east, east, and north, entered the ocean at the strait now connecting Wanganui Inlet with the main body of salt water. Subsequent to this time came the depression of the land, which produced the original West Wanganui Inlet. The tributaries entering the former river from the north gave the irregula north-eastern arm of West Wanganui Inlet, and similarly were produced the bays on the south-eastern side and the main south-western arm. The probable decrease in the size of West Wanganui Inlet on the south-western side seems due to insilting of the entering streams rather than to elevation since the period of depression, as there is apparently no evidence of that phenomenon having occurred. When the shallowness of West Wanganui Inlet is considered, it will be realised how comparatively little insilting would be required to change even its present surface into dry land. Sand dunes, advancing from the coast on the northern side of the strait connecting the inlet with the sea are even now gradually decreasing its area.

The water which formerly drained to West Wanganui Inlet from the south-west has been captured successively by the Sandhill River and the Patarau River, so that the great south-west and north-east valley is now deserted by all main drainage channels, which instead traverse its course. A small stream entering the Patarau River from the north-east forms an obsequent stream, being disposed contrary to the original drainage. The water gap, through which the Patarau River flows to the sea through the cuesta above mentioned, is a very modern feature, being a deep narrow gorge, with almost vertical walls.

Northward from the water gap of the Patarau to the strait joining West Wanganui Inlet with the open sea, a number of wind gaps notch the crest of the cuesta, and mark where streams flowing either westward to the ocean or eastward to the inlet have cut back into the limestone cuesta.

Curious open caves and stately bizarre rock columns are *en evidence* along the seashore of the ocean, and are also to be seen, to a lesser degree, along the shore of the inlet itself.

At full tide Wanganui Inlet and the surrounding country presents a landscape of great beauty. To the eastward low hills, clothed with a vegetation of almost tropical magnificence, rise from cresentic bays of yellow sand. To the westward wooded slopes lead up to the steep escarpment of drab weathering limestone, bare of vegetation, but carved into many a beautiful castellate form ; while away to the southward majestic peaks of broken rugged outline stand clearly defined against the sky.

12.—TANTALUM AND NIOBIUM IN AUSTRALIA.

By EDWARD S. SIMPSON, B.E., F.C.S., of the Geological Survey of Western Australia.

In the census of minerals of Australia submitted to the Association in 1890 no mention is made of any mineral containing tantalum and niobium. Since then, however, these rare metals have been recognised in several widely separated districts in the Commonwealth, and, in response to the recent commercial demand for tantalum ores, deposits of great richness and extent have been disclosed in the Pilbara Goldfield of Western Australia. In this paper an account will be given of the discovery of these interesting minerals in Australia, their mode of occurrence, and their chemical and physical characteristics.

GENERAL FEATURES OF OCCURRENCE.

Before dealing with purely Australian deposits, it will be well to go briefly into the general features of the question.

These two metals are nowhere found in the native state, nor in sulphide or other similar minerals, but exist always in combination with oxygen and one or more other metals, the oxides having an acid character and giving rise to tantalates and niobates. They invariably occur in conjunction, replacing one another isomorphously to a very variable extent, the niobate of a metal often passing by insensible gradations into the tantalate without change of form or physical characters other than a corresponding gradual rise in specific gravity, tantalum having an atomic weight double that of niobium. In the following pages, therefore, whenever a mineral is described as a tantalate it must be understood that it contains niobium as well as tantalum, but that the former is present in preponderating amount, and *vice versa.*

The ores hitherto detected in Australia are :—

(1) Columbite, niobate of iron and manganese.

(2) Tantalite, tantalate of iron and manganese. The subspecies manganotantalite contains more manganese than iron ; the normal variety more iron than manganese.

(3) Stibiotantalite, tantalate of antimony.

(4) Microlite, tantalate of lime.

(5) Euxenite, titanoniobate of yttrium, erbium, cerium, &c.

Until recently the best-known localities of the mineral tantalates and niobates were Sweden, Norway, Bavaria, Siberia, Greenland, and the United States. Though occasionally recorded as occurring in syenite rocks, the most usual primary occurrence in all these countries is in pegmatite veins in granite, especially in those characterised by the presence of much albite. In these veins they are commonly accompanied by quartz, orthoclase, and mica, as well as albite, whilst garnet, zircon, topaz, monazite, cassiterite, and other uncommon minerals are often present. The only primary deposits described so far in Australia are those of Finniss River (Northern Territory), Greenbushes (Western Australia), and the Wodgina District (Western Australia), all areas of granitic rocks.

Most native tantalates and niobates offer considerable resistance to chemical change, and, being in the main both hard and tough, are of frequent occurrence in detrital deposits, though usually overlooked unless the latter happen to be worked for gold or tin. Still, there are numerous records of their detection in stream deposits in America, Siberia, and England, whilst detrital ores are of great importance in North-Western Australia.

Within the last two years the search for these minerals has been greatly stimulated by the fact that they have suddenly become of considerable commercial value. This has been largely due to the discovery of the tantalum electric lamp, but partly also to the experiments being made with tantalum-steel alloys, which appear to possess many valuable properties. As much as 20s. per pound was paid in 1905 for bulk lots of high-grade tantalum ore. The price has, however, been very variable lately, ranging from about £200 to £1,000 per ton.

QUEENSLAND.—*Geraldton.*—The only record of any tantalum in this State is contained in publication No. 196 of the Geological Survey. A black sand occurring on the shore at the mouth of the Johnstone River, near Geraldton, was found on analysis to consist mainly of ilmenite (84 per cent.). With it was 0·78 per cent. of combined niobic and tantalic oxides, equal to 0·95 of tantalite or columbite. Which of these latter minerals was present is doubtful, as no separation of the oxides was made. The only other rarer minerals present were monazite and zircon.

According to the 1902 geological map of Queensland, the watershed of the Johnstone River is occupied mainly by crystalline schists, with smaller areas of basalt. It is probably from the former—which may include granitic schists—or from offshoots of the large masses of granite lying further to the north and west, that the tantalite has been derived.

NEW SOUTH WALES—*Ballina.*—In volume VII. of the Records of the Geological Survey of this State there is a description of some tantaliferous concentrates from Broken Head, near Ballina. The original beach sand from which these were obtained was composed of quartz, zircon, ilmenite, with smaller proportions of monazite, cassiterite, iridosmine, and gold. The concentrates consisted of—Monazite, 65 per cent.; zircon, 22 per cent.; cassiterite, 9 per cent., and carried 1·10 per cent. of tantalic oxide in one case and 0·86 in another, equal to between 1 per cent. and 1½ per cent. of tantalite.

Euriowie.—In the early nineties Mr. C. W. Marsh reported the occurrence of columbite in association with cassiterite at the Euriowie Tinfield, near Broken Hill. A small specimen of this columbite, about 2in. long and ¾in. square, is in the Geological Museum in Sydney. It is too small to permit of an exact analysis being made, and there is some slight doubt as to whether it may not be euxenite (niobate and titanate of yttrium, &c.). Its specific gravity is said to be about 6, which supports the theory that the mineral is columbite. The tin lodes at Euriowie, according to Mr. Pittman, consist of a series of coarse pegmatite dykes, traversing gneiss and mica schist. The dykes are described as being composed of quartz, felspar, and mica. It would be interesting to know whether the felspar is mainly orthoclase or albite, as the latter is so characteristic of tantaliferous dykes.

Silverton and Darling Range.—In a recent letter Mr. C. W. Marsh says: "About two miles east of Silverton (Barrier Ranges) there is a large granitic outcrop, from which building stone has been quarried, having as accessory minerals tourmaline (black and red), ilmenite, garnets, and a little wolfram and columbite. I also remember finding columbite in granite at the southern point of the Darling Range, in the Rock Well Paddock, Barrier Ranges."

Victoria.—So far no tantalum or niobium is known to occur in this State. A mineral discovered some years ago, and reported to be columbite, proved on further examination to be rutile.

South Australia.—As we leave the eastern side of Australia we find more frequent occurrences of these rare metals.

Boolcomatto and Mount Babbage.—In the previously quoted letter of Mr. C. W. Marsh, that gentleman gives the following particulars with regard to discoveries made by him apparently between 1885 and 1895: "Sent from Broken Hill to Boolcomatto, S.A., to inspect supposed important tin find, which turned out to be a large granite outcrop, containing as accessory minerals ilmenite and tourmaline, with a little wolfram and columbite. . . . . Sent from Broken Hill to Mount Babbage, on the northern end of the Flinders Ranges, S.A., to supposed valuable tin discovery, which turned out to be a deposit in creek bed consisting principally of dark garnets, with a little titanite and one large flat piece of columbite, with several small fragments of tantalite."

Northern Territory.—In a report on the north-western district of the Northern Territory by Messrs. H. Y. L. Brown and H. Basedow, recently published by the South Australian Government, a short description is given of the occurrence of tantalum ores in that region. Three localities are mentioned, all within 30 miles of Port Darwin, in tin-bearing country.

Finniss River.—This is apparently the only locality where tantalite is being raised for the market. The deposit was discovered 20 years ago, and worked for tin, the tantalite not being recognised as such until recently. As in so many other cases, it was—probably on account of its similar specific gravity—assumed to be identical with the tin ore which accompanied it. Messrs. Brown and Basedow described the deposit in the following terms:—"The ore-carrying body consists of a huge intrusion of greisen, trending south-westerly, with a slight underlie to the east. The outcrop measures from three to four chains in width, and about six chains in length. It is characterised by immense, compact, white inclusions of quartz. The texture of the matrix varies from abnormally coarse to sugary, the latter type of rock often containing epidote. Tantalite occurs practically throughout the mass, but is very erratic in its appearance as small bunches and isolated crystals. It assumes three modifications, depending largely upon the character of the enclosing matrix—firstly, as irregular inclusions in the compact white quartz, usually of a symmetrical outline or lamellar. In this form it occurs isolatedly, with no associated mineral. Secondly, as radial spherical crystal groupings in the rock of fine-grained texture. Thirdly, as regular rhombic crystal forms in a normal matrix, usually associated with tinstone. The country rock is an arenaceous mica schist. The main bulk of ore is obtained by surface work upon the decomposed dyke and its sheddings on the hill slope."

The ore in this locality is a mixture of cassiterite and mangano-tantalite, similar to that found at Wodgina, W.A., as shown by the following analyses taken from the report :—

	1		2
Tantalic oxide, Ta_2O_5	41·70	..	55·52
Niobic oxide, Nb_2O_5	19·00	..	24·92
Tin oxide, SnO_2	21·00	..	4·40
Manganese protoxide, MnO ..	14·83	..	11·16
Iron protoxide, FeO	2·14	..	2·73
Undetermined	1·33	..	1·27
	100·00	..	100·00

Bynoe Harbor.—Tantalum ore occurs as dyke disseminations on a mineral licence nine miles south of the Leviathan Tin Mine, and also on Horden and Paull's claim, close to the other deposit.

Port Darwin.—Tantalum ore is described as occurring in a similar manner six miles east of King's Table, West Arm of Port Darwin.

WESTERN AUSTRALIA—*Moolyella.*—This locality, 10 miles north-east of Marble Bar, is chiefly of importance for the tin ores which are produced there. According to the report of Mr. A. Gibb Maitland the field lies in the midst of a large area of granite, which is intrusive into sedimentary rocks of probably Cambrian age. This granite is traversed by numerous dykes of a pegmatite composed mainly of quartz and albite, with subordinate mica, garnet, and cassiterite. Considerable quantities of stream tin are being obtained in this field, this ore being undoubtedly due to the disintegration of the pegmatite dykes

In a parcel of stream tin ore in the museum of the Geological Survey of Western Australia is a single fragment of a mineral forming a quadrant of a sphere 1in. in diameter, with radiated crystalline structure. This mineral is of an intense black color, with a metallic lustre, and specific gravity 7·3. It is identical in appearance with some of the ore from Wodgina, and is without doubt manganotantalite. It is an aggregate of a number of wedge-shaped crystals, the mass parting readily along radial planes on being struck. Closely attached to its outer surface are numerous small fragments of quartz and several fragments of much altered albite. These indicate the original source of the mineral to have been those quartz-albite pegmatite veins which form the matrix of the cassiterite.

Another similar, but smaller, fragment occurs in a second sample of stream tin ore, and others still smaller may easily have been overlooked.

Cooglegong.—This tinfield occurs 30 miles to the south-west of Marble Bar. According to the researches of Mr. A. Gibb Maitland, it is situated in the midst of a large area of granite, which, in places, is gneissic. "The granite is intersected in certain localities by veins of pegmatite, which have doubtless been the original source from which the stream and residual tin have been derived."

Gadolinite has been found both in the stream deposits and, associated with cassiterite and monazite, in a pegmatite vein.

In a paper on this occurrence of gadolinite, read before the Royal Society of New South Wales, in October, 1902, Mr. B. F. Davis says:—"Amongst the minerals I brought from the north-west I have two varieties of a mineral allied to 'euxenite' in physical characteristics, as described by Dana. One differs from the other in having more manganese in the place of uranium. They are essentially *niobates* and titanates (with tantalum) of *uranium* iron and *yttrium earths*, with cerium earths and thorium. They occur with cassiterite and monazite in the washdirt. I have only a few small pieces, but one mineral at least was not uncommon. I saw it in all the tin ore bagged from different parts of the country."

Some of the mineral from this same locality, collected from samples of tin concentrates by Dr. McKenzie, of the Tin Smelting Works, Sydney, has been examined by Mr. D. Mawson, and found to be strongly radio-active.

It is not, however, at all clear from Mr. Davis's paper whether this mineral was really obtained at Cooglegong or not. It may possibly have come from Moolyella.

I have recently come across some specimens in the West Australian Museum, the locality of which is given as the Shaw River, so that they come either from Cooglegong or from the Old Shaw Tinfield a few miles out of Cooglegong. These specimens consist of a number of angular detrital fragments of typical euxenite, varying in size from 10 to 40 mm. in length, and coated externally with a brown clay. On a fresh fracture the mineral is brown in color, and possesses a brilliant resinous lustre. It has a specific gravity of 5·3.

Thelemann's Find.—Sixteen miles north-west of Lalla Rookh tantalum ore was obtained in 1906 by Mr. F. Thelemann. It is detrital ore, and is said to occur only in limited quantities. It is of little commercial value, being a low-grade iron columbite, assaying from 3 per cent. to 5 per cent. of tantalic oxide. One sample, consisting of more or less worn fragments from $\frac{1}{4}$in. to 1in. in diameter, contained 4·92 per cent. of tantalic oxide, 70·34 per cent. of niobic oxide, and no tin. The specific gravity of the constituent fragments was very uniform, averaging 5·5.

The ore from this locality is frequently well crystallised. One good crystal measuring 7mm. x 23mm. x 30mm., and having a specific gravity of 5·53, shows the following faces:—a, 100; b, 010; c, 001; u, 133; e, 021; m, 110; g, 130; y, 210. The lower half of this crystal has not developed, having apparently formed against an already crystallised mass of albite. Several other crystals, with fewer faces, have been collected from this locality. Many are not of the tabular habit of the crystal described. All are, however, of low specific gravity, indicating a low tantalum content. One fragment has the radiated spherical structure previously mentioned in connection with Moolyella. The only associated minerals observed were quartz, tourmaline, and albite. Granite is the prevailing rock in the locality.

Green's Well.—The main workings in this district are situated at a locality variously known as Green's Well, Mount York, and Chingamong. They were first developed in 1905, and are situated in the same belt of granite as extends from Thelemann's Find through Wodgina to Mount Francisco.

The original mine in this locality has been described officially in the following terms :—" On M.L. 100 (O. T. Bell and party) a rubbly felspar formation has been exposed for a few feet. This carries tantalite, but sufficient work has not been done to allow of an opinion as to the richness of the lode. On McBeth's alluvial reward claim tantalite can be easily seen in the gully that traverses the claim."

A sample of dressed ore from Green's Well, brought to Perth by Mr. A. Gibb Maitland, apparently consists of both stream and lode ore in angular fragments from 1mm. up to 20mm. in diameter. A great portion of it is more or less well crystallised, a few excellent crystals being observed in it, of which the following are details :—

No.	Size in Millimetres.	Sp. Gr.	Faces Observed.
1	6 x 9 x 16	6·31	a, b, c, u.
2	3 x 10 x 11	5·50	a, b, c, u, e, y, m, g.
3	6 x 10 x 13	6·49	a, b, c, q, h (?)
4	7 x 9 x 18	6·05	a, b, c, u.
5	7 x 7 x 12	6·32	a, b, c, u, k.
6	11 x 19 x 26	5·77	a, b, c, u, e, m.

The sample, as a whole, assayed—tantalic oxide, 42·39 per cent. ; niobic oxide, 21·09 per cent. ; metallic tin, 15·62 per cent. The mineral itself varies from a columbite, with specific gravity 5·35, to a tantalite, with specific gravity 6·84. For the most part it has a dull rusty-black surface, but occasional crystals exhibit brilliant black metallic faces, especially a. This face and b is often striated vertically. The only associated mineral observed in any abundance is cassiterite. The primary deposit from which the ore is derived appears from the above description to be a typical quartz-albite pegmatite.

The ore from Green's Well is characterised by the very variable extent to which tantalum and niobium replace one another. In another sample from here, individual crystals varied in specific gravity from 6·4 up to 7·7, indicating an approximate percentage of tantalic oxide varying from 46 to 81.

Wodgina.—By far the most important tantalum deposits in Australia are those of Wodgina, situated in the Pilbara Goldfield, in lat. 21° 15′ S., long. 118° 40′ E., 90 tons of dressed ore having already been shipped from this locality.

In a recent article in the *Mining Journal*, Messrs. F. H. and W. A. Mitchell (the latter assayer at the Mons Cupri Copper Mine, 80 miles from Wodgina) make the following statement with regard to the first discovery of tanta'um ore at Wodgina :—" This mineral was first observed by us in North-West Australia early in 1901, when a crystal was submitted to the British Museum authorities for confirmation; but it was not until about four years 'ater that we introduced this mineral into Europe for commercial purposes."

In May, 1904, a black mineral from this locality was forwarded for identification to the Acting Mineralogist and Assayer, Mr. C. G. Gibson, and proved to be manganotantalite, a preliminary analysis showing the presence of 80 per cent. of tantalic and niobic oxides and 16 per cent. of manganese oxide. At that time there was no market for the mineral except for museum and other educational purposes, for which purpose the demand was limited to a few pounds per annum. Towards the end of the year, however, the demand which arose in connection with the manufacture of tantalum lamps stimulated prospecting for these minerals, and since then a great number of ores from all parts of the district have been examined in the laboratory attached to the Geological Survey of Western Australia.

The locality has recently been geologically examined and mapped by Mr. Maitland, and from his report the following resumé of the structural features of the rock masses and ore bodies has been culled.

The tantalum ores occur in stream deposits, in shallow surface detritus in the immediate vicinity of the outcrops of pegmatite dykes, and in these dykes themselves. They occur in a mass of hornblende-schist, and are apparently offshoots of a mass of granite lying at a short distance to the north, east, and south-east. Between the hornblende rock and the granite on the south-east are a series of schists of indeterminate origin, mostly very siliceous and carrying either mica or hæmatite. Their origin is still a matter of some speculation. Within the area of these schists the pegmatite veins are tin-bearing, and are being worked for that metal.

The most important tantalum vein in Wodgina proper is that which passes through mining leases 86 and 87 in a north and south direction. It is from 30ft. to 40ft. wide, and consists of variable proportions of quartz, felspar (mainly albite), mica (muscovite and lepidolite), and tantalite ; the last-named in crystalline masses from the size of shot up to 5cwt. in weight. A little west of this main vein is a second smaller one of similar nature. From the outcrops of these veins a larger amount of ore has been shed, and the greater part of the ore hitherto exported has been obtained by " specking " and dryblowing the shallow detritus on the surface. About 71 tons is said to have been obtained in this way.

The main vein appears to continue for about a mile north, where it is 20ft. wide, and has there also been worked for tantalum.

Since Mr. Maitland reported on this field other tantalum-bearing dykes have been opened up in the vicinity, and ore is still being obtained from shallow surface soils, as well as from true alluvial deposits in the many small valleys.

The mineral which occurs most frequently at Wodgina, and constitutes almost the whole bulk of the ore exported, is manganotantalite. A typical fragment from a large specimen of detrital ore from miscellaneous lease 86 was analysed with the results given in column A. Those in column B were obtained from a single rhombic prism weighing 8 grammes.

	A		B
Tantalum pentoxide	68·65	..	69·95
Niobium pentoxide	15·11	..	14·47
Tintanium dioxide..........	·40	..	—
Tin dioxide	·48	..	·36
Tungsten trioxide	Trace	..	—
Water combined	·07	..	—
Iron protoxide	1·63	..	2·68
Manganese protoxide	14·15	..	(12·54)
Nickel protoxide	Trace	..	—
Lime	Trace	..	—
Magnesia	·15	..	—
Cerium and Yttrium oxides ..	Nil	..	Nil
Total................	100·64	..	100·00
Specific gravity	7·03	..	7·09

This mineral is black on a fresh fracture with a metallic lustre. Weathered surfaces are a rusty-brown color, due largely to a thin adhering film of ferruginous clay. The masses, whether of lode or detrital ore, frequently consist of an intergrown mass of parallel prismatic crystals, in which the faces a, b, and c are freely represented, and, less commonly, u (133). These prismatic masses are inclined at times to be wedge-shaped and, rarely, small masses are seen to be part of a spherical "rosette" or radiated crystal group. The faces are frequently indented by actual tabular crystals of albite, or by hollows from which albite has evidently been weathered out. Twinning about the plane e has been observed in several instances. The macropinacoid a is often vertically striated, and at times has a very brilliant lustre. In size the masses vary from many pounds in weight down to a few grains only, and in the alluvial are often associated with tin ore, though so far cassiterite has not been recorded from the veins which carry tantalite.

No normal iron tantalite has been observed at Wodgina, the whole of the tantalite there being of the manganese variety. It is usually of very uniform grade, containing from 65 per cent. to 70 per cent. of tantalic oxide. Manganocolumbite has, however, recently been obtained at Wodgina. This is identical with the richer ore, in all physical features, with the exception of specific gravity which, as one would expect, is correspondingly lower. Specimens of this mineral, and of an ore of intermediate composition, gave the following results :—

	Tantalic Oxide.	Niobic Oxide.	Specific Gravity.
Manganocolumbite	22·90	54·83	5·72
Low-grade manganotantalite	48·21	30·52	6·34

In "Dana's Mineralogy" there is a list of analyses of tantalite-columbite from the Etta Mine in the Black Hills of South Dakota, which show to what a large extent the ore in a single mine may vary in grade owing to the mutual replacement of tantalum by niobium, and *vice versa.* As has already been stated, this is not characteristic of most of the Wodgina deposits. The exception that proves the rule, however, is a small parcel of crystalline stream ore, individual fragments of which gave the following specific gravities :—5·98, 6·10, 6·55, 6·92, 7·03, 7·75, 8·03. These figures show that this ore ranges from nearly pure niobate of manganese to a nearly pure tantalate of iron.

Tin oxide appears to exist as an essential constituent of all tantalates and niobates. The amount thus present seldom exceeds 1 per cent., and, not being recoverable by any simple process, is of no importance to the miner. A mechanical mixture, however, of cassiterite and tantalite or columbite is readily separated by an electro magnet, so that the cassiterite which thus occurs with almost all Wodgina stream ores is not to be overlooked. The following figures give an idea as to the extent to which the tin thus occurs :–

Sample.	Tantalic Oxide.	Niobic Oxide.	Metallic Tin.
	Per Cent.	Per Cent.	Per Cent.
A	45	32	3·12
B	60	16	6·74
C	17·3	3·5	50·35
D	8·9	1·6	60·90

Microlite (pyrotantalate of lime) occurs in association with manganotantalite in a stream ore received from Wodgina. The exact locality from which this ore was derived has so far not been disclosed, but, judging from the associated minerals, it is from the immediate vicinity of Wodgina itself. The mineral, constituting about 2 per cent. of the whole parcel, is in irregular water-worn fragments up to 1in. in diameter. By the courtesy of Mr. A. O. Watkins I have been supplied recently with about an ounce in weight of this mineral, and a preliminary physical and chemical examination of it has been made.

The specific gravity of five fragments was respectively 5·37, 5·76, 5·61, 5·42, 5·73, evidencing a somewhat small variation in tantalum contents (probably about 15 per cent.). No evidence of crystallisation is apparent, the fragments being roughly rounded and water-worn. Parts of the surface are covered with a very thin black coating, which sends out what one may call small rootlets into the mass of the mineral. This coating, as well as more or less numerous minute black inclusions in the centre of the pebbles, appears to consist of tantalate of manganese. Where not covered with this black coat the microlite pebbles are grey or light pinkish brown. On fresh fractures the mineral is opaque and usually light pinkish grey, sometimes a little darker, and inclined to liver-color The internal structure as seen in a thin slice under a microscope is very interesting, being reminiscent of olivine largely altered to serpentine. It consists of numerous cores of clear unaltered isotropic microlite enclosed in a meshwork of the same mineral, more or less cloudy, and evidently altered somewhat—probably, judging from the analysis, by absorption of water. Throughout the section are tiny pinpoints of black manganotantalite.

A fragment of a pale pinkish color, which on sectioning was found to be practically free from included tantalite, was chosen for analysis. It has, unfortunately, not been found possible so far to complete this analysis, but the following are the results obtained up to the present :—

Tantalum pentoxide / Niobium pentoxide	77·16
Lime	13·46
Magnesia	·42
Iron protoxide	3·64
Manganese protoxide	·60
Potash	·20
Soda	1·66
Water on ignition	1·06
Water at 100°	·22
	98·42
Specific gravity	5·422

The analysis proves this mineral to be essentially a pyro-tantalate of lime of the form $Ca_2Ta_2O_7$, part of the lime being replaced by alkalis, iron oxide, &c. Like most tantalum minerals, it probably carries a little tin oxide, which has not been estimated.

Of interest in this connection are a few small pebbles received on another occasion from Wodgina. One consists of a large core of a dark-colored tantalate, completely surrounding which is a layer about five millimetres thick of pale microlite similar to that described above, covered in its turn again by a very thin coating of black tantalite. A second pebble is similar, whilst two others are wholly composed of a greyish-black opaque, and apparently homogeneous mineral. One of these latter pebbles, weighing 18grms., was broken in half, and one half analysed, with the following results :—

Tantalum pentoxide	73·82
Niobium pentoxide	6·44
Tin dioxide	·72
Titanium dioxide	·54
Iron protoxide	8·42
Manganese protoxide	1·39
Lime	7·78
Magnesia	·62
Cerium and yttrium oxides	Nil
	99·73
Specific gravity	6·04

Without further investigation it is impossible to say whether this is only a very intimate intergrowth of microlite and tantalite, or, as I am inclined to think, a new subspecies of tantalite, in which lime to a large extent replaces iron oxide. If the latter be the true explanation of the observed facts, the name calciotantalite naturally suggests itself as descriptive.

Mount Francisco.—This locality is about 15 miles south-west of Wodgina, and has only recently been discovered. According to accounts of the field received in Perth, the ore occurs under similar conditions to those which obtain at Wodgina. The mineral, however, contains much less tantalum, being a manganocolumbite with specific gravity 5·73, equal to 23 per cent. of tantalic oxide. The pegmatite in which the ore occurs is composed mainly of albite, orthoclase, and quartz, with more or less muscovite and garnet. The columbite is in irregular masses, in which parallel groups of crystals are often well defined. The faces most commonly developed are a (striated), b, and u. Twinning on e was observed in one case. Small parallel crystals are developed in great numbers at times on the macropinacoid a.

A little detrital ore has been obtained from this locality. It is thickly coated with ferruginous clay, which is sufficiently adherent to give a rusty-black color to the ore, even after hard scrubbing with water. The actual ore itself does not apparently weather readily, as careful cleaning reveals bright black faces. The ore has not travelled far, as excellent crystals with sharp edges occur amongst it.

Greenbushes.—The last locality to be described was almost the first in which tantalum and niobium were recognised in Australia. It is interesting also as being the scene of the first mining for tantalum ore in the Commonwealth, a lease having been secured and worked in 1902 to provide tantalite for the Foote Mineral Company of the United States.

Greenbushes is situated in the Blackwood Ranges. The prevailing rock on the surface is a laterite composed largely of bauxite, and completely concealing the underlying primary rocks from view except in a few isolated areas adjacent to streams. The country appears to be mainly granite, traversed by dykes of diorite and pegmatite, all foliated more or less strongly in places. Considerable quantities of tin ore have been recovered from the streams and older gravels and cements, smaller quantities from the pegmatite dykes and foliated bands of greisen.

In 1893 Mr. J. J. East, of the Adelaide School of Mines, in examining some alluvial tin ore from Greenbushes, turned his attention to a mineral present in it, which had been looked upon by the miners as "resin tin," or in some cases as scheelite. A few blowpipe tests revealed the fact that this mineral was a new compound of antimony. It was therefore submitted for analysis to Mr. G. A. Goyder, who established the fact that it was a tantalate and niobate of antimony. This new mineral species was subsequently named stibiotantalite.

Although only present in the ores from the southern part of the field, and even then in quantities not exceeding 1 per cent. or 2 per cent., stibiotantalite threatened at one time to become a serious trouble to the tin miners, as the antimony from it found its way into all the smelted tin, and reduced its value by about £10 per ton. It would appear to have almost disappeared from the ores raised in recent years, only occasional very small fragments being seen in the concentrates.

In 1900, at the time when the author was examining some of the antimonial tin ores with a view to suggesting a method of treatment, trouble was again experienced at Greenbushes with a second class of concentrates. Some apparently clean tin concentrates from alluvial ground refused to yield up any tin, either in the assay pot or in the smelting furnace. Several samples of this mysterious ore were forwarded to the author, and proved to be tantalite of the normal iron variety. No other tantalum minerals have so far been detected at Greenbushes, except a doubtful new species, a hydrated tantalate of antimony, which will be described later.

Very little lode mining has been done at Greenbushes, either for tin or tantalum. The total tantalum ore exported—2½ tons—having been obtained almost exclusively from alluvial workings. The principal lode workings are at the head of Bunbury Gully, on mining lease 369 (Enterprise), where there is an ore body 18in. wide, consisting of a crushed rock composed almost wholly of pale-green mica with accessory quartz, tourmaline, cassiterite, and tantalite in fragments from the size of sand up to an inch in diameter. Overlying the lode is 12ft. of alluvial, carrying fine and coarse tinstone and tantalite.

On mining lease 379 (Galtee More), one mile further south, a decomposed lode of apparently similar character carries tin and tantalite. Some lode tin concentrates from mining lease 56 (Amanda), lying between these two, was found to yield on assay 5·5 per cent. of mixed tantalic and niobic oxides. This ore is described as coming from a weathered tourmaline-bearing dyke.

The alluvial tantalite at Greenbushes occurs principally in Bunbury and Floyd's gullies, in fragments from the size of sand grains up to lumps 13lbs. in weight. Its composition is not very variable, and, as shown by the following analysis of a typical fragment, it is a high-grade ore, occurring, unfortunately, in very limited quantities.

Tantalum pentoxide	80·61
Niobium pentoxide	2·50
Tin dioxide	1·51
Titanium dioxide	·71
Tungsten trioxide	·13
Water combined	·14
Iron protoxide	10·89
Manganese protoxide	3·78
Nickel protoxide	·02
Lime	Nil
Magnesia	·19
Cerium and yttrium oxides	Nil
	100·48
Specific gravity	7·74

This specimen, like all others from Greenbushes, showed no traces of crystal faces but exhibits an ill-defined cleavage. Dr. G. F. Kunz reports that its radio-activity is less than 0·02 times that of uranium.

The mineral is of a brownish-black color, and on a fresh fracture has a bright metallic lustre. Some fragments are wholly or partially coated with a smooth, hard, and strongly adherent coating of ferruginous bauxite, as much as 3 or 4 millimetres thick in places. This peculiarity extends to the tin ore also. Other fragments have no decided coating, but a slightly rusty tinge, which enables them to be readily picked out from the associated tin ore. Quartz, weathered felspar, and stibiotantalite are found adherent to it, whilst associated with it in the gravels are cassiterite, tourmaline, quartz, mica, cyanite, and other minerals.

The most interesting mineral found at Greenbushes is the previously mentioned stibiotantalite. This has not yet been located in lode material; but in some parts of the southern part of the field was at one time somewhat plentiful in the stream deposits. It was never shown to exist in amounts which would justify its being put on the market as a tantalum ore, and as time goes on it appears to become more and more rare. Greenbushes was, up till recently, the only known locality for this mineral, but quite recently well-defined orthorhombic crystals have been found at Mesa Grande, California, in a pegmatite vein, with tourmaline, beryl, &c.

The chemical composition of the Greenbushes mineral is shown by the following two analyses by Mr. G. A. Goyder :—

	A	B
Tantalum pentoxide	51·13	51·95
Niobium pentoxide	7·56	4·49
Silica	—	3·14
Combined water	—	·61
Antimony trioxide	40·23	38·04
Bismuth trioxide	·82	·79
Iron peroxide	Trace	·39
Manganese protoxide	—	Trace
Nickel protoxide	·08	Trace
Copper oxide	—	·20
	99·82	99·61
Specific gravity	7·37	6·47

Its formula is Sb (Ta Nb)O_4, or more probably, according to Penfield and Ford, $(SbO)_2$ (Ta Nb)$_2O_6$, which would explain the resemblance of its crystals to those of columbite.

Two well-marked features of the Greenbushes ore are of great interest, as indicating the probable origin of the mineral. In the first place stibiotantalite is often seen filling minute veins and occupying small vughs in masses of tantalite. Secondly, a very large number of the water-worn pebbles contain a central core of tantalite, the boundaries of which are very irregular, and which penetrates often in thin tongues out into the surrounding stibiotantalite. It would appear that the original mineral has been tantalite, and that this has been more or less replaced by pseudomorphs of stibiotantalite on the infiltration at a later stage of antimonial solutions into the lodes.

Greenbushes stibiotantalite exhibits only occasional traces of an external crystalline form: the only faces recognised with any certainty are a and b, with possibly m and u. A very distinct cleavage parallel to the macropinacoid is almost invariably noticed, and at times traces of a second cleavage have been seen. In color and transparency it varies very largely. Many small fragments are perfectly transparent, and of a pale-lemon yellow or amber color; the greater part of the ore is, however, more or less opaque, and varies in color from light-yellow or grey to brown or even dull black. Some of the more opaque mineral is cellular in structure, shows no cleavage, has a dull rough surface, and breaks with an uneven fracture. This may be an alteration product of true stibiotantalite, one such specimen yielding an amount of water of combination expressed by the formula $(SbO)_2\ Ta_2O_6\ 7H_2O$. Such a fragment had a specific gravity of only 4·77. In the unaltered stibiotantalite Goyder found a range in specific gravity from 6·47 to 7·37. The author has made the following specific gravity determinations, amongst others :—6·41, dark-yellow pebble; 6·75, grey pebble; 7·18, grey pebble, with yellow veins, strong cleavage; 7·43, pale-lemon yellow, indistinct crystal; 7·48, dark-yellow crystalline; 7·50, pale greyish yellow, indistinct crystal. The bulk sample from which most of these pieces were taken assayed tantalic oxide, 50·57 per cent.; niobic oxide, 12·58 per cent. A second bulk sample assayed tantalic oxide, 51·13 per cent.; niobic oxide, 7·56 per cent.

The stibiotantalite occurs in fragments from the size of a pin's head up to about 1in. in diameter. A single exceptionally large crystalline mass, about 2½in. in diameter, is in the possession of the Foote Mineral Company.

This mineral has been examined for radio-activity, with negative results, by Messrs. Mawson and Laby.

CONCLUSION.

In conclusion I desire to express my indebtedness to several gentlemen for the material information obtained from their letters or published papers. Amongst others, I am specially indebted to Messrs. A. Gibb Maitland, C. W. Marsh, G. A. Goyder, D. Mawson, and J. C. H. Mingaye.

13.—THE FORMATION OF GLACIAL VALLEYS AND LAKES IN SOUTHERN NEW ZEALAND.

By PERCY MORGAN, New Zealand Geological Survey.

[ABSTRACT.]

All New Zealand geologists agree that during late Tertiary or recent time there was a great extension of the glaciers in the South Island, but there is less agreement as to the influence of ice on the topographical features of this region. The writer takes a rather moderate view, and gives prominence to faulting as a factor in the formation of glacial valleys and lakes.

U-shaped valleys in Southern New Zealand, or elsewhere, may be formed in the following ways :—

(1) By glacier excavation along a pre-existing stream valley.

(2) By glacier excavation along a fault line.

(3) By trough faulting, the effects of which may be enhanced by ice corrasion.

" Glacial valleys may originate by ice corrasion alone, but in the southern part of New Zealand their formation has been much aided by zones of crushed rock fault-produced. In some cases block or trough faulting is largely, perhaps even mainly, responsible for U-shaped valleys, which have at one time been occupied by glaciers."

Reference is made in the paper to the small rock-bound basins or flats which are common among the Westland mountains. These are considered to be excavated sometimes by ice action alone, but more commonly the glacier has been aided by the existence of a body of crushed rock—fault-produced—at the points where these flats occur. Some may be due to trough or block faulting.

The larger and deeper rock-bound basins, occupied as a rule by lakes, are stated to be due to trough-faulting. Some " glacial " lakes, however, if of moderate size and depth, may be produced by ice excavation alone, especially at or below the junction of two ice streams. Others are formed by the damming up of a glacial valley by terminal moraine, and some lakes are increased in depth by the same cause.

When a glacial lake has originated in trough-faulting it is believed that the faulting went on during the time of the glacial extension, so that the depression filled with ice as it formed. This ice is supposed to have remained almost quiescent, whilst the upper part of the glacier was in more or less active movement, over-riding the lower portion below the level of the rock rim, or in some instances below the terminal moraine. On the retreat of the glacier the melting of the ice left a hollow—the basin of the modern lake.

" If the views herein advanced be substantially correct, it is evident that the glacial lakes and valleys of Southern New Zealand are accounted for without recourse to the theory of a glacial epoch, or an extraordinary increase in the size of the present glaciers."

14.—ON THE LOWER CAMBRIAN AGE OF THE BARRIER RANGE (NEW SOUTH WALES), PREVIOUSLY REGARDED AS SILURIAN (?).

By D. MAWSON, B.E., B.Sc.

15.—SOME PROBLEMS OF AUSTRALIAN GLACIATIONS.

By T. W. EDGEWORTH DAVID, B.A., F.R.S., Professor of Geology, University, Sydney.

In view of the fact that the Glacial Research Committee of this Association has now been in existence for just 15 years, and has accumulated a considerable amount of evidence relating to at least three Ice Ages through which Australasia has passed, it may not be inopportune to now summarise the evidence with a view partly to suggest special lines of inquiry and partly to formulate certain working hypotheses. The latter, while to a certain extent speculative, may perhaps be found of use in directing the attention of geological workers to what, as it appears to the author, are salient points requiring further study.

Of the three proved glacial epochs, viz.—The Lower Cambrian, the Permo-Carboniferous, and the Pleistocene, the oldest may be considered first.

LOWER CAMBRIAN.

The evidence so far adduced by Mr. Howchin appears to the author to point to the following conclusions :—

1. The widespread distribution of this till for 300 miles of longitude and for 450 miles from north to south, from lat. 29° 40′ S. to lat. 36° S., suggests that the ice gathered on a plateau of comparatively low relief.

2. As shown already by Mr. Howchin, the ice probably moved from south to north.

3. The presence of casts of what appear to be radiolarian shells in the Tapley's Hill shales, overlying the glacial beds, suggests that the ice came down very close to sea-level, even to sea-level, near the latitude of Adelaide in Lower Cambrian time.

4. Glacial conditions became less marked as the tropic was approached, and as the ice front would be more or less at right angles to the general trend of the movement of the ice, the area glaciated in Lower Cambrian time in the Australasian region was approximately concentric to the present South Pole of the earth.

Obviously the evidence on this important point is as yet rather slender ; but, as far as it goes, it appears to the author to point in the direction above indicated.

5. Inasmuch as glaciers and ice-sheets usually grow to windward, going out as it were to meet their food supply, and we have seen that the ice in Lower Cambrian time in South Australia moved from south to north, the winds which fed its gathering grounds with snow probably came from the north or the north-west, and therefore were derived from the southern anticyclone belt of that period. If this conclusion is correct the southern anticyclone belt may not have been, as it now is, a comparatively dry belt, but probably yielded large supplies of snow to a plateau of moderate elevation lying to the south of the present southern coastline of Australia. It is to be noted that the present

winds moving poleward from the southern anticyclone belt do not owe their moisture to what they bring down with them from the anti-trades in their descent near the parallel of 32° S. lat., but rather derive their moisture *en route*, after their descent to the earth's surface, from the ocean over which they pass in their subsequent south-easterly course towards the belt of polar calms. It seems to the author that the following points might well claim our attention amongst, no doubt, many others which might be suggested in connection with this remarkable Lower Cambrian glaciation :-

1. Can any spots be found where the Cambrian till immediately overlies unconformably Pre-Cambrian rocks ? If any such can be discovered there can be little doubt, in the opinion of the author, that striated pavements will be found which will give definite evidence as to the nature of the ice which produced the glaciation, as well as of its direction of movement.

2. What is the origin of the remarkable thin beds of limestone which are interstratified with the top of the glacial beds ? Are they of freshwater origin ?

3. What is the exact sequence and thickness of these glacial beds at various areas, situated at different distances with regard to one another along the general path of ice movement ?

4. Are any microscopic or macroscopic fossils contained in the strata which immediately overlie or underlie, or are interstratified with them ?

The discoveries of Mr. Howchin in South Australia should be considered in conjunction with the more recent discoveries of Mr. Bailey Willis, of the United States Geological Survey, of Lower Cambrian boulder beds near Ichang, on the Yang-tsze River below the horizon of the *Olenellus* limestone, and perhaps, also, with the earlier discovery by Dr. Reusch of glaciated pavements and a boulder bed at the Varanger Fjord in North-eastern Norway. The age of the latter beds are still doubtful, for while Reusch and Strachan assigned to them a Cambrian age, Professor Tschernjchew relegates them to the Devonian, and others again to the Permian. The supposed glacial conglomerates of Spitzbergen, recorded by Gregory and Garwood, of the Lena River in Siberia, of the Coppermine River in the Northern Territory of the Dominion of Canada, as well as the conglomerates recently found by A. W. Rogers in South Africa, are now thought to be of probably Pre-Cambrian age, and therefore cannot be correlated with the Lower Cambrian glacial beds of South Australia, or with those of the Yang-tsze.

PERMO-CARBONIFEROUS.

In attempting to summarise the evidences of ice action in Permo-Carboniferous time, the author will first consider the Australasian evidence, and afterwards evidences in extra-Australasian areas.

In Australasia the evidence appears to him to point to the action of land ice in the form of a great piedmont glacier or ice sheet. That it was land ice and not floating ice which accomplished such a widespread grooving and striation of rock surfaces in southern Australasia, in Permo-Carboniferous time, appears to be proved by the following facts :—

1. The persistence of striæ and grooves over great distances, and their systematic radiation from near some common centre or gathering ground.

2. In the Bacchus Marsh area, as Messrs. G. Sweet and C. C. Brittlebank and the author have shown, the grooves made by the ice are developed both on the stoss-seite and lee-seite of old valleys with steep sides. Floating ice could not possibly have accomplished such work as this.

3. The nature of the ground mass of the till varies with that of the subjacent rock, proving that the till, as regards its ground mass at all events, was manufactured locally. This could not have been accomplished by any form of ice other than that of glaciers or ice sheets.

4. There appears to be an absence for the most part of microscopic or macroscopic marine fossils in the till beds proper. Such fossils as are found are plants, usually in a more or less fragmentary condition.

5. In the next place, on the assumption that the glaciation was the work of land ice, there is evidence in the great thickness of the glacial beds, with their interstratified deposits, that the first Permo-Carboniferous glacial epoch, that of the Lower Marine series, lasted for a considerable amount of time. In the Bacchus Marsh district, for example, as already pointed out by Messrs. C. C. Brittlebank, G. Sweet, and the author, the glacial series attains a total thickness of over 2,000ft. In South Australia, in the Inman Valley, the section supplied by the Back Creek bores for coal, and the natural sections afforded by the hills and valleys, show that the glacial series there is over 1,000ft. certainly in thickness.* As recent observations by the author on the Wynyard beds of Tasmania show, this same glacial stage of the Lower Marine series, as developed there, has a thickness of about 1,200ft.

If now we compare these thicknesses with those of the glacial beds left by the great Pleistocene ice sheets of the Northern Hemisphere we find that where they attained their maximum thickness, towards their margins, they are about 150ft. thick. It is estimated that even this comparatively small thickness of strata required for its formation some scores of thousands of years. If, therefore, so great a period of time was needed during the Pleistocene epoch, in order to form 150ft. of glacial and interglacial strata, what period of time was needed, during the Permo-Carboniferous period, in order to produce a thickness of no less than 2,000ft. of similar beds ?

Next, the evidence in the type districts of Wynyard for the land glaciation, and of Lochinvar for the evidence of floating ice, both show that an important interglacial epoch or age intervened between the Lower Marine glacial stage and that of the Upper Marine. Evidence for this interglacial stage is afforded by the intercalation of the Greta coal measures, over 100ft. in thickness, and containing in places fully 40ft. of coal between the Upper and Lower Marine series.

* Mr. Howchin now estimates their thickness at about 1,500ft.

That ice action persisted in Permo-Carboniferous time, into the age when the Upper Marine series was formed, is, perhaps, clearest in New South Wales, as well as in the Bowen River Coalfield of Queensland. In both those regions there are abundant erratics, in some cases showing evidence of having indented the soft muds of the sea floor on which they fell. Although these erratics and boulders of the Upper Marine series rarely exhibit definite grooves or striæ, such do occur occasionally, and the great size of the blocks, which frequently weigh from 3 to 4 tons, makes their transport to their present positions inexplicable except by the agency of floating ice. Obviously, they are far too large to have been carried entangled in the roots of floating trees. Clearly a vast interval of time must have separated the Lower Marine glaciation from that of the Upper Marine, inasmuch as the interval of time is represented by the deposition of no less than over 4,000ft. of strata, including the Greta coal measures above mentioned.

The author would desire to draw special attention to the fact that hitherto no undoubted till bed has been discovered anywhere in Australasia which could be referred to Upper Marine Permo-Carboniferous time. It is to be hoped that such till beds may still be found, perhaps in some portion of Tasmania. Probably this Upper Marine glaciation was less intense than that which ushered in the Lower Marine age.

The next problem which suggests itself, and one of immense interest, is the exact northern limit of the land ice in Permo-Carboniferous time, and the height to which the ice descended in relation to sea-level. So far in New South Wales, Queensland, and Western Australia there is conclusive evidence of the presence of drifting icebergs in the seas of Lower Marine time. Some of the most beautiful evidence is that afforded by the boulder beds discovered by Mr. Gibb Maitland, Government Geologist of Western Australia, in the Irwin River and the Gascoyne and Wooramel River districts. The ice-striated boulders of the latter region in particular are imbedded in what is almost a limestone largely formed of remains of the *Fenestellidæ*. Clearly then the ice must have come down to sea-level in Permo-Carboniferous time somewhere between the Lochinvar area in New South Wales and the Beechworth area of Victoria—that is somewhere between the parallels of 32° 45′ and 36° 20′ S. lat.

In South Australia undoubted Permo-Carboniferous boulder beds have not hitherto, as I am informed by Mr. W. Howchin, been traced further north than the Croydon bore, near Adelaide, which is in the parallel of 34° 55′ S. lat.

The glacial boulders of Permo-Carboniferous age associated with marine strata in Western Australia have so far not been traced further south than the latitude of the Irwin River, which is 29° 10′. It is much to be hoped that examinations extended still further to the south may yield evidences of Permo-Carboniferous till in Western Australia.

It is interesting to note, in connection with speculations as to the direction in Permo-Carboniferous time of the prevalent winds which brought the snow or moisture to supply snow to the gathering grounds of these great ice fields, that in the Wynyard district of Tasmania the axes of the ripples trend about W. 30° S. and E. 30° N., and the wind which produced them has apparently come from a direction about N. 30° W. If this was the direction of the prevalent wind which fed the snowfields it must be conceded that the wind was derived from the southern anticyclone belt, and that the anticyclone belt of that period was not comparatively dry, as it is now, but was highly charged with snow or moisture. In other words, the Permo-Carboniferous snowfields were nourished by snowy "brave west winds" or "roaring forties" coming from a cold but moist anticyclone belt.

With reference to the evidence in extra-Australasian regions, it is interesting to note that in South Africa the Permo-Carboniferous glaciation was chiefly the work of land ice, which had its gathering ground in the Northern Transvaal or Rhodesia, and which radiated eastwards towards Natal, and southwards across the Orange River and Cape Colony. There the development of the ice was close to the southern anticyclone belt.

The same may be said of the Permo-Carboniferous glacial boulder beds of Southern Brazil, known as the New Orleans conglomerates.

A similar remark applies to the wonderful glacial beds and striated pavements of the Central Provinces of India and the Punjab in the Rajputana area, as well as to the Salt Range. The ice there had its gathering ground near the parallel of 18° N. lat., or even still nearer to the equator. It moved northwards for at least 500 miles over a land area of comparatively low relief, just as was that of South Africa and of Australia, and somewhere between Jaisalmer and the Salt Range and the Indus Valley it actually reached sea-level, and scattered its icebergs, laden with boulders and erratics, on the surface of the seas further north. There is this remarkable difference, however, in the general geographical and meteorological situation of the glacial beds of India, as compared with those of the Southern Hemisphere in Permo-Carboniferous time: the Indian glacial beds, and the ice sheets which produced them, probably lay equatorwards of the northern anticyclone belts, and consequently the snow which produced these ice sheets of India could not have been derived from westerlies blowing out from the northern anticyclone belt, but must rather have owed their origin to snow or moisture transported in Permo-Carboniferous time by the north-east trade wind. Again, there is a suggestion of the existence of a cold anticyclone belt laden with moisture or snow, this time in the Northern Hemisphere.

PLEISTOCENE.

If the as yet doubtful, but none the less interesting, possible evidence of the ice action in Australia in Cretaceous or early Tertiary time, to which Mr. H. Y. L. Brown has called attention, be passed over for the present, until further and detailed evidence is collected, the Pleistocene problems of glaciation may next be briefly considered.

In the Southern Hemisphere there is evidence in New Zealand of the glaciers of the Southern Island being 50 or 60 miles in length during the epoch of maximum glaciation, as compared with their present greatest length of 16 miles. In Tasmania, where at present there is no perennial snow, much less any permanent glaciation, evidence shows that in Pleistocene time glacial ice came to within a few hundred feet of sea-level, if not down to sea-level itself. Evidence at Mount Kosciusko, at Kerguelen Island, in the Chilian and Bolivian Andes, in Patagonia, at Gaussberg in the Antarctic, and in Victoria Land in the Antarctic, all points to a former greater extension of the ice fields and glaciers in Pleistocene time than at present. Apparently one of the few exceptions to this rule in the Southern Hemisphere is the Balleny Islands. These, according to the accounts given by Captain Scott and Mr. Ferrar, are now undergoing a maximum glaciation. The fact should here be noted that, according to the observations of Ferrar, the Ferrar glacier ice was formerly no less than 3,000ft. to 4,000ft. above its present level, and yet, even now, the Ferrar glacier probably contains as much ice as any glacier in the world. Captain Robert Scott records the interesting fact that the snowfall in the neighborhood of Ross Island is now only about 4in. to 5in. a year—that is 4in. to 5in. of hard packed snow. This, if melted down, would, as the author presumes, be equal to only about half an inch to three-quarters of an inch of rainfall. The Antarctic regions are, therefore, at present suffering from an impoverished snow supply, which accounts for the present rapid dwindling of its ice sheets. Captain Scott suggests, in view of his observations, that most of the snow is brought by warm southerly winds, and that what is now needed, in order to augment the ice sheets of the Antarctic, is not a decrease, but an increase generally of surface earth temperature. An increase of temperature would mean more heat available for producing vapor, as well as a more rapid atmospheric circulation for quickly transporting such vapor from equatorial regions towards the South Pole. If these observations are generally true for the Antarctic regions it would seem that near the parallel of the Balleny Islands, on the Antarctic Circle, that is near the point where the isotherm of 0° C. comes near to sea level, glaciation is at a maximum; while further south still, where the mean annual temperature is considerably below 0°, glaciation is waning, waning for want of snow supply. In other words, the bulk of the snow is taken out of the atmosphere by the time the moisture-laden winds have reached as far poleward as the parallel of latitude in which the Balleny Islands are situated, viz., about 67° S. lat.

In the Northern Hemisphere it appears to the author that the general evidence points somewhat in the same direction. Certainly in North America the centre of maximum glaciation progressively shifted from the Rockies to the Keewatin radiant west of Hudson's Bay, thence to the first Labradorian radiant, subsequently to a second, then to a third, each one progressively north of its predecessor; while at the present day the maximum region of glaciation has shifted back into Greenland. This shifting was, perhaps, due to progressive sinking under ice load, the first great development of ice being as usual to windward. The evidence collected by Professors Gregory and Garwood in Spitzbergen points to a similar conclusion viz., that Spitzbergen is now at a maximum of glaciation. In this case we see that in the Northern Hemisphere the only areas where glaciation is at a maximum, or near a maximum, are Greenland and Spitzbergen respectively, in the parallels of between 60° to 80° and 78° to 80° N. lat. It will be noticed that these latitudes, too, are not far from where the isotherm of 0° C. comes down to or near sea-level. Poleward of this latitude the observations of Dr. Drygalski and others show that the ice sheets are probably slightly waning for want of snow supplies. One might infer from this evidence that the earth has quite recently passed through a warmer climatic period than that which it at present enjoys. During the climax of such a period the isotherm of 0° C. in the Northern and Southern Hemispheres would have been poleward of its present position, and under these circumstances the poles would receive a larger supply of snow than they do now, while areas near the Arctic and Antarctic Circles would receive a smaller snow supply than at present. Under these circumstances, too, areas of the earth above the permanent snow line, situated equatorwards of the Arctic and Antarctic Circles, would have their glaciers and snowfields, relics of the Great Ice Age, diminished with comparative rapidity. As this last interglacial epoch slowly passed away, and gave place to slightly colder conditions, obviously the isotherms of 0° C. would move equatorward, carrying with them the zone of maximum snow precipitation to about the present latitudes of the Balleny Islands, Greenland, and Spitzbergen; the snowfall near the poles would be diminished, while that of areas above the permanent snow line, situated in temperate or tropical regions, would be slightly increased. Such an increase, however, in such regions would not necessarily lead at all to an advance of the glaciers; it might simply lead to the glaciers wasting away in such areas more slowly than they did at the climax of this last assumed interglacial epoch. According to this view, therefore, the world has quite recently passed the climax of an interglacial epoch, and is now on its way towards another glacial epoch, an epoch which is to form one phase amongst the many phases of what is commonly known as the Great Ice Age. The Great Ice Age, according to the estimates of Professor A. P. Coleman, probably lasted for from 100,000 to 150,000 years, even 200,000 years. According to various very reliable authorities the last retreat of the ice sheets took place only from 15,000 to 20,000 years ago. Inasmuch as this period of 100,000 to 150,000 years was made up of several glaciations, divided by at least one interglacial phase, each occupying periods of time somewhere about 10,000 to 20,000 years, it cannot obviously be said that the world is already out of its Great Ice Age.

In Permo-Carboniferous time, as already stated, no less than 2,000ft. of glacial and associated strata were deposited, only about 150ft. of such strata were formed on the average during so much of the Pleistocene Ice Age as the earth has already experienced. If, therefore, this Pleistocene and recent Ice Age is to be comparable at all in its duration to that of Permo-Carboniferous time, and if the thickness of strata deposited is any index as to approximately how long that time should last, the ratio of the thickness of the Permo-

Carboniferous glacial beds to those of the Pleistocene being about as 10 to 1, our earth may as yet have experienced only about one-tenth of the Great Ice Age, that is to say nine-tenths may yet have to be experienced.

An alternative hypothesis is that, without lowering earth temperature so as to shift the isotherm of 0° C. from near the Antarctic Circle to somewhere near the neighborhood of the anticyclone belts, some causes may conspire to uniformly increase or decrease, as the case may be, the rainfall and snowfall all over the world. Such a cause may possibly exist in what is known as atmospheric nucleation or atmospheric ionisation. The researches of J. J. Thompson and of C. R. Wilson have shown the importance of ionisation in favoring conversion of water vapor into the form of water dust; in other words, in favoring the production of fog and cloud and so facilitating precipitation. Recently Professor Carl Barus† has shown that the number of the nucleations in the atmosphere in the neighborhood of Providence, New Jersey, varies very regularly. He shows (*op. cit.*, p. 224) a curve for mean monthly nucleations from October, 1902, to October, 1904, and draws attention to the fact that the maxima and minima of nucleation occur during the winter and summer solstices respectively. He comments that (*op. cit.*, p. 225), "The identification of maxima with the winter solstice and of minima with the summer solstice is alluring, for, in these cases, the earth is, respectively, nearest and farthest from the sun. At the same time the orbital velocities are, respectively, greatest and least, so that the path volume of the earth would have corresponding values. Both causes are qualitatively in harmony with the observed results if the nucleation comes in great part from the sun. Quantitatively the results are less convincing." For example, he shows that the ratio of greatest and least nucleation is about 3 to 1, which is enormously in excess of what it should be numerically as deduced from the greatest and least values for the radius vector of the earth's orbit. This and other valuations only give an aggregate valuation of the order of about 6·7 per cent. In other words, a decrement of about 2 per cent. of distance of the sun from the earth corresponds to an increment of about 100 per cent. of nucleation. While he states that in some cases the rise in atmospheric nucleation can be attributed to definite sources, as to sun spot disturbances, or to smoke particles derived from forest fires, the main cause of the remarkable difference between winter as compared with summer nucleation is at present unknown. It is clear, therefore, that such an important factor as nucleation, which has exercised so wide a control over rainfall and snowfall, is one which must by no means be neglected by students of the glacial problem.

In suggesting the above theories the author by no means seeks to tempt away his colleagues from the narrow road of careful and constant collecting of evidence which ultimately leads to the discovery of fresh truths. His object in tentatively putting forward hypotheses has merely been to show how very wide is the scope of the inquiry,

† Smithsonian Contributions to Knowledge, part of vol. XXXIV.

and how great are the issues involved. For an ultimate solution of the question the geologist must avail himself of the researches of the meteorologist, of the astronomer, the physicist, the chemist, and the biologist. Meanwhile, it is the duty of geological workers in the Australasian region, so exceptionally rich in evidences of past glacial action, to co-operate with one another in a broad and friendly scientific spirit in gathering in more evidence.

The author would suggest, in furthering this work in the immediate future, that special attention be paid to the following points :—

(1) The recording, as soon as possible, of any evidence of a perishable nature, such as that afforded by erratics.
(2) The examination of all cores from borings, especially artesian borings, which may penetrate the Permo-Carboniferous glacial beds beneath the porous Triassic beds.
(3) The careful study of the ground-mass of the till as well as of its contained boulders in relation to the character of the subjacent and other neighboring rocks.
(4) The comparison of the rocks forming the pebbles of the conglomerate beds interstratified with the till with those of the glacial boulders in the till.
(5) The search for esker gravels, giant's kettles, &c., in the Permo-Carboniferous till.
(6) The search for striated pavements, not only in the old floors under the till, but also in the till itself. Obviously, such can only be found where the present land surface corresponds with an old glaciated surface of till, as in the sea beach at Wynyard in Tasmania.

Many other questions may suggest themselves to the geologists of Australasia, and the author will be grateful for further suggestions.

In conclusion he desires to warmly thank colleagues, especially of the Glacial Research Committees, for their long-sustained and loyal support in the past, and trusts that he may count upon them for a no less hearty co-operation in the future.

16.—THE DISTRIBUTION OF *THINNFELDIA* IN AUSTRALIAN MESOZOIC ROCKS.

By W. S. DUN (Geological Survey of New South Wales).

17.—REMARKS ON THE GEOLOGY OF THE UPPER WAITAKI BASIN, WITH SPECIAL REFERENCE TO THE LOWER TASMAN GLACIER VALLEY, NEW ZEALAND.

By E. O. THIELE and A. E. KITSON, F.G.S.

18.—THE DYKES IN TOWNSVILLE DISTRICT (NORTH QUEENSLAND), AND THEIR RELATION TO SURROUNDING ROCKS.

By JOHN FEWTRELL.

19.—PROBABLE PRE-CAMBRIAN STRATA IN TASMANIA.

By W. H. TWELVETREES, F.G.S., Government Geologist, Tasmania.

Progress in our knowledge of the geological systems as developed in Tasmania is made slowly, partly on account of the difficult nature of the country, much of the island being uninhabited and covered with dense forest broken by mountain ranges and scarred by deep ravines; partly, however, owing to State financial considerations, in consequence of which State geological investigations are chiefly restricted to economic and industrial matters. Now and again visitors, as well as resident geologists, contribute some valuable papers to our literature, and some distinct advance is made outside the range of official work; but we have to deplore the absence of continuous organised effort in pure geology. Hence much of our knowledge is necessarily scrappy, the large tracts which exist between mining centre are neglected, and geological information accumulates in a desultory piecemeal fashion. This must be accepted as an excuse for the somewhat disconnected nature of the following remarks.

PRE-CAMBRIAN.

The stratigraphical succession of the more ancient strata has not been worked out, and great caution is advisable in giving definite expression to opinions. It is not certain that exposures exist of rocks belonging to the Archæan complex, *i.e.*, Pre-Algonkian.

Rocks generally referred to the Pre-Cambrian are the following:—

1. Gneissoid hornblendic schists at the Rocky River.
2. Hornblendic schist, on the Forth River.
3. Quartzite and mica schist, at Cox's Bight and in the Port Davey district generally.
4. Quartzite, at Rocky Cape, North-West Coast.

1. *Rocky River Schist.*—These strata are met with on the Waratah-Corinna Road, at 26 miles from Waratah, and continue to the 31½ miles, with a strike about N. 20° W. and a N.E. dip.

The observed width of this zone is about a mile and a half. On the east side they are bounded by the Pre-Silurian Long Plains series of quartzite talcose and graphitic schists. The country to the west has not been examined carefully, but slate and quartz schist are known to occur.

The Rocky River schists continue north-west for 10 miles to the Rio Tinto Mines on the Savage River, and perhaps three or four miles still further. For this distance they maintain their lithological characteristics, and at intervals expose their characteristic ore deposits. Large lenses of magnetite and hematite occur, with which are associated a variety of minerals—copper, silver, gold, pyrrhotite, baryta, arsenide, and antimonial sulpharsenide of nickel, cobalt molybdate, asbestos, siderite, dolomite, calcite, arsenopyrite, quartz, &c. On each side of the ore bodies, and separated from them only by bands of more siliceous schist, is the hornblende rock, which is sometimes gneissoid and fissile, resembling a compact diorite, or is coarsely granular, with irregular fracture. Talc-like schists accompany this rock.

With this variability of aspect the rock might easily be called gneiss, schist, gabbro, or diorite, according to the particular specimen under examination. Still the mineral constituents are the same, whatever the variety of structure.

A rather fresh-looking acid plagioclase felspar (albite ?), in large plates ; a green hornblende, often decidedly bluish green in this section but with the extinction angles of common hornblende ; apatite, in large formless crystals ; quartz and much epidote, are the elements which form the rock.

It obviously belongs to the amphibolitic crystalline schists, but it is not easy to say what it was originally. A possible hypothesis is that it was once gabbro, the pyroxene of which has been replaced by hornblende, and its basic felspar transformed into more acid felspar and quartz. The presence of the nickel ore and the common development of serpentine on joint faces of the rock are consonant with this theory. It would appear to belong to Grubenmann's order of epi-amphibolites and to his family of albite amphibolites.

Further north, at the junction of the Whyte River with the Nine Mile Creek, on the latter of which some copper mining has been carried on, this zone contains actinolite schists, distinguishable from the Rocky River schists by the amphibole being actinolite and by the absence of felspar. The entire belt, however, forms a geological unit.

These are lithographically so different from any of the members of the Silurian and Ordovician and Cambrian, as known in Tasmania, that we refer them to a more ancient date. What their definite age is cannot be stated. It may be surmised that they are Pre-Cambrian ; but whether they are Pre-Algonkian or not must remain an open question for the present.

HORNBLENDIC SCHISTS ON THE FORTH RIVER.

At Hamilton-on-Forth a picturesque river gorge exposes the ancient rocks beneath a thin covering of Tertiary basalt, occasionally limburgitic or felsparless. To the north-west of the township crags of saccharoidal white quartzite overlook the river. The bearing of this is west of north. The strata to the east of the quartzite are micaceous schist, with similar strike and dipping west. About half a mile from the township along the road an exposure of the rock on the west side of the quartzite is seen. This is serpentine. All our serpentine rocks in Tasmania are believed to belong to the Devonian, or close of the Silurian, and there is no reason to believe that the Forth occurrence forms an exception. The width of the serpentine intrusion is obscured by the basaltic capping and its talus, but to the west of it is a wide belt of garnetiferous zoisite-amphibolite with the general strike and dip of the quartzite and schists. Hornblendic schist, more or less garnetiferous, continues for a good distance up the road to the south over a mile, and is succeeded by quartz, micaceous and graphitic schists extending to the waterworks building six miles from Hamilton, where an intrusive mass of quartz porphyry (Devonian) occurs, bounded on the west by slate.

The aspect and lithological characters of the quartzites and schists suggest that their age is Pre-Silurian, and I have long regarded them as Pre-Cambrian. The amphibolite, or hornblende schist, if we prefer that name, may represent the metamorphism of a basic rock, the original pyroxene having contributed to the formation of amphibole, and the plagioclase and olivine being represented by the garnet and zoisite.

Garnet is found occasionally in purely eruptive rocks, but in schists such as these it must be a metamorphic mineral.

Zoisite is a mineral which is characteristic of the middle zone (Katamorphic zone, zone of cementation [v. Hise]), in which both the dynamic and chemical effects of pressure are the chief factors in rock reconstruction.

Although this rock may be a metamorphic eruptive, it is, as said before, associated with quartzite, and it is consequently difficult to relegate the series to the Archæan complex. Rather may the Forth group be referred provisionally to the great Algonkian formations (Proterozoic, of Chamberlin and Salisbury), which fill the interval between the lowest Cambrian and uppermost Archæan. The characteristics of the Algonkian do not give the stratigraphist any very firm foothold; but as a rule gneiss is met with only occasionally, and rocks of sedimentary origin are dominant. On the other hand, in the underlying Archæan, orthogneiss and other eruptives are abundant, and the tectonic structure of the complex is variable and involved.

COX'S BIGHT.

This district borders on a broad bay on the south coast of Tasmania, about 12 miles east of the south-west extremity of the island, and seven or eight miles from the head waters of Bathurst Harbor, Port Davey. Mr. T. B. Moore, in a report to the Surveyor-General, 1901-2, mentions it as follows:—"At Cox's Bight a granite boss, about a quarter of a mile in diameter, rises through the Silurian strata at the southern end of the Bathurst Range. The creeks on the east and west side of this intrusive mass have been worked in a very primitive way for alluvial tin."

The country between here and Recherche Bay, at the southern end of D'Entrecasteaux Channel, is wholly uninhabited by man. At the bight at present a few miners are pursuing their calling, but the land north of the high ranges which fringe the shore is practically unknown. Mr. Moore marked out a track through to D'Entrecasteaux Channel, but I do not know that anyone besides himself has ever gone through on it.

A recent visit to the bight has enabled me to construct the following table of the geological succession there :—

Recent.—Swamp and lagoon land at foot of terrace ground. This deposit descends to a few feet below sea-level.

Terraces of tin-bearing detritus and wash at the foot of the coastal mountains, from 50ft. to 150ft. above sea-level.

Tertiary.—Terrace of clayey sand, with carbonaceous material fringing foot of mountains, 150ft. to 200ft. above sea-level.

Jura-Trias and Permo-Carboniferous.—Not represented.

Devonian (?).—Biotite-granite forming the bed rock below the terraces and exposed from sea-level up to 600ft. Intrusive in quartzite and schist and intersected by veins carrying tin ore, with accessory molybdenite.

Hornblende-lamprophyre intrusive in quartzite. Found as loose stones on beach at east end of the western bay.

Veins of griesenised quartz intrusive in quartzite near the junction of latter with granite.

Actinolite contact rock as loose stones on beach near Sand Bluff.

Silurian, Ordovician, and Cambrian.—Not identified.

Pre-Cambrian (?) *Algonkian.*—Quartzite of Cox's Bluff Range, Foley's Pimple, Bathurst Range, Red Point Range.

Mica Schist and quartzite at Point Eric.

Mica Schist at Black Point.

Slate and sandstone on Slate Range.

Silvery mica schist on fall of range to Louisa Bay.

The bight is six miles across, and is divided into two bays by a small promontory called Point Eric, which rises to a peak 160ft. above sea-level. This headland is composed of alternate beds of biotite schist and saccharoidal quartzite, greatly contorted and dipping at low angles to the south-west. The strike of these strata is north-west and north-north-west. These are the general strike and dip of all the schists and quartzites in the locality, excepting in the case of a range of dark muscovite schists on the eastern bay, where the strike is only a few degrees west of north. At the neck of the Point Eric promontory a junction with granite takes place, and the latter forms a spur with rocky knobs rising north from sea-level to 600ft., where it again junctions with quartzite, which continues to the summit of the Bathurst Range, 2,800ft. above sea-level. Cox's Bluff Range is a high headland (about 1,000ft.) forming the western horn of the bight, and consisting of quartzite, like many of the bluffs which jut out on this part of the south coast, with bare snow-white crests visible for many miles. The dense white quartzite of Port Davey has long been considered to be of Pre-Cambrian age, not to say Archæan.

These mica schists are intimately involved with the undoubtedly sedimentary quartzites : this and the absence of gneisses and eruptive rocks generally seem to require that the Cox's Bight series be placed among the Algonkians. A possible exception is the muscovite schist of the Black Point, which may prove to be a gneissified schist.

There are some slates and sandstones in the same area, and the fact of the processes of regional metamorphism having impressed on the rocks, clearly of sedimentary origin, characters so different from those which we see in the mica schists might lead us to attribute an eruptive origin to the latter. But repeated alternations of schist and quartzite sometimes take place every few inches in such a way that, if we consider the one to have been a sediment, we must say the same of the other.

The mica schist has probably been formed from an altered sediment such as clay, and the quartzite evidently represents sandstones. Those sediments we may imagine were from the decomposition of Archæan rocks, of which now no trace remains. This series of crystalline schists and quartzite continues westward to South-West Cape, and eastwards certainly as far as Louisa Bay, if not as far as the New River. But, taking the minimum width as 15 miles, and assuming that no large anticlinals exist, the least thickness of the beds must exceed 13,000ft., if the average dip is not less than 10 degrees.

QUARTZITE AT ROCKY CAPE.

A series of quartzites and quartz schists is exposed along the north-west coast of Tasmania, from Jacob's Boat Harbor west of Wynyard to Rocky Cape, which forms a promontory on the east side of the bay extending to Circular Head.

The Rocky Hills constitute a high range of quartzite which trends south or a little east of south to about a mile south of the main road, when it sinks rather abruptly and subsides in the geologically unknown country which extends south across the Arthur River towards the Heazlewood and Long Plain. Immediately west of the cape are contorted quartz schists, which apparently belong to the complex of schists and quartzites which are seen succeeding each other on this part of the coast.

The Rocky Cape quartzites resemble those of Cox's Bight, but that in itself gives no very decisive help in correlating them, except that we cannot match them in our known Silurian or Ordovician strata. Their strike, however, is east of north and dip north of west. There is some reason for doubting that they belong to our Palæozic series ; they have been looked upon as of Pre-Cambrian age.

The above have come under my notice since the last meeting of the Association. There are other occurrences in the island which most probably belong to the same system, but too little is known of them as yet to hazard any statement on the subject.

The conclusions in this paper are based mainly on lithological and analogical considerations, and it must be admitted lack the strength and certainty which can only be given by stratigraphical evidence, for the present, unfortunately, not attainable.

20.—NOTES ON CRUSH PHENOMENA IN THE CAMBRIAN ROCKS NEAR BLACKWOOD, SOUTH AUSTRALIA.

By H. BASEDOW and J. D. ILIFFE, B.Sc

[WITH PLATE.]

The following notes on crush phenomena in and surrounding the Cambrian conglomerate of the Sturt Valley are a brief resumé of a paper read by us before the Royal Society of South Australia in 1905,* references to which may be found in the Transactions and Proceedings of that society.

On the eastern side of the conglomerate certain siliceous and felspathic quartzites and clayslates occur in alternating bands of hard and soft rocks, varying in thickness from a fraction of an inch to a foot and more.

The fine-grained beds contain pseudo ripple marks and pseudo sun cracks, the latter being produced by fracture along lines crossing each other obliquely, the result of cross-folding on a small scale in beds of brittle rock. Examples may be noted in the first railway cutting east of the Metropolitan Brick Works.

Contortions in the beds adjacent to the conglomerate are very pronounced, and, in the case of overfolds in the harder rocks, have resulted in fracture; thus the first step in the production of false pebbles becomes evident.

Near to the eastern junction of the conglomerate the argillaceous rocks have been minutely puckered. The cataclastic phenomena of obliteration of bedding planes and laminæ is marked, acute angular wrinkles developing into thrusts along the middle limbs of the folds, giving rise to an unstratified mass closely resembling the matrix of the conglomerate. Illustrations of this occur about 100yds. west of the 10th milepost on the Hills railway line, and, neglecting a few crushed and fractured quartzitic bands, continue right up to the conglomerate, barely another 100yds. to the west.

In the same cuttings several of the quartzitic bands have been pinched out, lenticular masses resulting, one overlapping another. In the clayslates of Tapley's Hill, to the west and south of the conglomerate, bands of limestone occur, which thin out similarly, and are in parts brecciated. The separated fragments in parts show signs of rounding. The cleavage of these limestones does not agree with that of the enclosing slates. The phenomena is best seen in sections 27, 28, and 70, hundred of Noarlunga, The hard bands of quartzites in the railway cuttings to the east of the conglomerate have further broken up along planes oblique to the bedding, each fractured portion having slipped slightly along the plane of fracture, forming small step faults. This movement, combined with that which resulted in small cross folds, has produced false pebbles. Abundant examples occur in the railway cuttings. In several instances one and the same

* Vol. XXIX., pages 334 and 335. Vol. XXX., pages 233 and 343.

band of quartzite is in parts fractured, but still incoherently in contact, yet in parts consists of false pebbles of identical material, rounded and separated from one another. The major axes of these pebbles usually point in the same direction.

Another method of formation of cataclastic pebbles is illustrated in the section along the tributary of the River Sturt, at the eastern boundary of the conglomerate. Stretched bands of arenaceous rocks, in parts retaining their continuity, in parts dragged out into a series of lenticles, simulate a string of large pebbles. The eastern portions of the conglomerate itself contain many of these false pebbles. Strings of pebbles and large "floating" masses of quartzite can be seen in the 10th mile cutting and the one containing the tunnel close to the Metropolitan Brick Works. "Pebbles" occur in lines parallel to the cleavage, and with their longer axes in the same direction, and are composed of rock identical with that of the beds bordering on the conglomerate. They consist mainly of fine-grained quartzite covered by a brown mineral film with a chalcedonic lustre, and of decomposed felspathic grit or arkose, probably pegmatitic, both of which are conspicuous *in situ* in the adjacent beds.

Quartz veins have undergone like deformations by stress.

Similar phenomena can be traced in zones through the heart of the conglomerate in the Sturt Valley. The pebbles are mainly oblong-ovate in shape, often having their faces grooved by "slickensides," and frequently the matrix surrounding the pebbles shows in section "lines of flow," this characteristic being repeated to a microscopic scale. The pebbles have been sliced along parallel planes oblique to the cleavage of the matrix; these sheared planes have, however, no definite relationship to the planes of cleavage of the matrix.

Whatever may have been the origin of the conglomerate, whether original or secondary, or partly both, a careful consideration in the field of the phenomena above described will, no doubt, convince members of this association that cataclastic action has played its full part in the formation of "pebbles" in the conglomerate.

DESCRIPTION OF PLATE.

Fig. 1. Pinched out quartzite bands producing pebbles by small faults; railway cutting, Blackwood.

Fig. 2. False pebbles, railway cutting, Blackwood.

PHOTOGRAPHS OF ROCK SECTIONS SEEN IN RAILWAY CUTTING, BLACKWOOD.

Fig. 1.

Fig 2.

Section D.—BIOLOGY.

1.—CLIMATIC AND GEOLOGICAL INFLUENCE ON THE FLORA OF NEW SOUTH WALES.

By R. H. CAMBAGE, F.L.S.

[WITH MAP.]

Of the various influences which affect the growth of plants two of the most important are those of climate and geological formation. Irrespective of these, the questions of rainfall, aspect, moisture, and shelter operate largely in the regulation of plant life.

Dealing first with geological considerations, it is found that, broadly speaking, the rocks which produce distinct lines of cleavage in the flora may be divided into two classes, viz., igneous and sedimentary; although the floras produced on fine and coarse forms of each section sometimes show a marked divergence. Metamorphic schistose rocks seem to produce floras with affinities to those of sedimentary areas, rather than typical igneous formations. An instructive paper by A. G. Hamilton (5) gives the flora on the basalt of Mount Wilson and adjoining sandstone.

Among the igneous rocks, a gradation exists in the floras found on formations derived from fine basalts (basic) on the one hand to coarse granites (acid) on the other. A somewhat similar gradation occurs among sedimentary rocks, as exemplified by the changes between fine shales and coarse sandstones. The points at which the floras of igneous and sedimentary formations more nearly approach each other are between the coarse granites and the sandstones. Nor is this remarkable, seeing that the sandstone areas are merely redistributed disintegrated igneous rocks, and are in many instances composed of quartz derived from coarse granite, porphyry, &c. Should the granite contain a fair percentage of hornblende, ferro-magnesian silicates, as when biotite, &c., are present, the flora on such a formation departs from that of a sandstone area, and, provided moisture is present, becomes more luxuriant. An instance of this may be seen at Mount Dromedary, on the south coast, from which locality the rock has been examined by Mr. G. W. Card, A.R.S.M. (3). I recently drew attention (4) to the great similarity between the flora of an area of decomposed granite near the Wombeyan Caves and that of the Triassic sandstone around Sydney and on the Blue Mountains, the features being accounted for by the suggested common origin of both formations.

Many plants, however, will not sharply discriminate between geological formations, being probably affected by other factors, and the subject becomes difficult when an attempt is made to enumerate the species which it is thought may be confined to either an igneous or sedimentary area. Although plants may in some localities be confined to one class of geological formation, it does not follow that this selection is always due to the chemical constituents of the soil—though in a great many instances such is the case—but may be regulated by its physical features, such as adaptability to hold moisture, or otherwise. Other factors, including rainfall and aspect, may assist in governing the question of distribution in such cases. There are many plants which thrive on hillsides but cease as soon as the valley is reached, although the soil in the latter may be produced from the weathering of the adjacent hills. *Eucalyptus hæmastoma* Sm. (white or brittle gum) is one of these; and it seems remarkable that a large tree should prefer a rocky hill to an alluvial flat. Many plants, of course, which flourish on the flats do not occur on the surrounding hills, and the question of suitable drainage appears to be one of the factors in regulating these preferences. For these reasons, the chemical analysis of a soil may not of itself be sufficient to indicate what plants will be best nourished in the locality whence such soil is obtained.

T. W. Woodhead, F.L.S., (9) in writing on the Ecology of Woodland Plants in the neighborhood of Huddersfield, states:—"The present study indicates that, in this district, the physical properties of the soil and accompanying conditions play a more important part in determining the character of plant associations and the distribution of species than the chemical composition of the soil."

The flora of New South Wales may be divided for purposes of general study into four divisions, viz.:—The coastal area, the mountain area, the western slopes, and the interior. These divisions are illustrated on the accompanying map, and, although shown by fairly straight lines, the actual boundaries follow a most sinuous course, according to the contours of some of the mountain gorges and intervening elevations, which it is difficult to trace with exactness. The Great Dividing Range plays an important part in regulating the growth and distribution of the vegetation. The amount of moisture along the coastal area is greater than that of the interior, consequently the two floras are quite distinct, while a third may be found along the highest part of the mountains as the result of climatic influence. Owing to the great extent of sloping country on the west, a fourth flora is found connecting the interior with the mountains.

The mean annual rainfall of the coastal area south of Sydney is about 41in., while to the north of Sydney it approximates 51in., though these averages are exceeded at many points along the seashore. The average annual rainfall of the mountain area is about 34in., of the western slopes about 26-27in., and of the interior about 13-14in., with less than 10in. at Broken Hill.

The physiographic features of the State in relation to their influence on the flora may be briefly described as follows:—The main range forms a backbone, traversing from north to south at an average distance of about 80 miles from the coastline on the east, and some 500 miles from the central portion of the Darling River on the west. On the eastern, or coastal, area the geological formation over a fairly considerable extent is sedimentary, consisting in many places of sandstones and shales, the latter of which are somewhat readily removed by the action of water and ordinary weathering, and in this way effect the undermining of the sandstone with which they are interstratified, thus producing deep valleys and gorges among the mountains. Although the eastern rivers are short, and, in view of the height of their sources, consequently rapid, they have not yet succeeded in reducing much of their channels to base level, and the work of lateral corrasion referred to by Mr. E. C. Andrews, B.A., (1) is in many places only beginning. The result is that the coastal area, even where the rock is not sandstone, is full of well-sheltered valleys, subject to a good rainfall, and which are nestling under the steep eastern face of the dividing range.

On the western watershed the streams are very much longer, have a much more even grade, the lateral corrasion is considerable, deep sheltered valleys are practically absent, the descent from the mountains to the low land is gradual, producing an area referred to as the western slopes, and terminating in a vast tract of level plains.

It will thus be seen that the physiography of the country has a most important bearing upon the flora. With the eastern aspect in New South Wales a wealth of vegetation is produced, even in valleys among the sedimentary formations ; but where the soil is enriched from the decomposition of volcanic rocks—as in parts of the south and north coast—the vegetation can only be described as luxuriant. Plants which require an eastern aspect in New South Wales are practically altogether absent from the western fall. Instances have been noticed where coastal species have crossed to the western side of the main range, but are then restricted to the eastern side of the hills. Interesting observations may be made on hills in somewhat exposed situations, the flora on one side, even with the same geological formation, being quite different from that of the other, the regulating factor in such an instance being aspect.

The question of aspect, therefore, which is an important phase of climate, has a very great influence on the regulation of plant life, and, as previously stated, is dominated in New South Wales by the position of the main range.

THE COASTAL AREA.

For studying the effects of geological formation and climate, the area around Sydney and on the Blue Mountains to the westward is eminently suitable, though had the latter been 1,000ft. higher the influence of climate would be more pronounced. Here we have a tract of country for the most part covered with Hawkesbury sandstone of the Triassic period, and varying in altitude from sea-level to upwards of 3,600ft. A large proportion of plants are found to persist over a great part of this area without regard to the change of climate caused by the increased elevation ; but after the 3,000ft. level is reached, near Wentworth Falls, a falling off of the Sydney plants is noticed, and the dominating influence of climate is further exemplified by the advent of what, in eastern Australia, are known as cold region plants. The common grevilleas which grow about Sydney—such as *G. punicea* R. Br., *G. oleoides* Sieb., and *G. buxifolia* R. Br.—all disappear long before the

3,000ft. level is reached, and instead we find *G. laurifolia* Sieb., and *G. acanthifolia* A. Cunn., neither of which descends to the vicinity of Sydney.

Doryanthes excelsa, Correa (giant lily or gymea), though common on the sandstone north and south of Sydney, has never been noticed by me at an elevation of 2,500ft. The genus Melaleuca is well represented around Port Jackson, but rare on the higher parts of the Blue Mountains.

Leptospermum lævigatum, F. v. M., and *Westringia rosmariformis*, Sm., are abundant on the sandstone along the seashore, but their occurrence on the mountains is unknown to me. The distribution of these two plants, however, is probably regulated to a great extent by their love of coastal conditions.

Among those which are common above the 3,000ft. level, but, so far as I know, do not occur on the same formation around Port Jackson, the following may be mentioned :—*Boronia Deanei*, Maiden and Betche; *Eriostemon obovalis*, A. Cunn.; *Epacris reclinata*, A. Cunn.; *Mitrasacme serpillifolia*, R. Br.; *Persoonia mollis*, R. Br.: *P. myrtilloides*, Sieb.; *P. Chamæpithys*, A. Cunn.; and *Casuarina nana*, Sieb.

At the same time there are many coastal plants which flourish on the Blue Mountains. The beautiful flannel flower (*Actinotus Helianthi*, Labill), so common around Sydney, does not find the elevation of Mount Victoria at 3,400ft. too great, and is even found extending intermittently, though sparingly, down the western slopes to Wellington. The charming waratah (*Telopea speciosissima*, R. Br.,) is also as attractive near Bell and Clarence at 3,600ft. as when growing on similar sandstone around Sydney.

Of the genus Eucalyptus, the common bloodwood (*E. corymbosa*, Sm.,) continues on the sandstone from Sydney to Wentworth Falls, at about 3,000ft; but, though the geological formation remains exactly the same, this tree is unable to face the colder climate of higher altitudes. Its discrimination between sandstone and shale formations is a notable feature. *E. eximia*, Schauer, has a much more restricted range, extending only up to about 1,800ft. *E. resinifera*, Sm., the red or forest mahogany, continues up to about the 2,000ft. level. The latter species, however, is not altogether typical of the Hawkesbury sandstone formation, and favors soils of finer texture. The latter remark applies also to the three well known ironbarks, *E. paniculata*, Sm.; *E. siderophloia*, Benth.; and *E. crebra*, F. v. M. These three species all cease before the 1,500ft. level is reached, and seem quite unable to withstand the conditions of a cold climate. Of course, as they proceed northward to warmer latitudes, a higher elevation is attained. On the other hand, as southern latitudes are approached, these species gradually recede to lower levels, until they cease altogether; not one species of the true ironbark being found in Tasmania.

A tree which is of interest from its regard for geological formations is *Syncarpia laurifolia*, Ten., the well known turpentine, so extensively used for piles in salt water. The most southern representative of this species is some 12 or 15 miles north of Bateman's Bay, having been recorded by Mr. J. H. Maiden, F.L.S., many years ago. A geological examination of the locality, however, discloses the fact that the southern margin of this *Syncarpia* practically coincides with the southern edge of the great Permo-Carboniferous coal basin which extends roughly from the Clyde River northerly to the Hunter. The turpentine continues north of the Hunter, and may be found at intervals throughout the north coast of New South Wales, extending also into Queensland.

Now much of this northern formation is carboniferous, which, geologically, is slightly older than the Permo-Carboniferous, but which produces a flora somewhat similar. From the fossils which have been collected on the country immediately south of the turpentine area the formation appears to be Devonian—again older than the Carboniferous—and it undoubtedly looks as if the geological formation has had all to do with regulating the distribution of the species in this locality.

Coming up along the south coast we find, at Milton, a group of igneous rocks, including basalt and allied forms, and embracing an area of about 15 to 20 square miles (6). Surrounding this is the sedimentary formation of Permo-Carboniferous age, and it is remarkable how the turpentine approaches the margin of the igneous area and then stops abruptly. Some years ago I noticed an acre or so of sandstone, only slightly exposed, in a clear field near the centre of the igneous formation, and, on drawing the attention of a local resident to the fact, he at once pointed to a few turpentine trees about a quarter of a mile distant, and expressed the opinion that the rock under them was also sandstone, though none were visible. The incident demonstrated that the turpentine was regarded as typical of the sandy area in this district.

As an evidence of the important influence of geological formation on vegetation and the productiveness of the soil, it may here be noted that if these volcanic rocks had not been exposed in the locality the district known as Milton would not exist, but in its place would be an unbroken tract of uninviting sandstone country.

Just westward of Sydney the Hawkesbury sandstone is covered by the fine Wianamatta shale formation, which embraces a district with its boundary just outside of Parramatta, Richmond, Penrith, and Picton. Now, here again, we have a most interesting example of geological influence on plant life; for, on leaving the sandstone for the shale, we step practically from one flora to another. Some species are common to both formations, but numerically the sandstone is by far the richer, and the general facies of the two floras is quite dissimilar. Once more we find the *Syncarpia* vigilant in regard to any change in geological formation, but here it compromises slightly, and appears to thrive best where the sandstone has a thin coating of shale.

As the Wianamatta shales were originally deposited in a broad basin it can readily be seen that near their margin they become shallow. The result is that the turpentine in places extends some distance on to the shale, and to the casual observer may be regarded as typical of that formation; but an examination of this particular district discloses the fact that *Syncarpia laurifolia* forms a sort of fringe around it, and its progress is arrested by the increasing depth of the original basin, which places the influence of the sandstone beyond reach. It is of interest to note that the turpentine is not typical of the pure Hawkesbury sandstone, but flourishes best where the sandstone is mixed with the shale, or in the sandy gullies, and is probably affected by some condition of drainage or moisture.

A well known locality where the feature can be studied is at Springwood, on the Western Railway line. This is a point on the margin of the shales, which are shallow in consequence, but it would seem that had their denudation been completed, this locality would be without its turpentines, which at present contribute so much to the beauty of the local landscape.

Apart from geological considerations, *Syncarpia laurifolia* seems to be much restricted in its westerly course by climatic conditions, and in no instance is it able to reach the vicinity of the great dividing range, but, south of the Hunter, is usually confined to that part of the sheltered coastal belt below an altitude of about 2,000ft.

Eucalyptus hemipholia F. v. M., the common box of the Sydney district, exhibits exactly opposite geological tastes to *Syncarpia laurifolia*, for it is one of the commonest trees to be found growing on the deep Wianamatta shale, and is practically absent from the Hawkesbury sandstone. Some instances of its occurrence on this latter formation, however, have been noticed on the Macdonald River, a tributary of the Hawkesbury. In this locality the grouping of various species was found to be most unusual and puzzling. One example was that *Eucalyptus hemipholia* was found growing beside *Angophora lanceolata*, Cav., a so-called red gum of Port Jackson, on a formation which, from its horizon, could only be Hawkesbury sandstone. Now, *A. lanceolata* is never found on the deep shales, but in the Sydney district is restricted to the sandstone, and is therefore rarely associated with the box, except at the points of contact between the two formations. The occurrence of the unusual associations in the locality named was found on further examination to be due to the introduction of some volcanic soil, probably as the result of a local lava flow in Tertiary time, evidence of which was found on some basalt-capped hills near. The addition of a slight percentage of volcanic soil was sufficient to sustain the box trees, but not to prevent the growth of *Angophora lanceolata*.

A striking example of the regulating influence of geological formation on the flora in the same district is given by A. C. Barwick (2), where he points out that the small isolated basaltic areas are known as clears, in contrast to the much more dense growths on the surrounding sandstone. They are sometimes spoken of as box clears, owing to the quantity of *Eucalyptus hemipholia* growing thereon.

Although *Angophora lanceolata* is typical of the Hawkesbury sandstone around Sydney, it seems unable to withstand the cold of the Blue Mountains above an altitude of about 3,000ft., which provides another instance of the dominating influence of climate. As an equally interesting example of geological influence, it is pointed out that *A. lanceolata* crosses to the west of the main range through a low part of the Liverpool Range, and is flourishing on a somewhat similar sedimentary formation along the northern part of the western slopes; thus showing that the question of aspect is not of paramount importance to this species.

A. cordifolia, Cav., though common around Sydney, is not known to me on the higher parts of the mountains.

These examples have been selected to show that in the coastal area there are certain plants which favor particular geological formations, while the conditions of climate remain the same; but as the mountains are ascended, and the cold increases, the climatic influences become more important than the geological in deciding the limitations of these plants.

THE MOUNTAIN AREA.

The division described as the mountain area is practically that on both sides of the Great Dividing Range above an elevation of approximately 1,500ft. in the south to about 2,500ft. in the north, and ranging to upwards of 7,000ft. in the south and about 5,000ft. in the north.

This division includes some plants which do not occur in any other part of New South Wales, being restricted to the higher altitudes owing to their preference for cool conditions. It is interesting to trace the effects of climate over this area from south to north.

Eucalyptus coriacea, A. Cunn., the snow gum of Kosciusko, may be found in Tasmania in some cases practically at sea-level; but in coming northwards it gradually ascends till, in the latitude of Sydney, it is not found below an altitude of 2,500ft., while in northern New South Wales it rarely descends below 3,000ft. On the other hand, while it thrives at elevations of 5,000ft. in New South Wales, it is absent from the higher parts of Mount Wellington, in Tasmania, which reaches about 4,600ft., the climate, perhaps, owing to an unsuitable aspect, being too severe in a latitude so far south.

The above remarks apply in a measure to another white gum—*E. viminalis*, Labill; but this tree is not able to withstand such extreme cold as *E. coriacea*, and is found at lower levels in New South Wales.

E. amygdalina, Labill (peppermint, or messmate), occupies a position between the other two, and recollections of the pleasing effect of its scented foliage are always associated with visions of a cool, invigorating climate.

In the central part of the mountain division, near the upper portion of the Hunter River, there is a distinct break in the continuity of the cold country flora, which is due to the influence of climate. Reference has recently been made by T. Griffith Taylor, B.Sc. (8), to the temperature in this locality. Owing to the amount of denudation effected by the Hunter River and its tributaries, the country is here lower than in any other part of the Dividing Range, and some species do not continue into the valley, although the majority reappear on the opposite side. This intrusion of a western influence on the eastern watershed causes an unusual associating of plants, and increases the difficulty of correctly delineating the division boundaries.

The Upper Hunter provides one of the most interesting localities in New South Wales for studying the effects of climate on the general flora. It is, perhaps, assisted to some extent by the geological formation, much of which is the same on both sides of the main range, viz., Permo-Carboniferous. In other parts of the State the Great Dividing Range acts as a cold barrier in separating the eastern and western floras more particularly in the south. But in going northwards the cold of the elevated New England plateau is tempered by the increasing warmth of northern latitudes.

The important question of aspect is practically decided by the position of the main range. On its eastern side there is a combination of warmth, moisture, and shelter which stimulates the growth of brush or jungle. On the western side there is a reduced rainfall, less shelter and moisture, and a full exposure to the chilling and drying influence of westerly gales in winter or the scorching north-westerly winds of summer.

Apart from the typical eastern or western plants, those occurring on the mountain area—which might be regarded as neutral ground—often show a decided preference for aspect, of which the following are a few examples.

Eucalyptus coriacea, which extends throughout the entire length of the State, and is practically restricted to the top of the mountains, favors a westerly rather than an easterly aspect. It is growing around Goulburn at elevations as low as 2,500ft., but away from easterly influence. It is absent from Blackheath and Mount Victoria, where the altitude is 3,500ft.; but, owing to the gentle slope from these places towards the coast, the aspect may be regarded as more easterly than westerly. The species may be found to the north of Clarence, however, at about 20 miles northerly from Mount Victoria, and on the same Triassic sandstone, but with a westerly aspect, though still on the eastern watershed. It becomes common as soon as the western side of the mountains is reached, near Lithgow, being distributed over Permo-Carboniferous, Devonian, and granite formations, and extends to the top of the Canoblas, near Orange, at over 4,000ft., where it is subject to the full effect of westerly influence. Although it occurs on Hawkesbury sandstone north of Clarence, it is not typical of such formation, and on the borderland of a westerly and easterly influence, such as around Mount Victoria, *E. coriacea* would probably be found, if the formation were granitic, not excessively acid.

Another eucalyptus found along the main divide is *E. dives*, Schauer (peppermint), and this also prefers a westerly aspect, though it shows rather more partiality for sedimentary formation than *E. coriacea* does. Although absent from Blackheath it may be found near Mount Victoria, at Fairy Dell, and from this point westward becomes common until the western slopes are reached just beyond Orange. This species does not, so far as I am aware, cross to the northern side of the Hunter Valley, and its absence from the New England plateau suggests that it may possibly be newer than the valley itself. On the other hand, species which are on both sides might therefore be regarded as older; but the whole question requires special investigation. *E. dives* is not the only species which seems unable to cross this warm valley.

E. piperita, Sm. (Sydney peppermint) is often found in the mountain division, but undoubtedly favors an easterly aspect. It continues from Port Jackson up to Mount Victoria and Clarence, at an altitude of 3,COCft., but ceases when a decided westerly influence is encountered, and prefers a sedimentary rather than an igneous formation.

E. amygdalina, though a typical cold country tree, seems to favor an easterly rather than a westerly aspect.

It is interesting to note the number of Tasmanian species—several of them eucalypts—which are found on the elevated parts of New South Wales, the greatest quantity occurring on Mount Kosciusko, as recorded by Mr. J. H. Maiden (7).

The fact of so many cold region plants being met with in crossing the mountains affords a striking object lesson in the dominating influence of climate. Here we pass through a zone of vegetation quite a thousand miles long; but, although commencing at sea-level at the southern end, gradually ascends, owing to the increasing warmth of northern latitudes, until its minimum elevation at the northern extremity is about 3,000ft.

THE WESTERN SLOPES.

The area described as the western slopes forms a gradation from the mountains to the plains, and has a less rainfall than either the coastal or mountain division. Its eastern margin practically coincides with that of *Eucalyptus albens*, Mig. (white or grey box), and nowhere in New South Wales is any particular zone of temperature better defined by the vegetation over such a distance than along the eastern edge of these white box trees. This species seems to slightly prefer an igneous to a sedimentary formation, but may be found on both, and is usually looked upon as an indication of good wheat-producing country. Its distribution throughout the length of the State affords an excellent illustration of the gradual change of climate from south to north. In the south it is seldom found above an elevation of 1,500ft., but in the north it often ascends to upwards of 2,500ft., and in places reaches 3,000ft.

The flora which properly belongs to the western slopes provides one of the best possible examples of how plants which are amenable to climate will seek out suitable zones of temperature. In the south these plants keep well down on the western foothills of the main range, but in their northerly progress every advantage is taken of the increasing warmth of northern latitudes until, near the border of the State, some manage to ascend to the low parts of the mountain tops and over to the eastern watershed on the Upper Clarence.

Where the hills are lowest along the main range, near the central part previously alluded to, the flora from the western slopes simply swarms over on to the Upper Hunter in conformity with the temperature; but the western plants gradually diminish in numbers as the valley is descended and eastern influence encountered, though even so far down as Singleton such trees as *Eucalyptus rostrata*, Schl. (Murray red gum), and *Casuarina Luehmanni*, R. T. Baker (bull oak), may be found, both of which extend to South Australia.

On the western slopes much of the country is of an open forest character, particularly where the formation is composed of igneous rocks, the sedimentary areas being numerically richer in species.

Eucalyptus macrorrhyncha, F. v. M., the common stringybark of the western slopes, shows a distinct preference for the sedimentary areas, generally occupying the ridges, and never descending so far as the alluvial flats. It shows a marked aversion for the soil upon which *E. albens* grows, and the latter exhibits equal disdain for the company of the stringybark.

Another tree which prefers a sedimentary formation is *E. sideroxylon*, A. Cunn., the mugga or ironbark of the western slopes and interior, though it may sometimes be seen growing on decomposed granite formation.

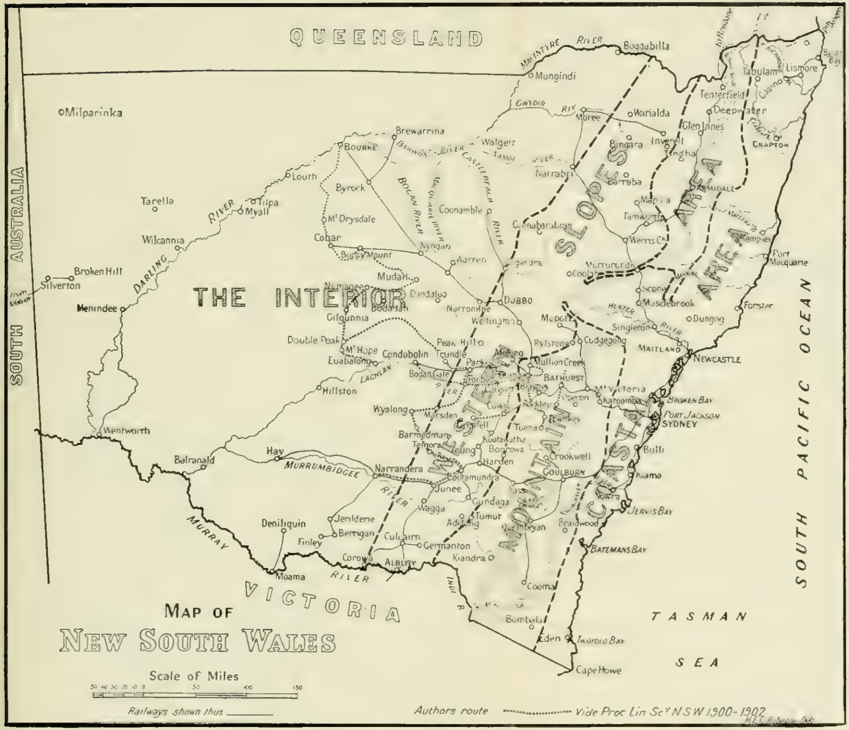
THE INTERIOR.

This division embraces all the western part of the State beyond the western slopes, and similar country extends into South Australia, Queensland, and the north-west corner of Victoria. The flora of this area is decided chiefly by climate and rainfall, with important internal divisions according to changes of soil. Owing to the low rainfall and high temperature the conditions are dry and hot, and, in contrasting the flora of this division with that of cool Tasmania, it may be mentioned that not a single species of eucalyptus found in the interior is recorded for Tasmania, where neither a true ironbark nor a box tree is found.

The vegetation of the interior is more stunted than in other parts of the State. A eucalypt 100ft. high is here regarded as a very tall tree, the average not exceeding 50ft. or 60ft., with a gradual diminution in height as the far west is approached. Over much of the central part, say around Bourke and Cobar, the forests do not average more than 50ft. high.

As climatic conditions, rainfall, and aspect are similar over a great part of this division, the various changes in the flora may be regarded as due to variations in the geological formation, or to the difference between rocky and alluvial situations; and some of these changes are very marked. The hills are generally only a few hundred feet high, some of them being composed of porphyry or granite, while the sedimentary ridges are either of sandstone or Silurian slate. Stretching for many miles from the foot of these hills are almost level tracts of deep friable soil, fine in texture, often reddish in color, and made up for the most part from the weathering of the surrounding elevations. This class of soil extends until it meets the river country, or what is generally known as the black soil plains. The black soil is of a close, sticky nature, and has apparently been spread over a vast area of the western country in geologically recent time. Some of its properties are similar to those of soils in mountain valleys which have been filled from the weathering of basaltic hills, and it seems probable that the black soil plains represent areas over which material from basaltic country has been deposited. Rivers which drain granite or sandstone hills produce alluvial flats with a loose soil, altogether different from that derived from basalt, and having a distinct flora.

Taking the genus acacia, which is very common in the interior, it is interesting to note how very partial some of the species are in regard to their selection of soils, and in this way serve as admirable indicators of the quality of the land. *A. pendula*, A. Cunn., (myall or boree), is always an indication of the black soil, its occurrence on a



MAP OF NEW SOUTH WALES

hillside of granite or sandstone formation seeming an absolute impossibility. No picture of a black soil plain seems complete without a few myall trees or old stumps. *A. aneura*, F. v. M. (mulga), belongs to the red soil area, and practically never associates with *A. pendula*, while *A. doratoxylon*, A. Cunn., (currawong) selects the very tops of hills, with a preference for sedimentary formation.

Hills of sedimentary origin in the interior are much richer in species numerically than the porphyry hills, though only separated by a few miles. Two in particular have been noted about four miles apart, viz. :—Mount Allen and Double Peak, the former being composed of porphyry and having a sparse flora, while the latter is made up of Silurian slate and thickly covered with vegetation. It was moreover noticed that *Casuarina stricta*, Ait. (sheoak), was plentiful on the former but absent from the latter, while *Acacia doratoxylon* was abundant on the latter but not represented on the former.

My conclusions are that an ecological study of the distribution of the New South Wales flora goes to show that the changes in geological formation have a very marked effect upon the production and grouping of the forests, and a transit from one class of soil to another is invariably followed by a considerable change in the vegetation. In ascending to the highest altitudes, however, the growth of plants is further regulated by the influence of climate, though still in conformity with the geological formation. In addition to these factors the further distribution is to a great extent governed by the consideration of aspect, whether east or west, and this important point is decided by the position of the Great Dividing Range which passes through the eastern part of the State in a northerly and southerly direction.

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2.—A RECORD OF THE GEOGRAPHICAL DISTRIBUTION OF THE BIRDS OF THE BANDA ISLANDS OF THE ORDERS PASSERES, PICARIÆ, PSITTACI, AND COLUMBÆ.

By J. R. McCLYMONT.

[Based chiefly on the collections made by Dr. Wallace and by the scientific staff of H.M.S. *Challenger*.—Ed.]

3.—ON THE STRUCTURE OF THE LEAF OF *BANKSIA SERRATA*.

By A. G. HAMILTON.

[With Four Plates.]

Among the many adaptations for preventing excessive transpiration from leaves, none is so remarkable as the placing the stomates in small cavities or crypts in the under surface of the leaf, these cavities being lined with hairs springing from the interstomatal epidermis.

One of the best known examples of this is *Nerium oleander*; but in the genus *Banksia* there are many species which possess this particular adaptation. All the flat-leaved species of this genus that I know have these peculiar cavities, and they are also found in the genus *Dryandra*. Some of the species of *Ficus* (*e.g.*, *F. rubiginosa* and *F. macrophylla*) have the same structures, but in a much less perfect condition.

Banksia serrata has flat leaves, the margin coarsely serrate, and the edge considerably thickened. The upper surface is hairless; the lower shows numerous small white dots about ·1mm. in diameter and ·1mm. apart, each dot being in the centre of a little square or rounded space, surrounded by the veinlets. These white dots are little bundles of hairs projecting out of the crypts (Plate II.).

The secondary veins run from the midrib to the margin, and are practically parallel; they are from 2mm. to 4mm. apart. Between each pair is a smaller vein, which runs only half-way to the margin, and then divides and is lost in the network of veins filling up the space between the secondary veins. The secondaries fork at the tip, each branch joining those from the veins on either side (Plates II. and III).

In texture, the leaf is hard and rather brittle, and the thickened margin adds to the strength and stiffness of the blade.

The young leaves are soft, but are protected from heat and drying winds by a thick coating of long, straight, rusty or fawn-colored hairs (Plate I., figs. 1 and 2). These are shed as the leaf matures. The hairs are shortly articulated and very thick walled, the cavity being very narrow and usually filled with air, although at times there are brown contents. Sometimes they are irregularly constricted (Plate I., fig. 2). On the midrib and margin there are hairs of the same character, but shorter, and twisted like corkscrews (Plate I,. fig. 3), and the midrib also bears a few very long straight hairs—quite three times as long as the ordinary straight ones.

The purpose of this thick coating is evidently protection of the tender leaf against dry conditions. The young leaf, when about 15mm. in length, shows no palisade or spongy tissue : it consists of undifferentiated cells, except that one layer of epidermis is developed and the inner layer just indicated. The vessels, except the midrib, are not formed, and there is no sign of the crypts and stomates.

When the palisade and spongy layers are fully developed, and the crypts and stomates complete, the thick-walled hairs drop off.

The Mature Leaf.—The upper epidermis consists of two, or sometimes three, layers. The outer wall or cuticle is extremely thick. In the just matured leaves there are oxalate of lime crystals in the cells of the outer row, and the cells of the inner row are filled with protoplasm. Later on the crystals and protoplasm disappear. The epidermis on the lower face of the leaf is in a single layer, the cells being thick walled, and usually filled with a tannin giving a blue-black reaction with iron salts.

The veins, instead of being round in section, as in ordinary leaves, extend from the upper to the lower epidermis in flat walls, like bulkheads, and divide the mesophyll into small compartments. They are characterised by a great development of the sclerenchyma. The vascular bundles run along at the junction of palisade and spongy tissues, and the sclerenchyma extends in a flat plate composed of two rows of fibres from the upper epidermis to the vascular bundle, and again below the latter to the lower epidermis. The thickening of the walls is very marked, the lumen being almost obliterated.

The vascular bundle proper is remarkable for the number of the pitted vessels, which are recognised as the water-carrying element. The predominance of sclerenchymatous tissue gives great strength and firmness to the leaf. In addition, as already mentioned, the wall-like shape of the bundles effectually partitions off the mesophyll into separate chambers.

Each of these compartments has in the centre a balloon-shaped cavity —the crypt (Plate I., fig. 4). This is bounded on the top and on the sides down to the widest part with palisade cells. Below this is the spongy tissue, which consists of a network of slender cells with wide intercellular spaces. Round the neck and mouth of the crypt there is more of the palisade tissue, shorter in the individual cells than in the upper layer. The chlorophyll granules of the mesophyll are large, and there are usually large starch grains present also. The palisade cells give a strong tannin reaction with iron salts, while the spongy tissue shows only slight coloration.

The crypt itself is lined with large broadly elliptical stomates (Plate I., fig. 5), which color very deeply with any of the protoplasmic stains. From the spaces between the stomates arise very peculiar hairs. These are club-shaped and thick walled, and have long curly cilia growing from the tip (Plate I., fig. 6). They generally contain cell sap which colors very faintly with the majority of stains.

The whole structure of the leaf is admirably adapted to lessen transpiration in dry weather. The thick cuticle on the upper side is impermeable by water or vapor. The stomates are doubly protected—first by their position in the cavities, and second by the plug of hairs which fills the cavity and closes its mouth.

But the same adaptations are equally useful to the plant in wet weather. The projecting tufts of hairs on the under side prevent water spreading over the under surface and making its way into the crypts, and so the stomates are not choked with water and prevented from fulfilling their function of exhaling the superabundant moisture which the plant takes up in wet weather, and which it is necessary should be got rid of as speedily as possible. An illustration of this action of the hairs may easily be seen if a leaf is dipped in water. The upper surface is wetted and shows a thin film of water all over it. But the under surface remains dry, the water gathering into drops and falling off as if the leaf were greasy.

EXPLANATION OF PLATES.

Plate I.—Figs. 1 and 2. Hairs from surface of young leaf.
Fig. 3. Hair from midrib of young leaf.
Fig. 4. Diagrammatic section of leaf.
Fig. 5. Outline of stomate.
Fig. 6. Hairs from interior of crypt.

Plate II.—Photograph of under surface of leaf, showing tufts of hairs projecting from crypts × 10.

Plate III.—Nature print of leaf showing venation.

Plate IV.—Section of leaf, × 100; *s*, stomates seen in section; *h*, hairs of crypts.

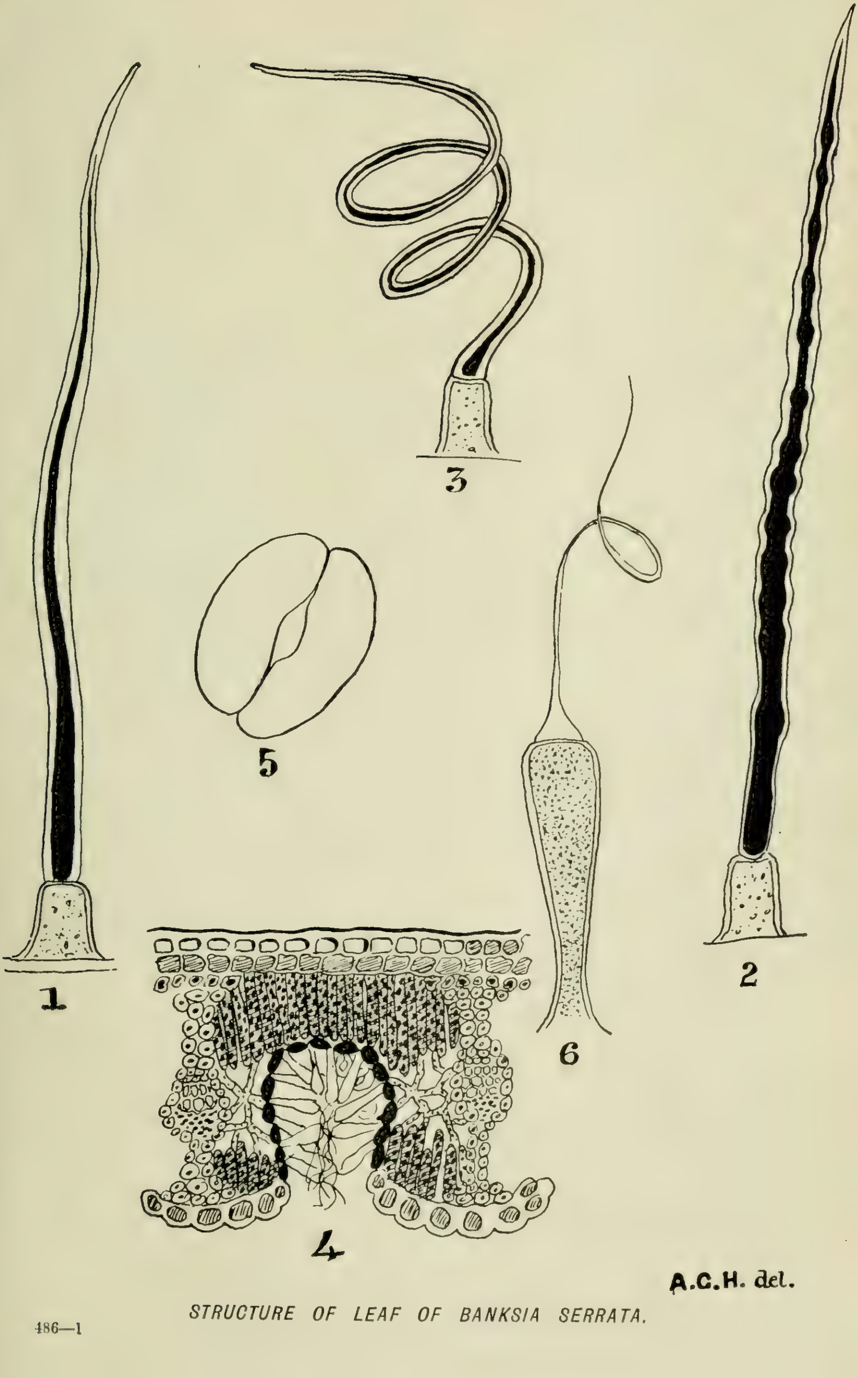
4.—A PRELIMINARY NOTE ON HETEROPHYLLY IN *PARSONSIA*.

By L. COCKAYNE, Ph.D., Cor., F.B.S., Ed.

[WITH PLATE.]

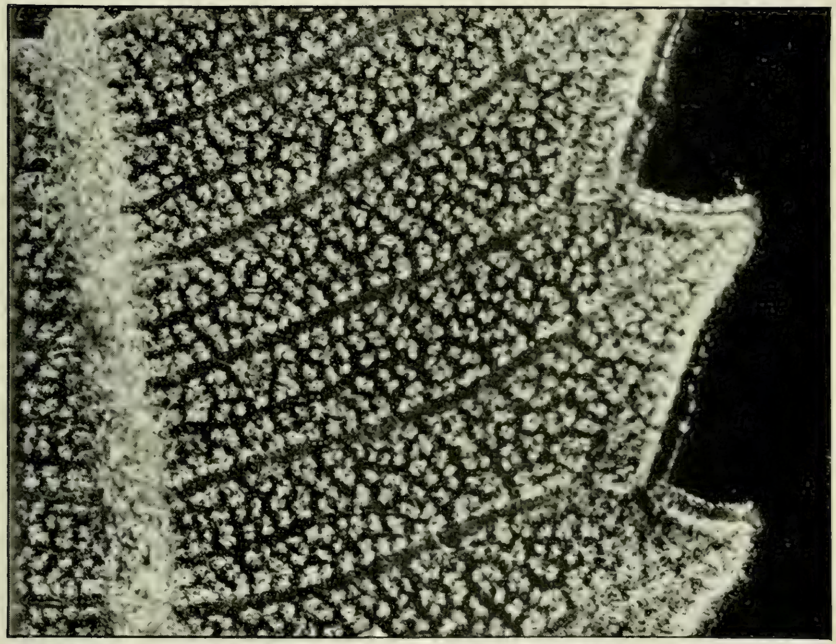
Parsonsia is a small genus of lianes containing some 33 species, found in tropical Asia, the Malay Archipelago, New Guinea, New Caledonia, Australia, and New Zealand; in fact the distribution is exactly in accord with the generally accepted theory of a former land extension of New Zealand northwards. The headquarters of distribution is New Caledonia, which contains 23 species. Australia is also fairly rich with four or five, while New Zealand has two, or perhaps three.

If a number of seedlings of the most common New Zealand species, *Parsonsia heterophylla*, be examined for the first time the number of leaf-forms are quite bewildering, and it looks apparently impossible to find any regular sequence of development. But a closer examination shows this not to be the case, and that there is a definite process of development and change. This complexity arises from the fact that there are two distinct types of leaf—a primary short broad leaf and a



A.C.H. del.

STRUCTURE OF LEAF OF BANKSIA SERRATA.



UNDER SURFACE OF LEAF OF BANKSIA SERRATA.

NATURE PRINT OF LEAF OF BANKSIA SERRATA.

SECTION OF LEAF OF BANKSIA SERRATA.

secondary long and narrow one. Between these two there are all kinds of intermediates (see figs. 1, 2, 15, 11, 21), and, moreover, "reversion shoots" freely occur, thus bringing primary leaves quite out of their proper place in the sequence.

The leaves which succeed the cotyledons are certainly variable in size and shape, but they are always of what may be called the short, broad type (see figs. 13, 14, 19, 20). Sometimes they are quite small and almost circular, at other times various varieties of oblong predominate. The next phase of development is an increase in length and narrowing of the base of the lamina (see figs. 5 and 6), so that in the most extreme cases a well-marked spathulate leaf is the result (see figs. 21 and 11). Then the circular leaf apex of this latter is lost, and the second leaf form, a long and narrow leaf, comes into being (see figs. 3, 4, and 24). This second stage persists for some considerable time, *i.e.*, there is a prolonged juvenile form; but sooner or later, when, by the twining of the ever lengthening stem round its support, the brighter light is gained, the adult and third form appears, the leaves large and broad and of a more or less oblong character (see fig. 25). These adult leaves vary a good deal in different individuals and in various localities, but they are of one type and are quite distinct from those of the two juvenile stages.

Parsonsia capsularis, to which all the remaining forms of *Parsonsia* in New Zealand have been hitherto referred, commences its development in exactly the same manner as *P. heterophylla*, so that in their early stages the two species are quite indistinguishable. There is the early circular leaf, the narrowing of the base of the lamina, the spathulate leaves, and the long, narrow leaf; but at this stage, in one very distinct form of *P. capsularis*, further development always stops, and the adult leaf in this case is identical with that of the second stage of *P. heteropyllah*, *i.e.*, *the adult of the one species is merely a fixed juvenile form of the other.* But this is not so for all forms of *P. capsularis*, since the adult of some proceed further and resemble rather narrow-leaved adult forms of *P. heterophylla*. This matter, too, is complicated by the fact that it is almost certain that natural hybrids between the two species are not uncommon. All the same, one particular form, unnamed as yet, which occurs chiefly as a liane in dry mountain stations of the south island of New Zealand, never assumes a special adult form, but is merely, so far as its leaves go, a fixed juvenile form of *P. heterophylla*. This also opens up the question of specific rank, and it seems to me abundantly clear *that any plant, such as this, with a peculiar life history of its own, must be considered a distinct species.*

So much for the New Zealand species. Now comes the question, how do the species of *Parsonsia* without New Zealand behave as to leaf-changes? Evidently, from their distribution, the species should be closely related and should be descended from some common ancestor. In order to throw some light on this most important matter I applied for information and specimens to my esteemed correspondent, Mr. H. J. Maiden, Director of the Sydney Botanic Garden; to Mr. R. T. Baker, of the Sydney Technological Museum; to my friend Dr. L. Diels, of the Royal Botanical Museum of Berlin; to Mr. H. N. Ridley, Director of the Singapore Botanical Gardens; to Dr. M. Treub, of Buitenzorg; and to the Forestry Department of the Philippines. Without going into details, it seems clear that the Asiatic and Australian species exhibit no heterophylly such as the genus does in New Zealand, while as to the New Caledonian species nothing has been said of their leaf variation; but, as Diels writes to me, the specimens of these at Berlin "are not large enough for a definite opinion to be expressed." If this is a fact that the extra-New Zealand species show no marked heterophylly, then there seems, so far as New Zealand is concerned, to be a crucial case in *Parsonsia*, for in one small region there is a genus behaving, so far as its life history is concerned, differently altogether to what it does in the rest of its area of distribution. And this, taken in conjunction with the fact that about 200 species of New Zealand plants, *i.e.*, some 12 per cent. of the spermophytes, belonging to most diverse genera and natural orders, exhibit heterophylly of a more or less striking character in their life-histories, seems to distinctly point to there being some reason in New Zealand itself for this special phenomenon; and this reason, it seems to me, must be sought for in the manifold changes which the geological history of the New Zealand archipelago has brought about. This explanation (1) was first given by Dr. L. Diels regarding the occurrence of extreme xerophytic structure in New Zealand, and since that time evidence in other directions has come forward to support his bold and splendidly conceived theory. (2)

As for the special case of the *Parsonsia* species, it seems possible that the various leaf forms are epharmonic adaptations evoked by ancient environments, and that the species, like those alluded to above, are not fixed as yet, but remain eminently "plastic." Nothing can be clearer, too, than that lianes, all the world over, are ligneous or herbaceous plants, which have gradually adopted the climbing habit through forest conditions. In the case of *Parsonsia*, too, the primary small orbicular leaves put one in mind of those small-leaved shrubs (*Coprosma* species, &c.), so common in xerophytic stations in New Zealand at the present time.

Also, there are several examples amongst New Zealand plants where the same genus furnishes both shrubs, lianes, and even herbs. Thus the genus *Senecio* is made up of shrubs, one low forest tree, various herbs, and the climbing *S. sciadophilus*. There is the herbaceous *Angelica gingidium* and the climbing *A. geniculata*. But more striking are the fuchsias, where there is the forest tree, *Fuchsia excorticata*, and the closely-allied *F. Colensoi*, which is a shrub pure and simple in the open, but in the forest occasionally a scrambling liane. Finally the third species of *Fuchsia*, *F. procumbens*, is a coastal liane of Northern New Zealand, climbing near the upper strand over tall sedges and the like.

The long narrow leaves would be explained in a similar manner, they being the early climbing leaves after the liane habit had been

(1) Vegetations-Biologie.—von Neuseeland, Eng., Bot., Jahob., XXII., B. 2 Heft., 1896, pp. 246–247.

(2) Cockayne, L.—Various papers in Trans. N.Z., Inst., especially from vol. XXXIII., 1901, to vol. XXXIX., 1907.

Heterophylly in Parsonsia.

evolved, but which would be a different shape to the final leaves owing to the different light relation, a common occurrence amongst lianes, and seen in New Zealand in *Rhipogonum scandens* (Liliaceæ), *Lomaria heterophylla* (Filices), *Metrosideros scandens* (Myrtaceæ), *Rubus schmidelioides* (Rosaceæ), &c. So far as plasticity goes, *Parsonsia* does not seem particularly sensitive to stimuli. Injury, to be sure, will at once cause the formation of juvenile shoots, and these frequently appear, too, without any apparent cause from the bare, rope-like stem, or even from amongst the upper adult foliage. But with a seedling plant of *Parsonsia capsularis*, var. *rosea*, which I placed for some time in a moist chamber, no changes of any kind took place, and development proceeded normally. More experiments, however, are needed before any definite conclusions can be arrived at as to the determining causes of leaf form in these remarkable plants. One matter of considerable interest, and the solution of which should be possible, is the curious natural variegation which so many early stages of the seedlings show, while in others it is altogether absent. Indeed, there is still nearly everything left for investigation regarding this striking heterophylly; and, in the first place, I would urge Australian botanists to study the seedling forms (3) of the Australian species—a matter of great moment with regard to this inquiry—for it certainly seems an astonishing fact, if it be a fact, that species so outwardly alike as the Australian and New Zealand should have absolutely different life histories.

EXPLANATION OF FIGURES ON PLATE.

Outlines of leaves of *Parsonsia heterophylla*, at various stages of development, traced from nature-prints; 8, 9, 13, 19, 20, leaves of the short round type; 3, 4, 12, 24, leaves of the long narrow type, 24 being almost identical with the adult of one form of *P. capsularis*; 6, 5, early leaves, becoming narrowed at the base; 1, 2, 15, 7, 10, 16, 17, 21, various transitional leaves between the first and second types; 25, adult leaf of *P. heterophylla*; 22, 23, narrow leaves of *P. heterophylla* given off from adult shoots, but reverting to an earlier stage, and resembling the adult of some forms of *P. capsularis*, var. *rosea*.

5.—REMARKS ON THE ANATOMY OF SOME AUSTRALIAN FROGS.

By GEORGINA SWEET, D.Sc. (Melbourne).

6.—NEW STIMULUS AND INHIBITIONS IN PHAGOCYTOSIS, WITH THEIR ACTUAL VALUE.

By Dr. D. MACDONALD.

(3) Mr. R. T. Baker very kindly sent me seeds of *Parsonsia*, but unfortunately they did not germinate.

7.—ON SOME RECENT ADVANCES IN OUR KNOWLEDGE OF THE SALTS OF PROTEINS AND OF THEIR ROLE IN BIOLOGICAL PHENOMENA.

By T. BRAILSFORD ROBERTSON, B.Sc., Instructor in Physiology in the University of California.

It is a fact which has for some time been familiar to physical chemists that the activities of many chemical reagents are functions of their degree of dissociation or ionisation; thus the electric conductivity of a solution of an acid, the depression of the freezing point of the solvent which produced by it, its tendency to displace other acids from the bases with which they are combined, and the acceleration of the hydrolysis of cane sugar or of methyl acetate which it can bring about are all intimately connected with the degree to which the acid is dissociated into ions.

The first clear indication of the importance of electrolytic dissociation in biological phenomena was afforded by the experiments of Dreser (1), who, in 1893, showed that the greater the concentration of free mercury ions in a solution of a salt of mercury the more toxic is the solution for yeast cells; and, moreover, that the formation of complexions containing mercury diminished the toxicity of the solution. Thus a solution of potassium mercury thiosulphate contains but little mercury in the form of mercury ions, for the mercury combines with two SO_3 groups to form complex ions which no longer possess the characteristic properties of free mercury ions. Such a solution is but slightly toxic for yeast cells, but a solution of another salt of mercury, such as the sulphocyanate, containing precisely the same percentage of mercury as the solution of potassium mercury thiosulphate, is highly toxic, for in this solution the mercury exists in the form of free mercury ions.

These experiments of Dreser's were followed in 1895 by those of Klem (2), who found the actions of different strong acids in disintegrating the protoplasm of cells were identical, and he attributed the disintegration to the hydrogen ions of the acids.

In 1896 the papers of Kahlenberg and True (3), and of Heald (4), appeared, in which they described extensive experiments showing that equivalent concentrations of strong acids, and also, in Heald's investigations, equivalent concentrations of different salts of copper were equally poisonous for plants. In 1896, also. Paul and Krönig (5), showed that, in general, the more highly ionised a salt is—such as salt of copper or mercury—the more powerful is its toxicity for bacteria, and, therefore, the more intense is its action as a disinfectant.

In 1897 Loeb (6) showed that the amount of water taken up by a frog's muscles, excised and immersed in solutions of strong inorganic acids, was dependent upon the hydrogen ion of the acids, since equal quantities of the hydrogen ion in a given volume of these acids produced quantitively equal effects. In the same way the absorption of water by muscles placed in solutions of strong inorganic bases could be referred to the hydroxyl ion of the bases.

Subsequent investigations by Maillard (7) on the toxicity of solutions of copper sulphate to which sulphates of the alkalies has been added; by Eckardt (8), on the relation of the velocity of diffusion to toxicity; by Schuerlen and Spiro (9), Spiro and Bruns (10), Roemer (11), and Bial (12), on the action of antiseptics; by Höber and Kiesow (13), Kastle (14), and Kahlenberg (15), on the taste of dissolved electrolytes; and by Loeb (16), on the absorption of water by muscles, placed the importance of electrolytic dissociation in life phenomena among the established facts of biological science.

This role of electrolytic dissociation in life phenomena suggested that the action of electrolytes upon living tissues was to be attributed to their ions. The fact, however, that in the case of non-electrolytes, and, probably, also in the case of some electrolytes (17), the undissociated molecules of dissolved substances may unquestionably affect living tissues, suggested a chemical rather than a physical explanation; and in 1899 Loeb (18) suggested that the ions of an electrolyte diffusing into a living tissue combined with, or altered chemically, some constituent of the tissue. He based his arguments in the first place upon the different properties exhibited by a tissue when placed in solutions of different electrolytes. This dependency of the properties of an organism or of a tissue upon the nature of the ions diffusing into it is very well illustrated by the absorption of water by muscles in different solutions which, as Loeb showed (16), presents marked analogies to the absorption of water by the different soaps of the alkalies and alkaline earths. Further illustrations were, at the time, afforded by the experiments of Biedermann (19), Ringer (20), Howell and Cooke (21), Locke (22), and Loeb (23), on the influence of electrolytes upon the nature and duration of the contractions of contractile tissues placed in solutions of various electrolytes. More recently, however, the manifold instances of control by chemical agencies of life phenomena, such as muscular irritability (23a), parthenogenesis (24), regeneration (24a), hybridisation (25), maturation (26), heliotropism (27), galvanotropism (27a), etc., have multiplied enormously our examples of the dependency of the properties of a tissue upon the nature of the substance diffusing into it. This change of properties in different solutions is precisely what we should expect were different chemical compounds formed in the tissues when placed in the various solutions. In the second place, Loeb based his argument for the existence of definite compounds between some constituent of a tissue and the ions of an electrolyte diffusing into it upon the definite reactions called forth from a tissue by definite ions, examples of which are afforded by the unique position of the salts of the heavy metals in regard to toxicity, and the almost equally unique position of the salts of the alkaline earths in regard to protoplasmic irritability and secretion (28). In a subsequent paper, in February, 1900 (29), Loeb reiterated his conclusion that the ions of an electrolyte on entering a tissue combined with some constituent of the tissue, presumably proteid, and he conferred upon these compounds the name "ion-proteids." Independently, and almost simultaneously, Paull (30) arrived at identical conclusions, and also gave the name "ion-proteids" to the compounds formed; while T. W. Richards (31), also in February, 1900, pointed out that some of the phenomena of taste could best be accounted for by supposing that the ions of the electrolytes entered into combination with some constituent of the tissues affected.

Granted, therefore, the existence of these ion-proteid compounds, in endeavoring to utilise them as a means of furthering our acquaintance with the intimate processes underlying life phenomena, it is of prime importance to try and obtain some idea as to their actual nature, and, in the first place, to inquire whether the reactions towards electrolytes of the living tissues themselves afford us any clue to the physico-chemical nature of the ion-proteid compounds.

First, as regards the question of equilibrium, it is evident, from the preceding discussion of the experimental basis of the ion-proteid theory, that the ions introduced into the complex from the surrounding solution must frequently be readily replaceable, the one by another. Thus if we place the jellyfish *Polyorchis* in a mixture of 50cc. of three-eighths molecular sodium chloride, plus 5cc. of three-eighths molecular magnesium chloride, rythmic contractions of the swimming-bell will occur; but if we now add 5cc. of three-eighths molecular calcium chloride the beats will at once stop (32). The active peristalsis of the intestine produced in rabbits by the intravenous injection of a minimal dose of sodium citrate, fluoride, sulphate, tartrate, oxalate, or phosphate can be almost entirely suppressed by the subsequent injection of an equal quantity of eighth molecular calcium chloride solution (33). If an electric current is led through a medium containing paramoecium, and the medium is such that they swim towards the anode, the movement towards the anode may be immediately abolished, or even reversed and converted into a movement towards the cathode, by the addition of a small amount of calcium chloride (34); or, to carry our illustrations even further, the crustacean *Cyclops*, which is indifferent to light, can be rendered positively heliotropic by the addition to the medium in which it is swimming of a small quantity of CO_2; these in turn can be rendered indifferent in even negatively heliotropic by the addition of NaOH, and we may repeat the process as often as we please (35). Instances of properties manifested by tissues in various solutions which are modified, abolished, or reversed by the addition to the solution of another chemical substance might be multiplied almost indefinitely. Attributing the properties exhibited by tissues in these solutions to the various ion-proteid compounds formed—when, for example, a tissue exhibits a certain property in a solution of magnesium chloride, which property is abolished or reversed by the addition to the solution of calcium chloride—it is an obvious probability that the magnesium proteid formed in the first instance has been partly or wholly converted into calcium proteid by the addition of calcium chloride. That the chlorine ions may also play an important part in bringing about the result does not affect our argument. In other words, the ions in combination with the proteids of the cells are often readily substitutable one for another, so that as in most chemical reactions, the mass of the reacting substances plays a part. If chiefly magnesium salts are present the greater part of the ion-proteid formed will be magnesium proteid; if calcium salts are now added they will displace the magnesium and combine with some or all of the proteid, according to the mass of calcium chloride which is added.

The salts of the heavy metals, such as zinc, lead, silver, etc., stand, however, in a somewhat different relation towards proteids. When added to a solution of proteid they usually form insoluble compounds with it. When applied to tissues they usually cause irreversible changes in it, changes which culminate in death. Possibly this is because they cannot be replaced from their combination with proteins, inasmuch as the combination is insoluble, and is therefore carried in part or wholly out of the sphere of chemical action. The actions of some of the salts of the heavy metals can, however, be partly or wholly counteracted by a great excess of other salts (36).

It is a curious fact, however, and of great theoretical interest, that even the salts of the alkalies and alkaline earths, which do not, as a rule, form insoluble compounds with proteins, nevertheless stand in a double relation towards tissues. On the one hand they induce properties which are readily modified or reversed by other salts; on the other hand, in some instances, they undoubtedly form compounds of a more stable type, and not nearly so readily converted by substitution into other compounds. I refer to the well-known power possessed by certain living tissues of "selecting" or storing up certain salts in a concentration much greater than the medium in which they live. For example, the muscles of animals contain a very much higher percentage of potassium than the blood which bathes them. Obviously, if the potassium existed in the muscle in a dissociable, readily replaceable form, it would speedily diffuse out into the blood, and its place would be taken by some other substance, probably sodium. That this does not occur indicates that the potassium, is partly and temporarily present in the form of an irreversible compound—irreversible because the potassium ion in dissociation is not split off as such. We are therefore in possession of the suggestive fact that, whereas in the type of alkali or alkaline earth ion-proteins usually formed, the alkali or alkaline earth ion is readily dissociated as such; yet another type of combination exists, possibly with the same molecule in which the alkali or alkaline earth ion is not dissociated as such, but is bound up in a non-diffusible complex.

Secondly, as regards the chemical affinities of the ion-proteids when formed. In a paper published in the "Transactions of the Royal Society of South Australia," early in 1905, and in subsequent papers (37), I have pointed out that the relative velocities of migration of the ions in a medium in which a tissue is bathed probably play an important part in determining the kind and proportions of the ion-proteids formed in the tissue. We have seen that the mass of a given ion present in a solution bathing a tissue determines to a large extent the amount of the compound with that ion which will be formed in the tissue. When magnesium ions are in excess, for example, the magnesium compound will be the one chiefly formed; when calcium ions are in excess the calcium compound will be the one chiefly formed, and so on. Now a salt, before it can combine with a constituent of a tissue, has to diffuse into the tissue, and both ions of a salt do not diffuse equally rapidly, while in acids and alkalies the hydrogen and hydroxyl ions respectively have very much higher velocities of migration, that is, diffuse more rapidly than the other ions in the solution. It is this principle which is made use of in Lipman's capillary electrometer (38). Here mercury and a dilute sulphuric acid solution are brought into contact with a capillary glass tube. The hydrogen ions of the sulphuric acid diffuse into the mercury much more rapidly than the SO_4 ions. Now hydrogen ions carry a positive charge, and SO_4 ions carry a negative charge; hence, since an excess of hydrogen ions enters the mercury, an excess of SO_4 ions are left behind in the sulphuric acid solution, and the mercury becomes positively charged, while the sulphuric acid solution becomes negatively charged. The difference of electric potential thus established between the mercury and the sulphuric acid solution tends to slow down the hydrogen ions which are diffusing in and to accelerate the SO_4 ions; hence the difference of electric potential increases more and more slowly, and finally reaches a constant value, and a constant excess of hydrogen over SO_4 ions is maintained in the mercury. In the case of an electrolyte diffusing into a tissue we have a somewhat different state of affairs. Here the ions, on entering the tissue, combine with some constituent of the tissue in proportion to their concentration in the tissue. In so doing they must set free from the tissue other ions bearing the same electric charge, and since, for example, if positive ions enter into the tissue in excess more positive ions will be set free from the tissue than negative ions; the positive ions thus set free will diffuse out of the tissue more rapidly than the negative ions which are set free. This excess of positive ions diffusing out of the tissue will take the place of the excess of positive ions which has diffused into the tissue from the solution, and no difference of electric potential will arise; so that the process will be limited only by the power of the tissue to combine with the ions diffusing into it.

To clarify our conceptions of this process let us consider a concrete example. Suppose we have a tissue in which the chief saline constituent is sodium chloride, and that we place this tissue in a solution of magnesium nitrate. In a solution of magnesium nitrate the NO_3 has a much higher velocity than the magnesium ion, so that many more equivalents of NO_3, carrying negative charges, enter the tissue in a unit of time than equivalents of magnesium carrying positive charges. These NO_3 ions will displace chlorine, and also, probably, hydroxyl ions from the ion-proteid constituents of the tissue, while the magnesium ion will displace sodium and hydrogen ions. But, since very many more equivalents of NO_3 enter the tissue than equivalents of magnesium, very many more chlorine and hydroxyl ions will be displaced from the tissue than sodium and hydrogen ions. Hence many more chlorine and hydroxyl ions, carrying negative charges, will diffuse out of the tissue than sodium and hydrogen ions; and this excess of negative charges carried out of the tissue will tend to neutralise the excess of positive charges left behind in the solution of magnesium nitrate, on account of the excess of NO_3 ions which has entered the tissue. Thus the process will go on, if the medium is a solution of pure magnesium nitrate, until nearly all the ion-proteid is in the form of a compound, or of compounds, with magnesium nitrate, and nearly all of the sodium chloride is displaced from the tissue; then, just as in the case of the capillary electrometer, a potential difference will begin to arise between the tissue and the solution, and the proportion of NO_3 and magnesium ions entering the tissue per unit of time will gradually assume equality.

On the basis of this hypothesis it is evident that the chemical properties and affinities of a tissue must be profoundly influenced by the relative velocities of migration of the ions in the solution bathing it. We should especially expect to find the acid or basic properties of a tissue profoundly affected by the relative proportions of anions and cations entering the tissue. Just as phenol, by the substitution of three of its hydrogen atoms by three nitro groups, with the formation of picric acid, has its acid properties greatly increased, and as ammonia and phosphine have their basic properties greatly increased by the substitution of methyl or ethyl groups for one or more of their hydrogen atoms, so we should expect the ion-proteid compounds, composed, as we may suppose them to be, of a comparatively inert protean moiety in combination with a chemically active moiety, to exhibit more or less basic or acid properties, according to the basicity or acidity of the chemically active constituent, or, in other words, of the ion in the surrounding medium which has the higher velocity of migration. Accordingly, I found (39) that tissues placed in solutions in which the anion has the higher velocity of migration combine readily with basic dyes, and show but a feeble affinity for acid dyes; while, on the other hand, tissues placed in solutions in which the cation has the higher velocity of migration combine readily with acid dyes and show but slight affinity for basic dyes.

The experiments were conducted as follows: — Two species of infusoria—*Paramoecium* and *Colpodium*—were thoroughly soaked in the solution of the salt to be investigated by shaking them up in the solution, centrifugalising and shaking up again, and so on, 10 minutes being allowed between each centrifugalisation, and the process being repeated three times. The infusoria were then stained in methyl green, as an example of the basic dye, or in iodine-eosin, as an example of an acid dye, precautions being taken in both cases to prevent reaction changes in the tissue during fixation, and to exclude the possibility of mere physical staining, due to the retention in the tissue by imbibition, of the free color acid or color base. The results, for a detailed account of which I must refer to my original paper, were strikingly in accord with the hypothesis. Indeed, in solutions of potassium acetate and sodium butyrate, in which the cations have very much higher migration velocities than the anions, and in which, therefore, according to the hypothesis which I have outlined, tissues should possess basic characters, even the nuclei of infusoria failed entirely to stain in methyl green. Now the nucleus of a cell is usually pronouncedly acid in its properties, and methyl green, being a basic dye, is a well-known nuclear stain. The effect, therefore, of solutions of these salts upon the acid and basic properties of tissues immersed in them must be very considerable. The effects were not due to the reactions of the solutions of salts themselves, because the excess of salt was always carefully removed by washing before the stain was applied, and because a totally different set of results was obtained if this washing was omitted. Nor were the results due to alterations in the permeability of the cells for the dyes employed, for just those cells, for example, which stained most intensely in methyl green also stained most faintly in iodine-eosin. In other words, were we to attribute these results to alterations in permeability we would have to suppose that just those solutions which render infusoria most permeable to methyl green render them at the same time least permeable to iodine-eosin, a supposition which does not fit in with any of our present knowledge of the properties of semi-permeable membranes.

The only marked exceptions which were found to the rule that cells in solutions of single salts assume the acid or basic properties of that ion in the solution in which they are bathed, which has the higher migratory velocity, were the cases in which the cells had been immersed in solutions of the salts of the heavy metals. In such cases the cells were always basic in character. But, as I have previously indicated, the heavy metals stand in a somewhat unique position as regards proteins, inasmuch as they form insoluble compounds with them; so that in these cases the reaction between the proteins of the tissue and the heavy metal cations is an almost unbalanced one, the product of the reaction being carried out of the sphere of chemical action as fast as it is formed; so that the reaction does not cease until practically all the proteins in the tissue are combined with the heavy metal cation, and hence possess predominantly basic characters.

I carried out similar experiments on the influence of electrolytes upon the toxicity of alkaloids (40), and here again I found a marked influence exerted by solutions of electrolytes upon the chemical affinities of tissues placed in them. A large body of evidence, to which reference will be found in my original paper, tends to show that the toxic action of an alkaloid depends upon its forming compounds with the tissues affected; and, I may remark, recent experiments, as yet unpublished, have placed me in possession of still further evidence in support of this view. The alkaloids are basic substances, some of which have also acid characteristics. Experiments upon an infusorian *(Paramoecium)*, a worm *(Tubifex)*, and a crustacean *(Gammarus)*, with 14 different alkaloids acting in solutions of a number of different salts, showed that alkaloids which are purely basic in character exhibit a maximum of toxicity when acting in solutions of salts in which the anion has the higher migration velocity, and that alkaloids which are both acid and basic in character show a maximum of toxicity when acting in solutions of salts in which the anion has the higher migration velocity, and also another maximum of toxicity in solutions in which the cation has the higher migration velocity. Thus these experiments confirmed those on staining power. The correspondence between theory and experiment in the investigations upon alkaloids extended to details upon which, however, I cannot dwell here. I should mention, however, that the toxicity of a solution was estimated by the reciprocal of the duration of life in the solution, and that the toxicity of the solution of the salt alone was always subtracted from that of the solution of the salt, plus the alkaloid.

Summing up, therefore, our information, derived from the chemical behaviour of tissues placed in solutions of electrolytes, regarding the chemical affinities of the ion-proteid compounds, we may state that the ion-proteids tend to assume the acid or basic properties of the ion derived from the surrounding solution with which they are combined.

Thirdly, as regards the influence of the concentration of a solution of an electrolyte bathing a tissue upon the properties and amount of the ion-proteid formed. That the older view that the influence of the concentration of the medium upon the cells suspended in it is to be attributed to purely osmotic factors is untenable has been shown, more especially by the experiments of Loeb (41), Wolfgang Ostwald (42), and Osterhout (43). Loeb, experimenting with a marine crustacean *(Gammarus)*, found that they died rapidly in distilled water, but that they died equally rapidly in solutions of cane sugar, dextrose, or even of sodium chloride which were isotonic with sea water. They died even more rapidly in a solution containing all the salts in sea water, with the exception of sodium chloride, in the concentration in which they occur in sea water. If, now, to the highly toxic solution of sodium chloride in the concentration in which it occurs in sea water there be added the even more toxic combination of the other remaining salts in sea water in the concentrations in which they occur therein, we obtain a solution in which *Gammarus* lives as long as it does in sea water—that is, as far as our purposes are concerned, indefinitely.

If the action of salts were a simply osmotic one the relation of concentration to toxicity should be simply a linear one. Wolgang Ostwald, however, working with fresh-water *Gammarus*, found a sudden and extraordinary increase in toxicity at a critical concentration of all the solutions, the effects of which he investigated, and this sudden increase in toxicity did not by any means occur at the same osmotic pressure in different solutions.

Osterhout, working with a fresh-water alga (*Vaucheria sessilis*), found that it lived three or four weeks in distilled water, and indefinitely in a dilute sea water corresponding in osmotic pressure to about a $\frac{3}{32}$ molecular sodium chloride; but it was killed in a few minutes in pure $\frac{3}{32}$ molecular sodium chloride, and in a few days by ten thousandth molecular sodium chloride. Very numerous similar and equally striking experiments of Osterhout's, an account of which will be found in the papers to which I have alluded, all point to similar conclusions. Indeed the whole series of experiments upon antagonistic salt effects and physiologically balanced solutions (44) establish beyond doubt the very subordinate role played by osmotic pressure in phenomena of toxicity.

Turning, therefore, to the other chemical and physico-chemical factors which may be concerned, we are naturally led, in the first place, to consider the influence of concentration upon the nature and proportions of the ion-proteids formed in the tissues. Were the reaction between an ion of a salt and the proteins in a tissue phenomena analogous to the neutralisation of a simple base or acid by another acid or base, and were the toxic action of a salt mainly due to the nature and proportion of the ion-proteid formed in the tissue, we should expect to find, as in the curves representing the neutralisation of an acid by a base (45), a comparatively slow initial rise in toxicity as the concentration of the toxic substance increased, followed by a relatively rapid rise in toxicity to a limit representing the extreme toxicity which it is possible to obtain at any concentration of the toxic substance. Accurate investigations on the influence of a series of concentrations upon toxicity are very few and are much to be desired. The experiments of Wolfgang Oswald, however, to which I have alluded, tend to support the idea that toxicity depends upon a process analogous to the neutralisation of a simple acid by a simple base, or *vice versa*. Certain other experiments upon tissues, however, show that this simple view of the case is inadmissible. In experiments on the influence of the concentration of sodium chloride solutions upon the amount of water absorbed by a frog's muscle placed in the solution. Loeb (46) found that in dilute solutions, in a given time, the muscle absorbs a large quantity of water; then, as the concentration is increased, the amount of water absorbed by the muscle reaches a minimum, very nearly zero; then, as the concentration is still further increased, the amount of water taken up by the muscle gradually increases also until it reaches a second maximum. Obviously this in no way corresponds to such a phenomenon as the neutralisation of a simple acid, such as acetic acid, by a simple base. The experiments of Cooke (47), also, upon the absorption of water by muscles placed in different concentrations of salts, lead to a similar conclusion.

Summing up the results, therefore, derived from a consideration of the influence of the concentration of an electrolyte upon living tissues, we may say that the results are such as to suggest a chemical reaction, but so simple a reaction as that represented by the neutralisation of a simple monobasic acid by a simple monacid base.

Finally, in continuing our analysis of the information regarding the properties of the ion-proteid compounds, which has been so far derived from a consideration of the properties and reactions of living tissues, we may allude to the influence of temperature upon life-phenomena.

Arrhenius (48) has shown that the velocity of a chemical reaction increases very much more rapidly with increasing temperature than any known physical phenomenon. The velocity of a chemical reaction increases about 10 per cent. per degree centrigade rise in temperature, while molecular velocity, the electric conductivity of a wire, the elasticity of a solid, the viscosity of a fluid, surface tension, &c., are much less affected by the same rise in temperature.

The quotient $\frac{\text{velocity of reaction at Tn.} + 10}{\text{velocity of reaction at Tn.}}$, called the temperature coefficient of the reaction, is about two for a chemical reaction, Tn. being the absolute temperature. The temperature-coefficient for "absorption-combination," as, for example, the absorption of a dye by filter-paper, is only about 1·36 (49).

Regarding the majority of life phenomena as directly or indirectly dependent upon the reactions and properties of the ion-proteid compounds, the effects of temperature upon life processes are of the greatest interest. The experiments of Christen, quoted by Duclaux (50), on the time of exposure to high temperatures required to kill the spores of bacilli would indicate a temperature coefficient of at least four for this process. The experiments of Lautenbach (51) on the influence of temperature upon reflex time would indicate a temperature coefficient of 6 or 7. Clausen (52), experimenting on the influence upon the production of CO_2 by seeds, found a temperature coefficient of 2·5. Hertwig (53), experimenting on the influence of temperature upon the rate of development of frogs' eggs, found a temperature coefficient of from 2 to 3. Abegg (54), working on the production of carbon dioxide by frogs and in other experiments, found temperature coefficients of about 2. C. D. Snyder (55), working under Dr. Loeb's direction, found a temperature coefficient of about 2 for the influence of temperature upon the rate of the beat in the heart of the terrapin. Loeb (56) has found that the velocity of artificial maturation in the eggs of a mollusc *(Lottia)* is doubled or trebled by a rise in temperature of 10 degrees. I found (57) that the average value of the temperature co-efficient for the rate of the heart-beat in a crustacean *(Ceriodaphnia)* was 2·03 for about 25 to 30 determinations, none of which varied very far from the average. Burnett (58) has found a temperature coefficient of from 2 to 3 for the shortening of the latent period with rise of temperature in muscles stimulated indirectly.

These results, having regard to our initial supposition, that these life-phenomena mainly depended upon the reactions and properties of the iron-proteids in the tissues, tend to show that the reactions of the iron-proteids are chemical reactions, that the iron-proteids are not, in fact, merely instances of the increase in concentration of ions at the surface of two phases, or merely instances of the physical retention of substances owing to the co-efficient of partition between the solution and the proteins of the cell favoring the proteins. Nor do these results lend support to the idea that the ion-proteids are "absorptions compounds" for, as we have seen, the temperature—co-efficient for a typical case of absorption-combination is only 1·36; on the contrary, the temperature co-efficients quoted above are many of them abnormally high even for chemical reactions.

Summing up, therefore, the information regarding the physico-chemical nature of the iron-proteid compounds which we have derived from a consideration of the reactions towards electrolytes and temperature of living tissues themselves, we find ourselves in possession of the following facts:—

1. That two types of ion-proteid compounds exist apart from those which are insoluble, namely, that in which the ion, derived from the external solution, is readily dissociable as such and is readily replaced by other ions according to their relative masses, and that in which the ion derived from the external solution is not dissociable as such, but is bound up in a non-diffusible complex.

2. That the ion-proteids tend to assume the acid or basic properties of the ion, derived from the external solution with which they are combined.

3. The effects of the concentration of electrolytes upon the properties of living tissues are such as to indicate that the reaction between the proteins of the tissue and the ions of the external solution which leads to the formation of ion-proteids is a chemical one, but not so simple as the simple neutralisation of a base by an acid.

4. The influence of temperature upon living tissues is such as to indicate that the iron-proteid compounds are chemical in nature and not "absorption compounds," but the temperature co-efficient for life-processes is often abnormally high.

These facts, while leading us, perhaps, to suspect the real chemical nature of the iron proteids, are not in themselves sufficient to enable us to decide as to what chemical types they belong, or to enable us to assert whether or not we can apply the ordinary laws of chemical statics or dynamics to their reactions. In order to answer these questions we must turn to the known chemical properties of the proteins themselves *in vitro*.

It has long been known that proteins in solution combine with acids and bases (59). Regarding the compounds with neutral salts there has been more doubt, but the recent researches of Hardy (60), Mellanby (61), and Arny and Pratt (62) appear to place their existence, in some instances at least, beyond a doubt.

That protean salts are electrolytes—that is, that they ionise in aqueous solution—has been especially pointed out by Mann (63), Billitzer (64), Freundlich (65), Laqueur (66), and Hardy (67).

The fact that proteins can combine either with acids or with bases indicates that they belong to that class of bodies known as amphoteric electrolytes, or, in the briefer terminology which I have recently elsewhere suggested, (68) ampholytes. Ampholytes are bodies which can split off either hydrogen or hydroxyl ions when in solution. The amino-acids, for example, are typical instances of this type of bodies. The NH_2 group in amino-acetic acid probably combines with H_2O when dissolved in water so that it splits off hydroxl, while the COOH group, in the usual way, splits off hydrogen ions. The polypeptids of Emil Fischer (69) are ampholytes simply formed by the NH_2 group of one ampholyte combining with the COOH group of another, so that the resultant molecule still retains an uncombined NH_2 group and an uncombined COOH group. The amphoteric properties of proteins and the large number of amino-acids obtained by their decomposition probably indicate a structure similar to Fischer's polypeptids. The attempts which have been made to apply to solutions containing proteins the ordinary laws of chemical statics and dynamics, such as apply in solutions containing only dilute non-amphoteric electrolytes, have met with varying success. The researches of W. B. Hardy on globulin (70) and those of Bugarszky and Liebermaum (71) on albumin and alnumose have been successful in proving that these proteins combine with acids in molecular proportions, and those of Laqueur and Sackur (72) and of Van Slyke and Hart (73), and others, have shown that casein combines with bases and acids in equivalent-molecular proportions. The attempts to formulate a mass-relationship between salts and proteins have, however, met with great difficulties. Thus, Galeotti and Guerrini (74) find that when protein is precipitated by salts the proportion of salt to protein in the precipitate varies continuously. Not even in the case of salts of the heavy metals is there any constant proportionality beween the concentration of the salt and the amount of protein precipitated (75). Hardy, however, considers that compounds between globulin and salts are formed, but that they are stable only when their dissociation is completely suppressed by excess of salt (70). Recent observers agree in stating that the rate of hydrolysis of proteins by pepsin, trypsin, and erepsin is proportional to the amount of ferment present (76), as would be expected if the enzyme acted upon the substrate through the formation of an intermediate compound according to Guldberg and Waage's mass-law; but this proportionality only holds good within circumscribed limits of subtrate, enzyme, and hydrion or hydroxidion concentration (77). My own experiments upon the hydrolysis of casein by trypsin (78) enable me to confirm these statements.

In another field, that of toxins and anti-toxins, and of allied substances, the Guldberg and Waage mass-law has been applied with considerable success, particularly by Arrhenius and Madsen (79); nevertheless objections have been raised, and, although many of these objections obviously arise from a misapprehension of the physico-chemical factors involved, we may nevertheless consider it highly probable that the principle of Guldberg and Waage's mass-law can only be applied to the toxin-antitoxon reaction, as to the ferment reactions which I have mentioned, under certain definite conditions. The facts appear to indicate that those instances in which the simple laws hold good are particular cases, under limiting conditions, of more general laws. In this connection it occurred to me that many of the difficulties encountered in applying physico-chemical laws to protein systems might possibly be attributed to the insufficient consideration of the amphoteric nature of proteins, and of the manner in which the ordinary conditions of chemical equilibrium are thereby modified. That the ordinary laws of chemical statics, as applied to dilute solution of non-amphoteric electrolytes are greatly modified in amphoteric systems, has been pointed out by Walker (80), who worked out the equations for the equilibrium of a non-associating ampholyte in the absence of other electrolytes. It is obvious, however, that the problem we have to consider is even more complex than that discussed by Walker. In the first place we frequently wish to consider the reactions of proteins towards non-amphoteric electrolytes, and so we have to include these in the system. In the second place Walker's equations do not take into consideration the possibility of the formation of association compounds or of polmeric modifications of the amphotetic electrolyte, analogous to the polypeptids to which I have referred, such as undoubtedly occur in the case of proteins. The marked influence of temperature upon the state of aggregation of proteins and the precipitate on neutralising a solution of acid—or alkali—albumin, to mention two well-known instances, point to the formation of large molecule-complexes, or, as Hardy (70) has called them, "pseudoions"; nor can we place any definite limit to the number of such different complexes which may be in equilibrium in a solution of protein. Indeed, we must regard the coagulation of proteins rather as a shifting of this equilibrium in the direction of higher complexes than as a sudden chemical or physical change unpreceded, even in minute concentrations, by similar molecular aggregations at a different temperature, or at a different concentration of the coagulating agent. Similarly we must regard the solution and swelling of proteins as a shifting of the equilibrium in the direction of lower complexes. Even in the simplest possible instance of an ampholyte, namely, water, Arrhenius (81), and, more recently, Sutherland (82), have pointed out that such polymeric modifications must at all times exist in equilibrium with each other, the point of equilibrium being shifted by alterations in temperature.

I accordingly carried out a mathematical investigation on the conditions of equilibrium of an associating amphoteric electrolyte in the presence of any number of non-amphoteric electrolytes (68). Before briefly outlining the results of this investigation, which most intimately bear upon the properties of the ion-proteids, I must preface an account of the terminology used, as it will serve also to illustrate some of the most important properties of an ampholyte system.

An uncombined ampholyte can be represented in a general way by the symbol HXOH where X is any radicle. Ampholytes which may be represented, as regards their dissociation, by the symbols $H^+ + XOH^-$ and $HX^+ + OH^-$ are designated acid and basic ampholates respectively, to distinguish them from their salts.

The simplest ampholate in a given system, represented by HXOH, is designated the ampholate of the first order; those represented by HXXOH...., HXXX.... OH being designated ampholates of the second......nth orders. The compounds of an acid ampholate with a non-amphoteric base, or of a basic ampholate with a non-amphoteric acid are termed ampho-salts. An ampho-salt formed by the substitution of a base for hydrogen in an acid ampholate can disssociate into ions in either of two ways; either it can dissociate into the ion which has replaced the hydrogen of the ampholate and an anion, or it can dissociate into a cation and a hydroxyl, for example, NaXOH can can dissociate either as a $Na^+ + XOH^-$ or as $NaX^+ + OH^-$, in the second instance the ampho-salt acts as a base and is termed a basic ampho-salt. Similarly the ampho-salt formed by the substitution of an acid radicle for the hydroxyl of an ampholate can act either as a salt or as an acid, and, when acting as an acid, is termed an acid ampho-salt. The combination of an acid ampho-salt with a basic ampho-salt, such, for example, as NaXCl, which can no longer split off hydrogen or hydroxyl ions, is termed a "di-salt."

The term "association salt" is restricted to the neutral substances formed by the combination to two or more ampholates of lower orders, such as, for example, XX, formed by the combination of two HXOH molecules with the elimination of water. Neutral substances may also be formed in ampholytes by a modification of internal structure, but on these I need not dwell here.

This investigation threw light in many ways upon the facts which I have outlined to you; for instance, the fact that in many cases Guldberg and Waage's law cannot be applied directly to two reacting proteins is explicable on the basis of the following considerations:—Let A be the mass of the acid ampholates in one of the proteins and B that of the basic ampholates; similarly let A' and B' be the acid and basic ampholates of the other protein, then the mass of the one protein, as estimated by weighing, is equal or proportional to $A+B$, while that of the other is equal or proportional to $A' + B'$. According to Guldberg and Waage's law, the active mass of the product is proportional to the product of the active masses of the reacting substances. Now, in this case the product of the measured active masses of the two proteins is $(A + B)(A' + B') = AA' + AB' + BA + BB'$, but in the actual reaction A only reacts with B' and B with A', not A with A' and B with B', so that the mass of the product will be proportional to $AB' + BA'$, and not the product of the measured active masses of the two proteins, unless A is equal to B or A' to B'. That is, as can be shown from other considerations upon which I cannot dwell here, Guldberg and Waage's law can only apply to the reaction between two proteins, if one of the proteins is isoelectric and remains so throughout the reaction—that is, does not drift under an electric field, or, if in one of the proteins the acid function is negligible, and in the other the basic function.

This point of view also clears up some of the relations of the swelling and solubility of proteins to the concentration and number and valency of the non-amphoteric ions in the medium; but for these and other applications of the theory I must refer to my original paper.

I have also recently shown that this point of view renders clearer many phenomena in the hydrolysis of proteins by trypsin (78), but for an account of these I must also refer to my original paper on the subject.

Returning to the question of the ion-proteids in living tissues, I may represent the relations between the results of this investigation upon the properties of an associating ampholyte, and the conclusions which we arrived at regarding the ion-proteids in tissues, as follows:—

In the ion-proteid compounds in tissues we find:—

1. That two types of ion-proteid compounds exist apart from those which are insoluble, namely, that in which the ion derived from the external solution is readily dissociable as such, and is readily replaced by other ions according to their relative masses, and that in which the ion derived from the external solution is not dissociable as such, but is bound up in a non-diffusible complex.

2. That the ion-proteids tend to assume the acid or basic properties of the ion, derived from the external solution, with which they are combined.

3. That influence of concentration of the external solution upon the proportions of ion proteids formed is such as to indicate a chemical reaction, but not a simple relation such as subsists in the neutralisation of a non-amphoteric acid by a non-amphoteric base.

In an associating ampholyte system we find:—

1. That two types of ampho-salts exist, as regards their dissociation, namely, those which dissociate into the non-amphoteric ion with which they are combined and an amphoteric ion, and those which dissociate into hydrogen or hydroxyl and an amphoteric ion containing the non-amphoteric ion of the salt bound up in a complex.

2. That in the presence of excess of anions the ampholyte assumes predominantly acid characters, while in the presence of excess of cations it assumes predominantly basic characters.

3. That the influence of the concentration of the non-amphoteric ions upon the proportion of acid to basic ampholates and upon the degree of association of the ampholyte depends upon the number of different non-amphoteric ions in the medium, exclusive of hydrogen and hydroxyl ions. If only one non-amphoteric ion is present the curve representing the influence of its concentration upon the association of the ampholyte consists of a number of small maxima and minima superimposed on one large maximum and minimum. If the number of non-amphoteric ions, exclusive of hydrogen and hydroxyl, is two, then the curve consists of a number of small maxima and minima superimposed upon two large maxima and minima. These are curves which have been obtained for the swelling of gelatine in solutions of electrolytes of different concentrations (83).

4. That the influence of temperature upon living tissues is such as to indicate that the ion-proteids are chemical compounds. But the temperature coefficients obtained are often abnormally large.

4. That the temperature coefficients for reactions involving amphoteric electrolytes are abnormally large because their dissociation is abnormally influenced by temperature (84).

Since we know that proteins are ampholytes, and that they combine with non-amphoteric acids, bases, and probably salts, and we have seen that an ampholyte system possesses the properties which have been ascribed to the ion-proteids, we are, I think, justified in making the following assumptions:—

1. That the compounds which have been termed "ion-proteids" are in reality ampho-salts of the proteins (*e.g.*, NaXOH, HXCl).

2. That the non-dissociable compounds of protein with non-amphoteric ions which exist in tissues are in reality ampho-salts dissociating as acids and bases or else di-salts (*e.g.*, $NaX^{+} + OH^{-}$, $H^{+} + XCl^{-}$ or NaXCl).

3. That the influence of electrolytes upon the properties and reactions of living tissues may probably be referred in the main to alterations in the ratio of the basic ampholates (*e.g.*, $HX^{+} + OH^{-}$) to the acid ampholates (*e.g.*, $H^{+} + XOH^{-}$) and to the formation of ampho-salts and di-salts.

In conclusion I may allude to the fact that the whole ion-proteid hypothesis has received striking confirmation from the recent very interesting experiments of Professor W. A. Osborne, of Melbourne University (85), who has succeeded in directly proving in the simpler case what the supporters of the ion-proteid theory have throughout assumed or endeavored to prove indirectly in more complex cases, namely, that the ions of a solution bathing a cell enter into combination with the proteins within the cell, displacing the ions previously in combination. Professor Osborne dialysed a solution of calcium caseinate against a solution of sodium chloride and found that after a certain period the calcium in the calcium caseinate had been replaced by sodium derived from the sodium chloride. Other dissociable salts of colloidal acids and crystalloid bases dialysed against solution of dissociable crystalloid salts behave similarly. Proteid solutions dialysed against weak solutions of mercuric chloride tend to retain the heavy metal, and thus acquire a greater concentration of the latter than exists in the dyalising fluid. Obviously we have here an almost complete analogy to the ion-proteid theory of the interchange of salts between a living tissue and the external solution.

Or, if we desire a still simpler analogy, and one derived from the field of inorganic chemistry, I may allude to the researches of Sullivan (86), who, following up the work of Lemberg, Van Bemmelen, and others, has recently shown that if the almost insoluble feldspars, orthoclase, albite, and microcline and other insoluble silicates containing alkali and alkaline earth bases be placed in a powdered condition in a solution of cupric sulphate, they will remove a considerable quantity of the copper from the solution, the copper of the copper sulphate replacing alkali and alkaline earth bases in the silicate. Obviously, if we substitute living cells for the silicate crystals, we have a somewhat analogous chemical process occurring in the two cases.

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8.—THE PRINCIPLES OF SCIENTIFIC DESCRIPTION IN NATURAL HISTORY.

By REV. T. BLACKBURN, B.A.

[Recommended by the Sectional Committee as a subject for discussion.—Ed.]

9.—REVISION OF THE AUSTRALIAN AND TASMANIAN MALACODERMITÆ.

By A. M. LEA, Government Entomologist, Hobart.

10.—THE ANATOMICAL VARIATIONS PRESENTED BY A CASE OF A THORACOPAGOUS LAMB MONSTER, TOGETHER WITH AN ACCOUNT OF THE DEVELOPMENTAL EXPLANATION OF THE SAME.

By RICHARD J. A. BERRY, M.D., Edin.; M.D., Melb.; F.R.C.S., Edin.; F.R.S., Edin.; Professor of Human Anatomy in the University of Melbourne.

SYNOPSIS.

Rarity of condition and occurrence in man.

Description of present specimen.

Dissection of same, with special reference to the alimentary and and circulatory systems.

Origin of double terata. Older theories, modern views, and author's theory.

Embryological errors responsible for production of present monstrosity.

Introduction.—Some few years ago Professor Berry was fortunate enough to have presented to him by Dr. F. W. N. Haultain, of Edinburgh, two cases of thoracopagous monsters, which were carefully dissected and fully described in the "Transactions of the Edinburgh Obstetrical Society" and also in the "British Journal of Obstetrics."(1) More recently, Professor Berry was equally fortunate in having presented to him by Mr. A. J. Beattie, a medical student of the University of Edinburgh, a similar monstrosity occurring in a lamb. The dissection of this last case was undertaken for Professor Berry by Dr. J. D. Sinclair.

Description.—The present example is a thoracopagous lamb monster, both the twins being full-term females, and of the subtype known as sternopagous tetrabrachius—that is to say, each twin has two upper limbs, and the internal organs—more particularly the heart—show various degrees of fusion. The present specimen came from a large sheepfarm at Luib, in Perthshire, Scotland, and, if the shepherd is to be believed, its rarity is shown by his statement that it is the first example of the kind which he has met with in an experience of 40 years, with an average of 1,000 lambs per annum.

External Appearances.—The line of fusion extends from the upper part of the thorax opposite the fore limbs to the umbilicus. Both upper and lower limbs are perfectly free, and are consequently eight in number. The twin on the right measures, on the dorsal surface, from the tip of the nose to the tip of the tail, 44cm., whilst the left twin similarly measures 46cm. The umbilicus is single, and common to both twins, and contains three vessels. Coils of jejuno-ileum are distinctly visible at the umbilicus, shining through the peritoneum. Along the thoracic line of junction is to be felt a distinct bony ridge.

Dissection.—The abdominal viscera were first dissected out, and thereafter the thoracic viscera. As the various stages of the dissection were identical with those already fully described by Berry in his previous cases (1), it is unnecessary to describe them again.

The Alimentary System.—Each twin possesses a stomach fully formed and developed and composed of four parts—a rumen, a reticulum, a psalterium, and an abomasum. From the abomasum proceeds a duodenum, which unites with the duodenum of the opposite twin, so that there is a single duodenal tube common to both twins. The duodenal tube measures in all 20cm.—11cm. belonging to the right twin and 9cm. to the left twin. From the junction of these two duodena proceeds a single jejunum, common to both twins, and measuring 162cm. The jejunum possesses a mesentery on both sides, with blood vessels running along both borders, and terminates below in a slight pouch-like dilatation 3cm. in diameter. From this point onwards each twin possesses its own independent alimentary canal; consequently, arising from the pouch-like dilatation in which the common jejunum ends, are the two ilea—one for each twin, and each of which measures 67cm. Each ileum terminates at its own ileo-cæcal junction, the position of which is marked by a large lymph gland. The large intestine is perfectly normal in each twin, and measures 74cm. in length, whilst the cæcal portion is 6cm. in length.

The alimentary canal is, therefore, perfectly normal, with the exceptions of the fused duodena and of the single jejunum common to both twins—that is to say, the alimentary abnormalities are exactly as they were in the two human instances previously referred to.

The liver is a single structure common to both twins, which sits, as it were, astride of the common and single duodenal tube. That the single liver is the result of the fusion of two separate livers seems almost certain, because two gall bladders are present, and there are two distinct series of biliary ducts.

The pancreas is duplicated—that is, there is one for each twin. It is normal in position in each case, being applied to the stomach and duodenal tube. The common bile duct and the duct of Wirsung join together on each side to form a single duct, and the single ducts so formed—one in each twin—unite together and open by a common orifice into the duodenal tube exactly opposite the commencement of the jejunum.

The Respiratory System.—The respiratory system is perfectly normal. Each twin possesses two pleural membranes and two lungs.

The Vascular System.—The vascular system, as might be expected from the thoracic fusion, is extremely abnormal. There is a single pericardial cavity, mesially situated, containing a single heart common to both twins.

The Heart: External Configuration.—The heart is, as stated, a single structure common to both twins. It lies mesially, in the pericardial sac. What appears externally to be a large left ventricle occupies the major part of the anterior surface, and forms the true cardiac apex. This ventricle is separated from what appears to be a right ventricle by an interventricular groove. At the basal portions of these apparent ventricles, and overlapping them, is what appears to be a single auricle; but there are, nevertheless, four distinct auricular appendages.

Internal Configuration.—On opening up the heart it was at once obvious that the apparent single heart was, in reality, two hearts fused into one. In this instance there are four auricles and four auricular appendages, and four ventricles. The heart primarily belonging to the left twin is the more nearly normal of the two. The only abnormalities in the heart of the left twin are :—

1. Incomplete separation of the two ventricles.
2. Failure of the inferior vena cava to open into the right auricle.

An examination of the same figure will show that as regards the heart of the right twin the abnormalities are more numerous, thus :—

1. The right side of the heart is inverted.
2. The separation of the two ventricles is even more incomplete than in the left twin.
3. The mitral and tricuspid orifices are fused into one.
4. The superior vena cava is absent.
5. The inferior venæ cavæ fuse into a single vessel which opens into the right auricle of the right twin.

Vascular Abnormalities : Left Twin.—The most remarkable variation in the great vessels of the left twin is the fact that the aorta and pulmonary artery, after an independent course from their respective ventricles, unite together beyond the origin of the right common carotid to form a single vessel, which is continued onwards as the thoracic and abdominal aortæ. From the thoracic portion of this fused vessel arise the right and left pulmonary arteries, and from its abdominal portion the two hypogastric arteries.

From the aorta—prior to its fusion with the pulmonary artery—arises first an innominate artery, which divides into the left subclavian and left common carotid arteries, and, second, the right common carotid artery.

The pulmonary artery, prior to its fusion with the aorta, gives off no branches whatsoever. Subsequent to the fusion of the two main vessels, the first vessel to arise is the right subclavian artery, after which come, as stated, the right and left pulmonary arteries, and, subsequently, the two hypogastric and external iliæ arteries. The most remarkable variations in the great vessels of the left twin are, therefore—

1. The junction of the aorta and pulmonary artery.
2. The abnormal origins of the right and left pulmonary arteries.
3. The abnormal origins of the two hypogastric arteries.

Vascular Abnormalities : Right Twin.—In the right twin, as in the left, the aorta and pulmonary artery again join beyond the origin of the left common carotid to form a single vessel. Prior to its junction with the pulmonary trunk, the aorta first gives off an innominate artery, which divides into a right subclavian and a right common carotid artery ; then comes the origin of the left common carotid, after which the aorta is joined by the pulmonary trunk.

From the conjoined trunk the first vessels to arise are the right and left pulmonary arteries, and thereafter comes the origin of the left subclavian. From the abdominal aorta arises a single hypogastric artery. The most remarkable variations in the great vessels of the right twin are, therefore—

1. The junction of the aorta and pulmonary artery.
2. The abnormal origins of the right and left pulmonary arteries.
3. The presence of but one hypogastric artery.

Venous Abnormalities: Both Twins.—The superior venæ cavæ are represented by a single trunk developed mainly in connection with the left twin, and joined by a smaller vessel from the right twin. The single trunk so formed opens into the right auricle of the heart of the left twin.

The inferior venæ cavæ are two in number—one from each twin. They ascend from their respective abdominal cavities through the liver, in which they fuse together to form a single trunk, which opens into the inverted right auricle of the right twin.

Such being the more remarkable of the variations found in this specimen, it is now necessary to say something as to their embryological explanation.

Origin of Double Terata.—Amongst the numerous theories which have been put forward to account for the origin of double terata, one of the earliest was that which regarded them as due to the fusion of two originally separate ova. This theory is not, however, supported by fact, and is untenable. A second theory of diplogenesis supposes the splitting or fissuring of an originally single embryo; but here, again, neither experimental teratogeny nor observed facts support such a view. Neither of these theories being sufficient to explain the numerous phenomena recorded, "it is now reasonable," according to Ballantyne, (2) "to suppose that the double nature of the organism is determined before the appearance of the rudiments of the embryo in the germinal area . . . . and that the formation of double monsters is decided either before or during impregnation, and not after the appearance of the embryo. It is due, therefore, to a germinal cause."

Working on this hypothesis, Berry first endeavored to explain his two cases of human thoracopagi (1) by assuming the formation of two primitive grooves on a single ovum produced by bilateral segmentation. The position was, however, untenable, and was abandoned in favor of the supposition that "the two embryos had been developed from a single ovum without bilateral segmentation." This latter theory was found to account for the various abnormalities then recorded, and it is perhaps not unreasonable to assume that this may be found to be the correct theory of the development of thoracopagous monsters.

In favor of this theory of the evolution of two primitive grooves upon a single ovum without bilateral segmentation, and the consequent production of some form of double terata, there are the following facts:—

1. Such a condition has been seen and described. References to two such cases will suffice. Bryce (3) has described a case of anterior duplicity in a chick embryo of 34 hours in which there were two separate notochords throughout. The medullary canals were in part separate

and in part fused. Miss Duncan, of Aberdeen (4), has described a similar case of posterior duplicity in a chick embryo, under the title of "The Anatomy of a Double Chick Embryo." In both these cases there were two, or portions of two, primitive grooves upon a single ovum.

2. Laguesse and Bue (5), in an account of a monster with two heads and one body, measuring only 19mm. in length, state that they think that there were first two primitive lines close to one another, and slightly curved, with their convexities directed towards one another. At the extremities of these two lines were developed two distinct cephalic prolongations, two neural canals, and two notochords. Up to this point it would have been possible to have had a pair of twins from this condition had the two primitive lines been sufficiently distant from one another. But so close were they that there was between them posteriorly only a narrow territory of common blastoderm, so that in the sacral region, though there were two cords, there was only a single cartilaginous vertebral column.

3. Duval (6), speaking to his theory of polyspermia, states that following upon the polyspermia would be the apparition of two primitive streaks, which may take any position with regard to one another—at right angles, opposite, side by side, &c.—and consequent upon their relative position to one another will be the position and amount of fusion of the future double monstrosity.

The present author is, therefore, of opinion that double terata result from the evolution, upon a single ovum, of two primitive grooves produced without bilateral segmentation of that ovum.

As to why two germinal areas should be induced in a single ovum, the most generally acceptable theory is that of Duval. In this theory polyspermia is the chief, if not the only, cause of redundancy of development. This theory is accepted, apparently in its entirety, by Laguesse and Bue in the article previously quoted, whilst Ballantyne (2) himself says: "The theory of polyspermia certainly affords a very good working hypothesis to account for the various finds of double terata."

The theory of polyspermia is not, however, universally recognised as affording the correct explanation of the occurrence of two germinal areas upon a single ovum. Schultze (7), for example, rejects the theory in favor of the idea that diplogenesis is caused by some condition of the ovarian ovum before impregnation, which condition he believes to be an incomplete cellular division. Another argument which has been adduced against polyspermia as the cause of double terata, and which has never been satisfactorily answered, is this—if the entrance into a single ovum of two spermatozoa can produce double monstrosities, why cannot three spermatozoa so gain access and produce triple monsters, and so on *ad infinitum.*

Arguments such as this are difficult to answer, for in man no ocular proof can be adduced either in favor of or against polyspermia; but, these adverse views notwithstanding, it seems probable that polyspermia is a determining cause of double terata. That irregular development does follow polyspermia seems to be practically proved by the observations of Gemmill, (8) who, in a valuable paper on the "Vitality of the Ova and Spermatozoa of certain Animals," says: "It is a remarkable fact that polyspermia and irregular development are more apt to occur in the case of ova that are fertilised immediately after being shed into sea-water than in those which have been left to themselves for a little, *e.g.*, for from one to four hours before fertilisation is attempted. Apparently the short interval gives them time to round off their circumference, and allows their peripheral layer to become accustomed to the medium of sea-water. . . . . As is well known, in the normal fertilisation of the sea-urchin egg, immediately after the entrance of the first spermatozoon head, the peripheral layer of the ovum throws off a delicate, but firm, membrane—'the membrane of fertilisation'—which effectually prevents the entrance of additional spermatozoa. In well-marked cases of polyspermia this membrane is never formed. It is to be noted, however, that when perfectly fresh ova are taken from urchins that are perfectly ripe immediate fertilisation may be effected without the occurrence of more than occasional cases of polyspermia. But whenever the ova are taken from a gland that is either immature or half spent, more cases of polyspermia occur with immediate than with delayed fertilisation."

Gemmill's remarks seem not only to suggest that polyspermia is a determining factor in irregular development, but also to show that the condition of the ovum has to be taken into account in the determination of monstrosities. It may, therefore, be that cases of triple monstrosities are unknown, because the ovum, being a mononuclear structure, cannot possibly tolerate for germinal processes more than two spermatozoa; consequently double monstrosities only occur. On this theory—which is merely put forward as a tentative reply to the argument as to why three spermatozoa do not gain access to an ovum, and so produce triple monstrosities—triple monstrosities would result in the event of polyspermia occurring in a polynuclear human ovum, a contingency so improbable as to be altogether beyond the laws of nature.

It seems to me, therefore, from personal observations and from a study of the works of others, that double terata result from polyspermia occurring in a mononuclear and single ovum, the ovum itself playing in an as yet undiscovered way some pathological part, and that fertilisation having occurred in this way development proceeds in the single ovum without bilateral segmentation.

Passing now to the consideration of the embryological errors which resulted in the various abnormalities in the case now recorded, it may be stated that the intestinal variations of the single duodenal tube, the single jejunum, and the hepatic and pancreatic variations are due to the development of the twins from a single ovum, and with but one yolk-sac between them as already fully explained in the paper by Berry already referred to.

The explanation of the very remarkable cardiac variations is more difficult, but is probably as follows:—The description which has already been given of the apparently single heart shows that it is in reality a question of the partial fusion of two originally distinct tubular hearts. The fusion of the two inferior cavæ to form a single structure prior to its termination in the right auricle of the right twin show that this fusion of the two originally distinct tubular hearts has been most marked in the region of the sinus venosus, whilst the greater imperfections in the auricles of the right twin and the absence of the superior vena cava show that the fusion has affected the right twin more than the left. (For fuller information regarding these abnormal processes, see Berry's previously quoted paper (1)).

In this instance it will be remembered that the only abnormalities in the heart of the left twin are :—

1. Incomplete separation of the two ventricles.
2. Failure of the inferior vena cava to open into the right auricle.

The first of these variations is due to failure in the development of the pars membranacea septi, and the second to the fusion already described as having occurred in the region of the sinus venosus.

In the heart of the right twin the variations mentioned were :—

1. The inversion of the heart.
2. The incomplete separation of the two ventricles.
3. The fusion of the tricuspid and mitral orifices.
4. The absence of the superior vena cava.
5. The fusion of the two inferior venæ cavæ.

The inversion of the heart is referable to the V-shaped bend, made under normal conditions by the ventricular part of the embryonic tubular heart to the right, having had in this instance to take place to the left, on account of the presence—on the right side—of the heart of the other twin.

The incomplete separation of the ventricles and the fusion of the tricuspid and mitral orifices is due to the failure in the development of the pars membranacea septi and of the septum intermedium, which last, under normal conditions, "projects like a stopper into the auricular canal, and divides the latter into the two auriculo-ventricular orifices, and also grows down beyond that canal to meet the uprising ventricular septum."

The absence of the superior vena cava is probably due to a fusion of the adjacent ducts of Cuvier of each of the twins consequent on the fusion in the region of the sinus venosus, whilst the fusion of the two inferior cavæ has already been explained.

Passing, in the last place, to the explanation of the somewhat remarkable variations of the great vessels, it may be stated that what might have proved a somewhat difficult task has been rendered comparatively easy by the admirable article on this subject by Professors Young and Robinson in Cunningham's "Text-Book of Anatomy"(9).

Commencing with the left twin, the presence of a right-sided aorta makes it perfectly clear that we are here dealing with a case of absorption of certain of the cephalic aortic arches of the left side of that twin consequent on the presence of the other twin and the consequent persistence of the right-sided cephalic aortic arches. The fifth left cephalic aortic arch is entirely suppressed, whilst the whole of the fifth right aortic arch has remained as the pulmonary artery. The aorta has resulted from the persistence of the ventral root of the fourth arch, the fourth right aortic arch, and the dorsal root of the same arch.

Persistence of the fourth and fifth arches in the manner described must inevitably result in the junction of the aorta and pulmonary artery, as found in the specimen.

The origins of the left subclavian and left common carotid arteries from a short innominate trunk is normal, with the exception that the vessels are necessarily inverted consequent on the inversion of the aorta ; that is to say, the innominate artery has here resulted from persistence of the ventral root of the fourth left arch, instead of from the fourth right arch. The origin of the right common carotid artery is also normal, with the exception of the inversion. The right subclavian artery has apparently grown out from the dorsal aorta opposite, or caudal to, the fifth arch ; at least, this seems to be the only possible explanation of the position of the vessels beyond the point of junction of the aorta and pulmonary arteries. If this explanation be the correct one, then it is obvious that the origin of the vessel is abnormally far back.

The origins of the right and left pulmonary arteries from the descending thoracic aorta can only be explained on the assumption that they are abnormal outgrowths from that vessel, or else by supposing that bronchial arteries have replaced the pulmonary arteries. In view of the remarks made in Quain's "Anatomy," (10) that cases have been seen where "the right and left pulmonary arteries have received their supply of blood from the aorta," the former assumption is, perhaps, the more correct.

The abnormal origins of the hypogastric arteries as terminal branches of the abdominal aorta is presumably due to suppression of the common iliacs.

The great vessels of the right twin are normal, with the following exceptions :—

1. The whole of the fifth left cephalic aortic arch has persisted, with the necessary result that a junction has been thereby affected between the aorta and pulmonary artery.

2. The aortic origins of the right and left pulmonary arteries are to be explained as in the left twin.

3. The origin of the left subclavian has been shifted caudalwards, as in the left twin.

4. The abnormal origin of the hypogastric artery is, possibly, though not certainly, due to the suppression of one common iliac artery.

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(1) Berry, R. J. A.—"The Anatomical Variations presented by Two Cases of Twin Monsters, with an Account of their Developmental Explanations." Journal of Obstetrics and Gynæcology of the British Empire, March, 1904.

(2) Ballantyne, J. W.—"Antenatal Pathology and Hygiene," 1904.

(3) Bryce, T. H.—Proceedings Royal Society Edinburgh, 1899, p. 622.

(4) Duncan, Miss.—"The Anatomy of a Double Chick Embryo." Proceedings of the Anatomical and Anthropological Society of Aberdeen, 1900–1902.

(5) Laguesse and Bué.—Journal de l'anatomie et de la Physiologie, 1898, p. 44.

(6) Duval.—"Les Monstres par Défaut et les Monstres par Excès de Féconda-tion." Ann. de Gynec. et d'Obstet., Fev., 1895.

(7) Schulze, O.—Arch. f. Entwcklngsmechan. d. Organ., I., 268, 1894.

(8) Gemmill, J. F.—The Vitality of the Ova and Spermatozoa of certain Animals. Journal of Anatomy and Physiology, page 163, vol. XIV., 1900.

(9) Cunningham, D. J.—"Text Book of Anatomy," 1902.

(10) Quain's "Elements of Anatomy," 1892-96.

11.—SOME REMARKS ON THE NATURAL HISTORY AND DISEASES OF THE RATS OF PERTH AND FREMANTLE, WESTERN AUSTRALIA.

By J. BURTON CLELAND, M.D., Ch.M., Government Bacteriologist and Pathologist, and M.O.H. to the Central Board of Health, Western Australia.

Mr. Woodward, Director of the Western Australian Museum, has published a list, consisting of 11 species, of the members of the genus *Mus* so far found in this State. Of these only six were recorded for the more southern portions. They are *Mus rattus*, the "Black Rat"; *Mus decumanus*, the "Brown or Norway Rat"; *Mus musculus*, the "Common Mouse," three introduced by man, and the three following indigenous—*Mus nanus*, *Mus assimilis*, *Mus fuscipes*.

As the first three are the only species we have met with during the extensive trapping necessitated in combating plague, my remarks will apply to them alone. It is, however, interesting to know that apparently no native members of the genus have become domesticated.

When it became obvious that the study of the natural history of the rat might be of great service in plague prevention it was clearly our duty to ascertain the nature of the species with which we were dealing, and what were their habits. We were at once struck, in trying to differentiate the species, with the great superficial differences between individuals. In otherwise similar rats the tail would vary in length. In the same litter might be some with pure white bellies, others with pronounced gray bellies; some of the rats had, generally, dark greyish-black hair, others snow-white bellies, with an indistinct fawn edge and gray back. Consulting Mr. Woodward on the matter, we decided to take the skins and skulls of these various types and forward them through the Western Australian Museum to Mr. Oldfield Thomas, of the British Museum. From the latter gentleman Mr. Woodward has received the following interesting reply:—

"Nearly all are, as I expected, the white or yellow bellied race of *M. rattus*, which occurs in ships and seaports all over the world. It may be called *M. rattus alexandrinus*, or simply *M. alexandrinus*, but is really essentially the same species as the black-bellied *M. rattus*—the old English black rat, to which most of your Albany specimens belong.

"Two only, from Perth, are the common grey rat, *M. norwegicus*, better known as *M. decumanus*.

"With regard to plague—to which, I suppose, your inquiries refer—there is no doubt whatever that the *M. rattus alexandrinus* crowd are guilty, and it is possible that *M. norwegicus* is innocent. It has been suggested that the disappearance of plague in Western Europe has been due to the killing out of *M. rattus* by *M. norwegicus*, but I do not make any assertion about it.

"The *M. rattus* and *M. alexandrinus* lot are very good climbers, and can get on ships, along ropes, &c., and, therefore, go all over the world.

M. norwegicus only gets to places by occasional chances, and only on big ships; so it is always a long time getting there, and then only found in big towns at first. Still, there is no doubt Nos. 8391 and 8392 are it."

This communication is very interesting and very important. Is it possible that the blind flea *Typhlopsylla musculi*, which does not bite man, is the predominant flea on *M. norwegicus*, and hence, when this rat exterminates *M. alexandrinus*, even though plague occurs in the now dominant *M. norwegicus*, it cannot reach man?

M. norwegicus has apparently only recently reached Perth and Fremantle. In Perth itself it is only occasionally met with. On the wharves at Fremantle, however, it is the predominant, if not the only, species, though within the town of Fremantle it is again in a minority.

I have had an opportunity of seeing a few caged Adelaide rats. They all appeared to be *M. norwegicus.* If this proves to be the predominant species here it may explain why plague has never established itself in South Australia, even though it has been at times exposed to considerable risk.

We have often had ocular proof in Perth of the climbing powers of *M. alexandrinus.* This species, we have found, will also live well in captivity, as is well known. Some we have had alive for months. They are very interesting pets. They keep themselves spotlessly clean, and are continually washing their faces and ears with their hands, much as we do. They sit up, holding a biscuit in two hands and nibbling the middle. They are very brave, and sometimes very savage. One we had, seemed to "run amok" among his fellows, killing a number of others in the same cage, irrespective of sex. It is very interesting to see two of them fighting. They stand up in front of each other holding their arms half bent, and "chirping" or "snarling." Then suddenly one makes a dash, and tries to bite the other's neck. Sometimes a large rat—like a big schoolboy—will stand in front of and bully a smaller one, the latter complaining in low, piteous accents. The reflex jump to any sudden noise is nearly always very marked, and apparently quite uncontrollable. A rat may be eating or drinking at the time, and will always jump at the sound, but as often as not without leaving the spot he is on, or even interrupting the operation in progress—probably because they have no hiding-place to which to run.

THE DISEASES OF RATS IN WESTERN AUSTRALIA.

Rats, as everyone knows, have suddenly sprung from comparatively innocuous, if not directly helpful, vermin into one of the most deadly enemies to man. I refer to the transmission of epidemic plague. From biblical times downwards their connection with this disease has been noticed; but it rested with latter-day epidemiologists—and at their head Dr. Ashburton Thompson and Dr. Tidswell, of Sydney—to show that they were not only more or less innocent victims to it, but in reality the chief means of its disposal almost throughout the globe, and of its survival in many places when once introduced. To those, therefore, who have to fight against this insidious epizootic amongst rats it is interesting, and sometimes exceedingly helpful, to study the other diseases with which they may be affected. Suspicion has further attached to them in regard to the transmission of *trichina* to pigs (and thence to man), but it is needless to relate that this invasion has not been met with in Western Australian rats.

I will not deal with plague further than to mention, as you all know, that during each of the epidemics in man in the West it has been found in epizootic form amongst the rats.

Enlargement of the Spleen.—Again and again, but especially in the case of many of the rats on the wharves at Fremantle, a firm enlargement of the spleen—occasionally six to eight times that of the normal organ—has been noticed. Occasionally the liver was also enlarged and congested. Films, cultures, and inoculations in no instance have thrown any light on the condition. Is it possible that it has any connection with trypanosome infection, which is so common ?

Ulceration of Feet with Death.—Amongst the rats in captivity it occasionally happens that cagefuls would mysteriously die off. At last this was traced to ulceration of the soles of the feet, swarming with organisms, with which was associated considerable œdema of the limbs. The condition was traced to damp cages.

Dark Pigmentations of Lymphatic Glands.—Not infrequently lymph-glands, not obviously enlarged, have been noticed with very dark pigmentation, as if from altered blood-pigment. Does this condition indicate any previous hæmorrhagic condition of the gland (*e.g.*, plague) ?

Chronic Abscesses.—These have been seen once or twice in the groin, etc. Though the pus that they contained was examined for *B. pestis*, it was not found. Inoculations were not made, however, and recent work in India strongly suggests that they might have had their origin in plague.

Warty Ears and Tail.—Quite a number of rats had the former condition in a marked degree, and a good many the latter. The former microscopically appeared papillomatous. We thought at one time the condition was associated with numerous ova (of an oval form) packed in the liver substance ; but later examples of warty ears without the latter were met with.

ANIMAL PARASITES OF RATS.

Tænia sp.—A tapeworm has been met with occasionally in the intestines.

Cystic Stage of Tænia sp. in Liver.—Fairly frequently a minute cyst containing a head and short neck has been encountered imbedded in the surface of the liver.

Round Worms in Stomach and Ova in Liver.—Round worms, like small ascarides, are very frequently found in the stomach. In quite a number of instances numerous ova, which correspond fairly closely with the immature ova in the bodies of these worms, are found in the livers of these rats, forming extensive, firmish white areas. These ova have a thick double wall with openings at each end, resembling somewhat the eggs of *Trichocephalus dispar.*

Trypanosoma lewisi.—This Trypanosome is a very common denizen of the blood of Perth rats. It may be found almost as often as searched for.

Leucocytozoon (probably *L. ratti*).—This was found once in the mononuclear leucocytes of a rat, strangely enough within a day of reading an account of the discovery of apparently the same species in a rat in Khartoum by Dr. Balfour. Its occurrence here has been recorded in the *Journal of Tropical Medicine.* Since then another observer has recorded finding apparently this same parasite in *Mus rattus* in India.

PREGNANCY IN RATS.

The usual recurrence of plague in Australia during the first six months of the year, and its comparative disappearance later on, have given rise to much speculation. Extending as it does from hot into cold weather in temperate parts would seem to exclude climatic conditions to some extent. Is there any inherent quality in the rats themselves which would tend to cause the epizootic to die out amongst them in the infected area? Undoubtedly all rats affected with plague do not die. Those that recover would be immune to a greater or less extent, and of the others some might be naturally very resistant to the disease. If this is the case, then plague might be expected to recur when young non-immune rats had to some extent replaced the loss caused by the epizootic, provided a few of the previous generation were able to hand on the disease to them. It has, therefore, seemed to me to be important to ascertain if possible whether any particular month of the year is especially a breeding time for rats. I give the proportion, for eight months, of pregnant females to adult non-pregnant females, though fully recognising that the figures are far too small to be trustworthy. Their presentation may, however, stimulate others to go more fully into the matter, with perhaps interesting results.

Month.	Total Rats Examined.	Adult Non-pregnant Females.	Pregnant Females.	Proportion of Pregnant to Non-pregnant Females.
April	121	76	5	1 to 15.2
May...............	104	51	5	1 to 10.2
June	72	34	1	1 to 34
July	31	13	2	1 to 6.5
August	91	25	4	1 to 6.25
September	36	8	3	1 to 2.6
October	41	6	2	1 to 3
November	128	33	14	1 to 2.3

It may not be without interest to record, also, the average number of young rats per litter. Thirty pregnant rats had in their uteri 198 fœtuses, giving an average of 6·6 per litter. The smallest number found was three (twice), and the largest 10 (once) and nine (three times).

RAT FLEAS.

A number of fleas on rats have been collected at various times. It has been found that these are numerous, even when plague is absent. It has also been noticed that they may remain on the body long after *rigor mortis* has set in, and even until putrefaction is commencing. It has been generally supposed that they leave the body as soon as it is cold.

Of 60 fleas found 32 were *Pulex cheopis* (Rothschild), 27 were *Typhlopsylla musculi*, and one was *P. fasciatus*.

Section E.—GEOGRAPHY.

1.—AN INVESTIGATION INTO THE PHYSIOGRAPHY OF THE BEN LOMOND PLATEAU, TASMANIA.

By COLONEL W. V. LEGGE, F.R.G.S., F.Z.S., &c.

(*This paper was withdrawn by the author owing to its length, and the difficulty in getting all the illustrations published. He therefore submits the following synopsis.—W. V.L.*)

[PREFATORY NOTE.]

The following treatise on the Ben Lomond Range, the summit of which constitutes the loftiest tract of land in Tasmania, is the outcome of five exploring trips made by the writer during 1905-6, and two small expeditions for the purpose of examining the plateau, and ascertaining the altitude of the northern division of it. This region has rarely been visited, except by hunters and the inhabitants of the remote bush districts lying to the north of the mountain.

The first exploring party, consisting of Mr. Lyndhurst Giblin, Mr. F. W. Ward (Government Analyst), and his brother, Mr. E. Ward, and the writer, was organised in 1906, for the purpose of examining the valleys in the plateau, taking the heights of the various fells and crags in the escarpment or boundary which forms the entire margin of the range; but more especially to compare the altitude of the trigonometrical station, fixed in 1852, on the south-western point of the mountain, with that of the lofty moorland ridges at the north end. It may be mentioned here in passing that the latter division of the moorland has always been thought to be the highest point by the writer; this opinion being based on the climatological conditions obtaining there, namely, earlier and greater fall of snow, frequent cloud-capping when all other portions are clear; and also its general appearance when viewed from various positions on the upland itself, in comparison with the trig. station.

Our party ascended the mountain by the new track formed by the Fingal Road Trust from Mangana to the south-eastern corner, and established a camp among the diabase tors, backing the mural cliffs, and close to the meteorological station fixed by the writer the previous year. The first two or three days were employed in exploration, surveying two of the lakes, extending the base already fixed for a compass survey of the plateau, collecting specimens of the alpine flora, and comparing our aneroid altitudes with the height of the trig. station (5,010ft.), as noted on the ordnance map of the colony.

During this period we were favored with a steady barometer, except on one foggy day, with easterly air-currents, when a slight fall (as is usually the case on the mountain) took place. On the day previous to our exploration of the north end a careful aneroid observation at the "Station" made it 602ft. above the camp, which was, as well as we could judge from several readings, 4,408ft. above sea-level, the glass being particularly steady on this occasion.

On the following day we had again a steady barometer, and taking our camp as a datum point, we left in the morning for our objective at the north end. *En route* we explored two of the interesting "trough" valleys, which were on our track, and discovered three small tarns, playing their part in the stream-system of the plateau, and to which we gave names.

At mid-day we arrived at the deep cross valley, or transverse depression, which divides the moorland into two divisions, and which will be referred to hereafter as the "Divide," or "Dividing Valley." Crossing this, we ascended a talus-floored valley, which divides the heights and crags of the eastern escarpment from the high hills of the central portion of this area, and halted for luncheon at the foot of the eastern slopes of the latter.

The ascent of the two highest ridges in the group was made in the afternoon by Mr. Giblin and the writer, the higher and more distant being chosen by the former. Only one observation was taken, the reading being, when referred to our datum point, 148ft. (1) higher than the ordnance station (5,010ft.). This altitude, however, being the the result of a single reading of the barometer, was set down as 148ft. ± 30ft. The height of the lower ridge was approximately 60ft. less than the above.

The second expedition was carried out in March of this year (1907), for the purpose of again taking aneroid readings of the altitude of the higher summit, (2) and exploring the valleys and fells of the northern "Division."

On this occasion, too, we had a steady barometer, and careful note was taken for an hour, at intervals of 15 minutes, of the readings, and repeated in the afternoon. The result of these led us to fix the altitude of the peak provisionally at 130ft. ± 30ft. higher than the old station of the Trigonometrical Station of the "Fifties."

The members of this party were Mr. L. Giblin, Messrs. Allen Giblin, E. L. Piesse, and the writer, to whom these well-known Tasmanian mountaineers rendered most valuable and indispensable service throughout the whole of the trip. While the writer made a compass triangulation of the fells and adjacent heights, Messrs. Giblin and Piesse, who have both made a study of the aneroid in connection with its variations and uncertainties as to hysterisis and weather conditions, took the readings. It may therefore be assumed that when the height of the Giblin Fells is accurately fixed by theodolite the altitude of the peak will be found not to differ considerably from our provisional determination.

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(1) Or 750ft. above the camp altitude taken that morning, which corresponded with the reading in the evening on our return.

Before our return to camp a substantial "pile" was placed on the summit of the peak, which can now be seen clearly from the original trig. station, (2) about eight miles south of it.

SYNOPSIS OF PAPER.

The orography of the north-eastern mountain system of Tasmania is first dealt with.

Ben Lomond, the finest and loftiest isolated range in Tasmania, is shown to form the trunk of a system from which spring two wide-stretching areas in the form of a lengthened plateau, averaging 2,000ft. in altitude, and which reach out to the north-west and north-east respectively. From these areas rise lofty tor-like mountains; those on the western part of the plateau being Mount Ben Nevis, Mount Barrow, and Mount Arthur; those on the eastern arm, Mount Saddleback, Mounts Victoria and Albert, Mount Maurice, and the "Blue Tier." The mountain chain so formed is shown to be separated in a very distinct manner from those of the northern half of the colony by the River South Esk, which rises to the north-east of the plateau, and after almost completely encircling it in its course, falls into the sea in confluence with the North Esk as the picturesque estuary called the Tamar.

The climatic conditions in this part of the State are shown to be much affected by the lofty chain of mountains enumerated, heavy precipitation occurring to the north and north-west of the range, when the south-east and eastern low country, sheltered by the proximity of Ben Lomond during westerly weather, experiences but little fall. The contrary conditions obtain during heavy easterly weather on the Tasmanian littoral, bounded by Tasman's Sea.

The Ben Lomond plateau is completely surrounded by a precipitous, and in some places lofty, diabase escarpment, which rises from the surrounding subsidiary tiers and supports it at elevations above sea-level of from 4,500ft. to above 5,000ft. The lofty upland so contained has the shape of an irregular rhomboid, with a bearing from south-east to north-west.

Its surface is composed topographically of two main divisions, divided by a deep depression crossing it from east to west, and into which "trough valleys," or hollows, with a maximum depth of about 230ft. enter from the northern half; while in the southern portion similar depressions, rising in its northern and eastern tracts, converge towards a deeper valley, containing the sources of the Nile River, and issuing finally by a profound gorge through the western escarpment.

The sides of these valleys are formed of rugged slopes of diabase *talus*, alternating with castellated portions formed of the columns *in situ*. The intervening moor-belts are, some of them, rugged, with basaltic tors and peaks, while others present a more even surface, with occasional tracts bare of alpine vegetation, and showing the smooth, geometrical structure of the cooled irruptive rock.

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(2) This was named "Legge's Peak" by Mr. L. Giblin last year on his first ascending it; the whole group of prominent heights, of which it forms the culminating point, having been named by the writer the "Giblin Fells," after that gentleman and his father, the eminent Judge and Chief Justice.

Along the floors of these valleys small creeks, rivulets, and burns find their way, in all but two or three instances, to a central moor valley to form the source of the Nile, which rises in a lake near the eastern escarpment, and finally passes down the deep gorge alluded to on the western edge of the range. In the valley leading out to this gorge are situated the tarns, or lakelets, known as Youl's Lakes. The upper lake, for which no fixed name has hitherto existed, and in which the Nile rises, is named by the writer Lake Baker, after the discoverer of the source of the Great Nile.

A detailed description of the crags, isolated precipices, bluffs, and walls composing the perimeter of the mountain is given by the author. The valleys spoken of above, and the moor-belts and tors are described in the portion of the paper devoted to the "Topographical Features of the Plateau," in which also the water system, the sources, and courses of all the creeks and burns, and a description of the tarns and lakes are entered into.

The *Climatology* is next deal with, showing the influence the lofty plateau, with the chain of outlying mountains to the north of it, has on the rainfall over the area of country between Ben Lomond and the Pacific littoral. The writer alludes to the varying rainfall on the plateau itself, the fall of snow in comparison with that on the colder ranges in Southern Tasmania, the striking cloud effects, as seen from the lowlands on the eastern side of the mountain, and finally the temperature, as registered by thermometer located during a period of two years on the plateau at an elevation of 4,470ft. above sea level. The minimum registered in this period is 10° Fah., and the maximum 93° Fah.; the latter reading probably referring to a day in January, 1906, with a hot wind from the north. In the winter of 1907, which was characterised by heavy falls of snow and unusually cold south-west winds, the minimum was only 14·5 Fah. This was perhaps due to the box (3) containing the thermometer being protected by the surrounding snow.

Succeeding this section of the paper is one on the "Flora of the Plateau," in which the writer exhaustively deals with the interesting alpine vegetation, clothing nearly all portions—vale and moor—of the upland, which has an area of about 17,000 acres. Few low-country plant forms exist, except on the slopes of one valley, where the spores of *Eucalyptus viminalis* have evidently been carried up by westerly winds from the gorge, through which the Nile descends, to the tiers below the escarpment. The dominant shrubs are four species of *Richea*, or "honey plants," two of *Orites* "yellow bush," two of *Olearia*, one *Ozothamnus*, the pretty *Bellendena montana*, and the mountain ti-tree. The mountain currant, *Coprosma nitida*, has a more stunted and thorny habit in its struggle for existence in this wind-swept region than on the uplands of the lake-plateau in Central Tasmania. It persists to the topmost peaks of the northern division, an example of it forming the sole representative of the plateau flora on the summit of Legge's Peak.

(3) This is 4ft. 6in. from the ground, but on a ledge—a basaltic outcrop.

The dominant grass on the plateau is the thatchgrass, *Poa cæspitosa*, growing in all portions of it, but one or two localities, in a stunted form. The kangaroo and wombat appear to feed chiefly on this grass. It flourishes in all places on the floor of the plateau, where soil has been formed from decayed vegetation, assisted by the dust and disintegrated diabase constituents caused by long ages of "weathering."

The concluding section of the paper is devoted to a notice of the fauna of the plateau. Birds predominate, though the list of *passerine* species is scanty. The only strictly resident form is the pipit, or "meadow lark," *Anthus australis*, which is ubiquitous in Tasmania. Hawks and the wedge-tailed eagle pass over the upland during the day-time, as also the crow and black crow-shrike (*Strepera*), one or two honey-eaters, and the migratory robin-chat (*Petroica flammea*) are plentiful in the spring, the former being attracted by the flowers of the honey plant, *Richea*. In regard to mammals, the author has only been able to identify three species of marsupial, an extended stay on the plateau being necessary for correct observation. The Tasmanian kangaroo (Bennett's wallaby) is numerous in some parts in the summer, but it is questionable if it occurs on the summit of the range after the early winter snowfall, in May or June. The wombat, judging by the "droppings," is numerous, although, owing to the excellent shelter provided by the crevices and "lairs" in the diabase talus, is not met with in the day time on the plateau. Though nocturnal, it may not infrequently be found abroad in thick bush.

THE SOURCE OF THE NILE RIVER, TASMANIA.

EXPLANATION.—Lake Baker, looking north over central area of plateau. One and a half miles distant, at left hand of picture, the river flows at a lower level through Youl's Lake and passes thence through an abysmal gorge to the lower country.

2.—ALLUSIONS TO PENGUINS AND SEALS IN A ROTEIRO OF THE FIRST VOYAGE OF VASCO DA GAMA TO INDIA.

By JAMES R. McCLYMONT, M.A.

Penguins were seen by the companions of Vasco da Gama in the Angra de Sao Bras, on the south coast of Africa, in December of the year 1497, and in March, 1499. In a copy of the original manuscript of a Roteiro of the voyage by an anonymous writer who accompanied the expedition it is stated that the birds (which are described) are called *fotylicayos*, which is, perhaps, an error of the copyist, and the word *sotylicayros* was probably in the original manuscript, which is lost. In a later entry in the Roteiro the name *sotelycairos*—in modern orthography *sotilicarios*—is employed. It was one of the names applied to penguins as well as auks.

We are told concerning these birds that they were as large as ganders (*patos*), that their cries resembled the braying of asses, and that they could not fly because they had no quills—feathers.(1) Manuel de Mesquita Perestrello, who visited the same coast in 1575, adds to this description that the ends of the wings of the *sotilicairos* [*sic*] were covered with fine down (*penugem*), that the birds dived for fish, and that they reared their young in nests constructed of fish-bones, which, it may be inferred from the narrative, were the residue of the repasts of penguins and seals. There is nothing to cavil at in these descriptions, except perhaps the statement that the nests were constructed of fish-bones, an observation which is not in accordance with the observations of naturalists of the present day regarding Cape penguins, for these birds, we learn, construct their nests with small stones, shells, and debris.(2)

In modern Portuguese penguins are called *pinguins* and, more precisely, *pinguins do sul*, when the speaker desires to distinguish them from auks, which are also called *pinguins ;* and we learn from the notes to the Portuguese editions of the Roteiro that they also bear the name *mangote*, sleeve, and *cotete* (? dwarf). The two last-mentioned names have also been applied to auks, as well as to penguins. In the same bay as that in which penguins were discovered—Mossel Bay, or another bay in close proximity thereto—were also seals in large numbers. They are called *lobos marinhos*. On one occasion the Portuguese voyagers counted 3,000 individuals. Some were as large as bears, and the sound of their voice was like the roar of a lion ; others were very small, and bleated like kids. The Angra de Sao Bras was evidently a mustering-place, or rookery, to which seals resorted from far and near. The author of the Roteiro writes as if there were more than one kind of seal in the bay, but I do not think that this is likely to have been the case,

(1) Roteiro de Viagem de Vasco da Gama em MCCCCXCVII., Segunda edicao. Lisboa, 1861, pp. 14, 105, 142.

(2) Moseley—Notes, p. 155.

for different seals do not usually herd together. The differences in size and in loudness and tone of voice were probably attributable to differences in age and sex, and all may have been of a species which has various names, for it is called *Otaria pusilla* by some zoologists and *Arctocephalus delalandii* and *Arctocephalus antarticus* by others. An adult male of *A. delalandii* is recorded to have attained a length of 8ft. 6in., and cubs of the same species from six to eight months old measure about 2ft. 6in. in length.(3) Anchovies (*achoas*) were also plentiful in the bay.

A brief mention of the other beasts and birds which are alluded to in the Roteiro in connection with the earlier stages of the journey may fittingly conclude this note. In August, 1497, when the *Sao Rafaell*, the ship commanded by Paulo da Gama, in which the author sailed, was making its way, probably, across the Gulf of Guinea, birds which resembled large herons (*garcoees*) were encountered. These may have been cranes in the act of performing a seasonal or casual migratory journey. On the 27th day of October of the same year, when nearing the west coast of southern Africa, whales, seals, and shellfish (*quoquas*) were seen. On the 8th of November the vessels cast anchor in a wide bay which extended from east to west, and was sheltered from all except north-westerly winds. It was estimated, subsequently, to be 60 leagues distant from Angra de Sao Bras, and as the Angra de Sao Bras was also 60 leagues distant from the Cape of Good Hope, the wide bay, which the voyagers named the Angra de Santa Elena, must have been very near the Cape. As it was sheltered from all winds except those from the north-west it was, probably, our Table Bay. A "G. de Sta Ellena" is delineated in the position of Table Bay on the anonymous chart drafted in Portugal in 1502, commonly called the Cantino Chart. The Portuguese held intercourse with the inhabitants of the adjacent country, who had tawny skins and were probably of Hottentot race. Their food consisted of the flesh of whales, seals, and gazelles, or antelopes (*gazellas*), and the roots of herbs. The birds were thought to resemble the birds in Portugal. There were *corvos marinhos*, which is generally translated "cormorants," but "seaside crows" would, I think, be an equally plausible rendering of the words; *guayvotas*, (4) which, I think, signifies waterfowl; larks; and turtledoves.

(3) Catalogue of Seals and Whales in the British Museum, by J. E. Gray, F.R.S. Second edition, p. 53 (1866).

(4) Perhaps connected etymologically with *guaiva*, a moat or ditch,

3.—NOTES OF VOYAGE TO YSABEL ISLAND, SOLOMONS GROUP, AND LE UA NIUA (ONTONG JAVA OR LORD HOWE), AND TASMAN GROUPS.

By REV. G. BROWN, D.D.

Mr. Woodford, the British Resident Commissioner in the Solomon Islands, having very kindly offered me the opportunity of visiting these little-known groups in the Government schooner, which was being sent on a visit of inspection, I gladly availed myself of his kind offer. I had been in communication with some of the people from Lua Niua many years previously, and I was anxious to find whether the opinion which I then formed that these people were a branch of the brown Polynesian race was correct or not. Mr. Mahaffy, the assistant Resident Commissioner, was in charge in the discharge of his official duties, and I owe much to his great kindness during the whole of the voyage.

We left Ruviana in the New Georgia Group on June 13th, 1902, on board the Government yacht *Lahloo*. Our course was down the Ruviana Lagoon, then passing under the lee of the large island of Banga and through the Back Passage, Hawthorn Sound, and Diamond Narrows, in passing through which we had to depend almost entirely on the sweeps. The *Lahloo* was a fine little yacht of about 30 tons, and as she carried a large crew we were able by hard pulling to get through the Sound by 1·30 p.m. But instead of the S.E. trade wind which we hoped to get we had only light airs and long periods of calm, so that we were close in to the coast of the mainland of New Georgia all night. Next day—June 14th—we got a strong breeze and a rough cross sea early in the morning. The vessel was close hauled, making a course of N.E. half E. for Ysabel. As we neared the Ysabel coast we ran across a very heavy rip which, at a distance, looked exactly like a long semicircular reef. No man who had not previous knowledge of the fact that there was sufficient depth of water on it would have ventured to go near it, much less attempt to sail across it, as it was breaking heavily along its entire length, and I confess that I felt somewhat anxious as we approached the breakers. We could see the bottom very plainly in crossing, but there was plenty of water for a vessel of our size. I may state here, in passing, that on the return voyage we passed near a large "patch," which, so far as we could judge, had not more than about five fathoms of water on it. The explanation of this rip appears to be that it is caused by a submarine reef, either rising or sinking, suddenly arresting the swell of the ocean. After passing this we made for a large sound about 12 miles south-east of Manning Straits. At this place the large island of Ysabel is pierced from side to side by a deep water-way, dotted all over with islands of varying size. This sound, on which the harbor of Port Praslin is situate on its northern side, is interesting as being the passage through which the Spaniards under Mendana, who discovered the island on February 7th, 1568, passed in the brigantine which they had built at Estrella Bay, and in which they circumnavigated the island and made a very adventurous voyage. We beat up the wide bay seeking for an anchorage, but did not find one until about 4 p.m. I noticed near the anchorage some large dead trees standing in the water some little distance from the shore. These certainly seemed to indicate that there was a subsidence of the coastline at this place. There were no signs of natives about. All those beautiful islands, and nearly the whole of the shores of the sound, were quite uninhabited, and, indeed, with the exception of a few villages near the north and south ends and some inland villages, the whole of that fine island of Ysabel, which was teeming with population 334 years previously, when the Spaniards first discovered the group, was then without inhabitants. The head-hunters of New Georgia are responsible for this to a considerable extent, but there must, I think, have been some other reasons for this great decrease.

Next day—June 15th—we got under way about 9 a.m., but found it quite impossible to make any headway against the strong tide which was rushing through the sound, and we were glad to find a spot in which we could drop anchor. At 2 p.m. we made a fresh start and got to anchor at the village of Kia, near Port Praslin. One part of Mr. Mahaffy's duties was to find and, if possible, arrest two men who had committed a murder near Kusagi Point, on New Georgia. At Kia he found that the two criminals had called there, but had gone to another place on the coast about 40 miles away. They took a boy with them when they left New Georgia, but came there without him, and there was little doubt that they murdered the poor lad on the way and probably ate him. Mr. Mahaffy offered a reward for their apprehension, but this was all he could do. At night we went ashore and got some water near the large canoe houses. The water was brought down from the hillsides in pipes made of bamboo, so we got it pure and clear, and there was no difficulty in filling the bags. Next day—June 16th—we left the anchorage and sailed for about two miles, and then out to sea up a very fine passage. We cleared the passage at 8 a.m., and had a very fine run the most of the day. Towards night the wind freshened, and from many signs some of us were of the opinion that we were going to have rough weather, and the *Lahloo* was hove to under close reefs with mainsail stowed most of the night. Some on board no doubt managed to get a little sleep from time to time, but I was on the weather side, and the sofa had no lee-boards, and after the *Lahloo* had several times rolled the bed, pillows, books, clothes, and everything which usually get piled up on a bunk—including the drowsy passenger—under the table or amongst the boxes on the cabin floor, I decided to camp down on the floor itself. Next day—June 17th—we had a strong easterly wind and a heavy sea, which got rougher as the day advanced. We were close hauled until we sighted the atoll, and as soon as our exact position was obtained the captain decided to run for a passage to leeward, as we could not reach the windward passage without beating, and, with the heavy sea running, that would have been a very uncomfortable operation. Captain Potts and Captain Perry went up aloft as we neared the reef, for the work of piloting a smart schooner running before a stiff gale and a heavy sea into an unknown supposed passage was one that required all possible skill and forethought, and a long look ahead. Very fortunately, however, there were no dangers in the way which could not be seen and avoided, and so we were soon glad to see the sorely-buffetted little vessel rounding the inner point of one of the numerous islands and finding smoother water under the lee of the protecting reef. Some natives came off, one of whom knew a few words of English. We got anchorage in 15 fathoms, under the lee of a barrier reef. The wind was still blowing hard, and it was evidently a very dirty night outside, so we were all very thankful that we were safe in a good anchorage. The natives were certainly Polynesian, and Selu (the Samoan who accompanied me) and I could understand many of their words and some of their sentences. The name of this atoll, as given in the chart, is Leueneuwa, but the name, I think, is wrongly spelt, as it bears no meaning whatever that I know of in any Polynesian language. The proper spelling is Le ua Niua. This was certainly the way in which I wrote it before I knew of the other spelling, and the Samoan who was with me also spelt it the same way. It is, I think, one of the largest atolls known. It was discovered by Lemaire and Schouten in 1616, again by Tasman in 1643, and by Captain Hunter in 1791. The British flag was hoisted on the group in 1900, when it was transferred from the possession of Germany to British protection. It is situate in latitude 5° 29′ 35″ south and longitude 159° 41′ 40″ east, and is, I think, considerably over 100 miles in circumference. The lagoon contains many islets and islands besides those on the main barrier reef.

On Wednesday, June 18th, we landed on the island of Keila. There was a large crowd of natives on shore, and as we neared the beach two of them came out on the reef, each holding the end of a long string of cocoanut leaves with one or two very young nuts on it, and some pieces of dried pandanus leaf. Before we were allowed to land, these leaves were brushed over the head of everyone of us in the boat. This was to drive away any sickness or ill luck that we might be bringing with us. This was the first time that I had ever been put through this ceremony in the Pacific. The people were all very friendly, and the women and girls soon came about us. This was very different indeed from the custom in the Solomons and other Melanesian groups, where the women are rarely seen by strangers. The women and girls gave us specimens of their dances, and altogether the people were very friendly. The men wore tortoise-shell ornaments in their noses, much as the Santa Cruz natives do; but in this place they were hung with the edge outwards, whilst in Santa Cruz they hang flat over the upper lip and mouth. We found here a native called Peter who understood a little English, and he introduced me to an old man in the following words:—"This fellow, he missionary, all same you." I could not understand at first what he meant, but soon found out that the man to whom he introduced me was the priest of the village, and we were afterwards shown the heathen temple or tabu house in which he lived. At the far end of the house was the sacred enclosure into which he entered when his services were required to drive away sickness, bring rain or good winds, or perform any other of the numerous functions which are required of a priest in this group. I found that I was evidently regarded as Mr. Mahaffy's priest, and so enjoyed a little prominence on that account. The sacred enclosure, so far as we could see, was merely a part of the house marked off by plaited cocoanut leaves and with a few small heaps of nuts placed about it. The natives were of a light coffee color, not much darker, if any, than the Samoans and Tongans. The men and women were tattooed, though the young unmarried ones had either not got any tattooing or only small bits of it done. I think the complete pattern was only finished after marriage. The name of the chief of this island was Kei. On another village I found that the name of the chief was Uo, and this was very familiar indeed to me, as the name of a powerful chief in Lufilufi, in the Samoa Group, called Moe-faa-Uo, which was generally contracted to Uo.

The language, as will be seen from the appendix, was very similar indeed to that of the Samoans. The "f" is changed into the aspirate "h," and in many instances the "l" into "r." The number of words in each language which are precisely the same is too great to particularise. It would need a regular vocabulary. The Samoan who accompanied me gave the natives a specimen of a Samoan ailao, or club dance, which pleased them all very much indeed.

On June 19th we left Keila at 11·30 a.m., and had still the same rough squally weather. We managed to beat up a few miles, and then had to anchor to leeward of another island. It seemed very strange to have such rough weather inside the lagoon. We had some very fierce squalls during the night, and altogether the weather was described by some of us as being simply disgusting. On June 20th we got away early in the morning under reefed sails, and had to beat up the lagoon, until at last, to our great satisfaction, we let go the anchor in front of the main village—Le ua Niua. The chief of the place—Uila, since dead—seemed to be also chief paramount of the principal part of the lagoon. We landed soon afterwards, and found a large village and crowds of excitable natives, who were, however, all very nice and pleasant. We first called on the chief, Uila, and found him to be a typical Polynesian chief — very dignified and polite. He had evidently great influence amongst the people, and occupied a position very different to that which is occupied by most of the Melanesian chiefs whom I have known. After leaving the house we walked across the island, which, as usual on these reef islands, was very narrow, probably not exceeding a quarter of a mile in any part. The surf was very high, and it was very evident that there was still a heavy sea running.

I have now to describe two customs which were entirely new to me. I have been connected with the South Sea Islands for more than 46 years, during which time I have either resided in or repeatedly visited the principal Polynesian and Melanesian groups. Had I been asked the question whether there were any idolators in any of these groups I should certainly have answered in the negative, as I should also have done had I been asked if the natives in any of those islands were accustomed to bury their dead in large general cemeteries, and in both cases I should have been in error. We know too little at present of the importance attached to the large carved figures in the temples of Le ua Niua, or of the worship which is paid them, to enable me to say definitely whether they are regarded as idols and have worship paid to them as such. But certainly the impression on our minds was that they were so regarded and treated. We looked in at the temple, or, as most of our party called it, the "devil house," but we were not allowed in this case to go inside. The chief priest and his attendants were seated inside, and did not come out to see us. The building was not in good repair at all. It was about 50ft. in length by about 20ft. wide. At one end there were two large rudely carved figures, considerably over life-size. One, we were told, was a male devil or god, and the other one a female of the same genus. On a low platform at the feet of the figures were two child idols—male and female—to complete the family. The house was full of carved representations of every kind of fish and all the animals with which the people had any acquaintance. So far as we could gather, the principal functions of the priests were to make spells for the cure of sickness, avert misfortune, control the winds and weather, and generally to do everything which the people wished them to do. It was a pretty large order, but from all I could hear the people had full confidence in their powers, and, as I heard afterwards, the priest attributed the misfortune which we had at a later date on our return from the Tasman Group, when the schooner was nearly wrecked, to the fact that we had not engaged the power of the priest to protect us in that voyage. He, I believe, firmly declares now, and has informed all subsequent visitors, that he himself was the cause of our narrow escape from shipwreck.

LARGE GENERAL CEMETERIES.

During our visit we inspected what I consider to be the most interesting places which I had visited in any of those groups. The general custom of burial in the Polynesian groups is for the dead to be buried near to the houses in which they lived, whilst in Melanesia they are either exposed on platforms on uninhabited islands or in mangrove swamps, cast into the sea, or, in some cases, cremated. In Tonga chiefs of importance have family "faitokas," or family burying-grounds, for their respective families; but this was the only case I had ever seen where the dead were buried in large general cemeteries. The cemeteries at Le ua Niua, of which I succeeded in getting some very good photographs, were in open clear spaces, covered with white sand, and they were kept most scrupulously clean, not a leaf or piece of dirt being allowed to remain upon them. Every grave was marked by a large upright coral slab, which, in many instances, was highly colored, and the top of the slab was also frequently covered with pandanus leaves. It was a most affecting sight to see some of the mourners for a child (which had been dead some months) sitting over the grave with heads bowed down and in complete silence. They had erected a small, rude hut close to the grave, and in this they lived for at least a year, most of which time was spent in sitting or lying on the grave by day and night. One poor widow was carefully and tenderly sweeping the sand over her late husband's grave. Some of the large slabs were in the shape of a cross. On one of these places there was a rudely carved figure. In the cemetery of the chief's family a number of women were sitting over the grave in which his deceased wife had been lately buried, and for whom the chief was still in deep mourning. I noticed a small post in front of one of the houses in the village, and was told that this was in loving memory of a boy who had died. His body was buried in the cemetery, but his memorial was placed just in front of the house door to remind them of the loved one who had been taken away. The chief, Uila, was, as I have stated, in mourning for one of his wives, and during that time he was not allowed to expose himself to the sunlight, but was supposed only to go out of the house after dark. I was, however, very anxious to obtain a photograph of him, and he apparently was very desirous of having it taken. When I suggested the matter to him he was quite willing, provided I took it inside the house; but I told him that I could not do so. After some discussion he was persuaded to come to the doorstep and sit there, but as I saw he was very uneasy I took off my hat and put it on his head as a kind of protection, and with this he was quite satisfied. I sent an enlargement of this to the island on my return, and it arrived there a short time after his decease. It was, however, very highly valued, and there was nearly a fight amongst the people as to who should possess it. I find from some notes by C. M. Woodford, Esq., the Resident British Commissioner in the Solomons Group, that "the tombstone over the grave of the chief Uila is about 12ft. high and 3ft. or 4ft. wide, and his widows, although he has been dead for more than two years, are still living in the neighborhood of the graveyard and sweep the grave carefully every day."

We left Le ua Niua at 11·30 a.m. on June 22nd, with a fine S.S.E. wind, and had a fine run down to Pelau, about 33 miles distant.

The size of this immense atoll became more and more apparent as we sailed down it hour after hour without being able to see the encircling reef on either side, except when some shallow patches necessitated our going near one side or the other. We passed many small islands and islets, some of them in the middle of the lagoon surrounded by deep blue water and others situated almost on the reef. We sailed for a long time close to the north-western side, which consisted of a long barrier reef with only one small opening. The islets were all marked by the protruding tongue of white sand, showing that the surf which beat so near them and the tidal currents were continually increasing their size. Some of them which were separate then will, I think, be joined together at no very distant date, as the process of growth is continually going on. We anchored at Pelau at about 5 p.m. We were then still some distance away from the end of the atoll, which, I am inclined to think, is the largest true atoll in the world. I was able to get a good deal of information in the comparatively short time in which we were in the group owing to the fact that I found amongst the natives two or three who had lived some years in one or other of the Polynesian groups, and had acquired the knowledge of languages with which I was familiar.

One had lived some years in Samoa, and spoke the language fairly well. Another had resided for some time in Tonga, and a third had lived in Fiji, and as I was acquainted with all these languages I found these men very useful indeed as interpreters. All the men were very much disfigured by the custom, which I have already described, of slitting each nostril, in which they inserted on special occasions a large pendant made of tortoise-shell. The men seemed to have two distinct kinds of tatooing which, I am inclined to think, were distinctive badges of their respective totems, but in conjunction with this they seemed to tattoo just as their fancy dictated. Some of the men had beards, but the majority had very little or none at all. The women all had their hair cropped very close. The men had the same wavy black hair that the Samoans had, and in many instances they wore it just as the old heathen Samoans used to do. We heard of several castaways having arrived in the group, the most recent of which appeared to be a large number from the Gilbert group, but after residing some time, I believe, were killed by the natives. We saw no weapons of any kind amongst the people, and I remembered that my old friend Captain Ferguson told me that when the *James Burnie* was captured at this place, some years previously, the mode adopted by the natives was that at a given signal each man seized one of the officers or crew and either pushed or dragged him overboard and so drowned him. The people, as I have stated, and it will be confirmed by a comparison of the words given in the Appendix, are Polynesian; but there is, I think, a strong Micronesian admixture, and to this I attribute the fact that the Le ua Niuans use the native loom for the manufacture of their mats, and these, so far as I know, are not used in any purely Polynesian group.

We did not go on shore at Pelau, as we expected to call there on our way back to Numanu (Tasman Group). We left on Monday, June 23rd, and had a fine light wind on starting. Just as we went through the passage our interpreter, "Bob," and the other Lord Howe man made a sacrifice to the "devil," or deity Aukao, who presided at this end of the lagoon. This was done to ensure a fair wind and a smooth passage. Aukao must, however, have been easily propitiated, for the offering consisted only of two pieces of cocoanut husk and three pairs of cocoanut leaf fronds plaited. Bob cast the offering out, with a few propitiatory words addressed to Aukao, and they all seemed to have great belief in the efficacy of the act.

We went out through a fine passage, and had a good quiet run to Numanu. We entered the lagoon at 1 p.m. It was a fine atoll, like an elongated horseshoe in shape, with the entrance through the reef at the open end. There was no entrance all round the circular part. It was very wonderful to see these atolls in the midst of the wide open sea, with deep blue water right up to the great breakwater of coral which encloses the comparatively shallow lagoon inside. The reef was dotted over its whole extent with islands and islets, all of which were evidently growing in size year by year. Each island had a bank of pure white sand at each end, showing newly made land. In some cases two or more islets were nearly united, and others showed that they had been united in years past. We had one very interesting fact made very clear to us. In a chart (the most recent one) made of Numanu, in 1888, there was only one island at the entrance of the passage by which we came into the lagoon, and a number of stones were marked on the chart a little further south ; but at the time of our visit that place was an islet with a number of cocoanut trees on it, most or all of which appeared to be in full bearing. We noticed also that in another passage, where a reef awash was marked in the 1888 chart, there were now four cocoanut trees growing on it. We found good deep water in the lagoon, and were most of the afternoon beating up with a nice breeze. We anchored at 5 p.m., but did not go on shore. The chief and two men came off, and they took all the Lord Howe people to the shore, which was a great relief to us, as the noise they made was just a bit distracting.

Next day we landed about 9 a.m., and as soon as we reached the shore the constabulary were marched to the flagstaff, on which the British flag was floating. The men presented arms, and then the chief, under Mr. Mahaffy's direction, lowered the flag, and so ended the British Protectorate in this small but very interesting group. The British flag had been hoisted on this group under the impression that it formed part of the British Protectorate, but it was subsequently found that it was included within the sphere of German influence ; and so one part of Mr. Mahaffy's mission was to declare this fact to the natives by lowering the British flag, and taking it away from the chief to whose care it had been committed. The chief was very unwilling to haul down the flag, and pleaded with Mr. Mahaffy to allow him to remain under British protection ; but this, of course, could not be done. We found the beach and village there very clean, and in this respect, as in some others also, it was much more attractive and pleasant than the Lord Howe villages. The houses also were very much better, and altogether the place presented the appearance of quiet and content. No doubt there were troubles in this little Eden, but none were apparent to us. I soon made the acquaintance of my "brother missionary," who, as usual, was walking about in gloomy state and apparently holding little or no intercourse with his fellow islanders. I managed, however, to get a photograph of him. After breakfast we went ashore again and visited the curious wells where the hawks-bill turtles were kept confined. There were 11 wells, which formerly were all filled, but only two of them were then occupied by the turtles. They were caught young and placed in those wells, which were connected with the tide, and the animals were fed regularly every day with shellfish. The top of each well was covered over with logs and cocoanut leaves, so that the turtle lived in a state of semi-darkness, and this, I think, was to cause the shell to preserve the amber or yellow color which the people valued so much. Each turtle was stripped of one or more plates of shell every year, and then put back into its well to grow more. It seemed very cruel to us, but the natives appeared to think that the turtle did not object to the process, as he was well fed every day with shellfish. Some old ladies gave us a series of very vigorous dances, which appeared to consist in some kind of challenge by the orchestra which was responded to by the dancers by voice, gesture, and dancing. It was all very good-natured, and provoked laughter without the slightest appearance of anything objectionable either in the word or gesture. Two of the old ladies got so excited that, amid roars of laughter, they attempted to rub noses with me, which was the nearest approach to kissing which they had. I objected, of course; but, when the dance was over, and we were coming away, they both came forward, took my hand, and we rubbed noses together in the most friendly manner. We, of course, visited the temple of the patron saint or devil-devil Puapua. Religion there, as in Lord Howe, was in a bad condition. The temple was a very large building, but was nearly falling down. The pillars were all covered with plaited sinnett, and when the building was new it must have been very imposing indeed. The "idol" was by far the best I had seen, and it seemed to us that it was regarded by the people as being the representative of the "deity" or "devil," and that it was worshipped by them. The remains of the old Puapua were visible around the feet of the new one—notably the remains of his helmet, with long points indicating spears. Our guide told us, with great gravity, that the old fellow used to kill too many people, so, when he got into a state of disrepair, and they made a new idol, they made his headgear much smaller, and did not put so many spear-points on it, nor make them as long as in the previous case, and so sought to curtail his powers of mischief. We went ashore at night and I gave them a lantern exhibition, which amazed and delighted them. It was a calm night, and we hung the sheet under the cocoanut trees, where it was very dark indeed. They had never seen anything like it before, and I certainly never showed the views under more peculiar circumstances. The place, a lonely atoll, standing alone in the waste of water in the broad Pacific; the crowds of wonder-stricken natives, and only two or three white men present; and yet we were as safe as in any city in our own land; whilst the joy one felt at being able to give so much pleasure, the curious remarks made by the people, especially by our interpreter, Bob, all combined to make the night memorable to us. After the views were shown I took out the burners, and the brilliant light of four acetylene gas burners completed the amazement of the people. As there was plenty of carbide unused, I left the light burning, and so they had another and larger dance organised; and this they kept up until we were all tired, and I put out the light, packed up, and went on board.

Next day, Wednesday, we left Numanu, but owing to light winds did not anchor at Pelau until about 5 p.m. Whilst anchored there we had a narrow escape. The night was calm, and we had picked up what we judged to be a good anchorage in that season; but this was a land of surprises, and during the night we had heavy squalls from the north-west which brought in a heavy roll of sea through the passage. I was not at all inclined to sleep, and after midnight I was often on deck to see if we were dragging our anchor, but saw no signs of that. Just before 2 a.m., however, I heard a sudden noise below, and awoke the captain. Just as I was doing this the boys called out, "Anchor, he broke," and everyone on board was awake at once. The vessel was going astern very fast right on to the reef, over which the sea was breaking heavily, and for a few minutes our situation was very critical indeed. It was simply a question as to whether the second anchor could be let go before she struck or not. Fortunately, the anchor was dropped in time and the vessel was brought up, but only a few yards from a detached reef, over which the sea broke very heavily. A few minutes' delay in letting go the anchor, and nothing could have saved the ship. Preparations were at once made for getting into a safer position. The boat was sent ahead, with a kedge anchor and long warp, and in time we were kedged a little further away from the dangerous reef under our stern.

Next day, 26th, we recovered our anchor, one of our crew having succeeded, by diving, in fastening a line to the cable. The effort must have tried him very severely, as the water was quite 10 fathoms deep, and he was quite exhausted when he came up, and vomited a large quantity of blood. On our way back to Le ua Niua we passed islets in all stages of growth: some were still under water, others just awash, and others, in a more advanced stage, consisted of a large mound of pure white sand on the reef, but with neither tree nor bush on them. Upon one there was only a solitary cocoanut, whilst others had small groves of those palms. This immense atoll may have been formed by subsidence, but it certainly presented abundant proof of upheaval and growth going on at that time. We anchored at Le ua Niua a little after dark.

Next day, Saturday, June 28th, we made an early start and got safely through the passage. We re-entered Port Praslin early on July 1st, called again at the village of Kia, and then, with a strong tide in our favor, we sailed through the channel and out to sea again, but did not reach Gizo until the 3rd, from which place we went to Ruviana in an open boat, arriving there the next day.

A short list of words in the language of Le ua Niua (Ontong Java, or Lord Howe Group), recognised as common to the Samoan or Tongan language.

English.	Le ua Niua.	Samoan.	Tongan.
Eat	ai	ai	kai
Sleep	moe	moe	mohe
Understand	iloa	iloa	ilo, iloa
Not understand	se iloa	le iloa	tae iloa
Go	haere (1)	alu	alu (haele) of chiefs
Go (plural)	o	o	o
Go slowly	haere gase	alu gesegese	alu totoka
Go quickly (pl.)	o vave	o vave	o vave
Quick	vave	vave	vave
Fly (v.)	hele	lele	buna
Fly about	heleleai (1)	feleleai	febunaki
Come	ha	sau	hau

(1) New Zealand "haera."

English.	Le ua Niua.	Samoan.	Tongan.
Look	vaai	vaai	vakai
Go about	fealuai (2)	fealuai	fealuaki
Come here	ha mai iinei	sau ia iinei	hau ki eni
Die, death	mate	mate (of animals)	mate
End, hind part	muli	muli	muli
Thirsty	hi, hunu	fia inu	fie inu
Hungry	hi ai	fia ai	fie kai
Wind	matagi	matagi	matagi
Water	vai	vai	vai
Sea	tai	tai	tahi
Wave	peau	peau	beau
Inland	i uta	i uta	ki uta
Sun	La or laa	la	laa
Moon	marama	masima	masima
Star	fetu	fetu	fetuu
Fish	ia	ia	ika
House	vare, or fale	fale	fale
Canoe	vaka	vaa	vaka
Fish hook	makav or matau	matau	matau
Rope	maea	maea	maea
Rain	ua	ua	uka
No	seai	leai	ikai
Hand	lima	lima	nima
Right hand	lima ha matau	lima i matau	nima matau
Left hand	lima he laua	lima tauagavale	nima hema
Cold	hamaleo	maalili	momoho
Belly	manava	manava	kete
Bone	ivi	ivi	hui
Cocoanut	niu	niu	niu
Ear	karigo	taligo	teliga
Egg	hua	fua	fua foimanu
Fire	afi	afi	afi
Fly	lago	lago	lago
Fowl	moa	moa	moa
Large	lasi	tele	lahi
Little	lii	itu	jii
Louse	huku	utu	kutu
Mosquito	namu	namu	namu
Man	kanaka	tagata	tagata
Woman	fafine	fafine	fafine
Father	Kama-na	tama	tamai
Mother	kinaa	tina	fae
Night	bo	po	bo

(2) The reciprocal form.

N.B.—The numerals and pronouns are practically similar to the Samoan and Tongan forms. The letter "g" has the sound of "ng," as "singer."

4.—EXPLORATION IN CENTRAL AUSTRALIA.

By H. VERE BARCLAY, F.R.G.S.

5.—NOTES OF A CRUISE ROUND MELVILLE AND BATHURST ISLANDS.

By LIONEL C. E. GEE, S.M.

[ABRIDGED.]

The following notes were made by me in 1905, as a member of the Government Geologist's staff, whilst making a geological and general exploration of the north-western portion of the Northern Territory.

We had an uncomfortable night at our anchorage in Clarence Strait, situated 10 miles south of Melville Island. The numerous tide races and rips on these coasts make the sea very jobbly. Early next morning we were under way, and were soon as close to the Melville Island coast, near Maclear Creek, as it was safe to approach, and anchored again; a sandy beach was in front of us, with a heavy surf rolling in upon it. The coast seemed to be well timbered, and low hills could be seen in the distance.

The wind died away, the sea moderated, and early in the afternoon we were able to land. Behind the beach there extended a low sandy rise timbered with large casuarinas, so large, indeed, that they reminded me of the fine bull oaks I had seen on the track between Deep Well and Ooraminna, near the Macdonnell Ranges. Remains of old camp fires were seen here, and buffalo tracks were plentiful. Close to where we landed, on top of the sandy rise, we found a circular space about 10ft. in radius, carefully cleared of all grass, and a small mound piled up in the middle; our boys pronounced it to be a native grave.

Maclear Creek is a mangrove-lined tidal inlet, and the tide being low we passed it walking westward along a sandy beach, with reefs here and there. Soon we came to a conspicuous clump of large casuarinas, with old camps in the middle—a most picturesque spot just above the beach. Near here we found a turtle's nest, but the Melville islanders had found it before us. At about a mile further on the low sand rises at the back of the beach gave place to low reddish clayey cliffs, the country at the back being well timbered with woolly-butt, stringy-bark, ironwood, &c., the soil evidently being very good. We followed these cliffs on to the end, about another mile; the tide was then very low, and on the exposed rocks we found a splendid lot of fossils. I also got a few good shells on the beach. We were all well armed, of course, and Bubs and Loman (native boys with us) kept a sharp look-out. Carlos (a Manillaman of our party) was very useful in finding fossils and helping to cut them out. We got back to the lugger at dark, tired and hungry, and favorably impressed with Melville Island so far.

In the morning a strong south-east wind was blowing. We intended to land again and make inland to some low hills which could be seen from the lugger, but this was rendered impossible by the heavy surf which was breaking on the beach, so we hoisted sail and bore away along the coast to the westward. The sea was too rough for us to attempt entering Medina Inlet, the southern end of Apsley Strait, running between Melville and Bathurst Islands, and we pitched and tossed across Shoal Bay at a spanking pace ; came fairly close into the shore at an unnamed point on Bathurst Island, and under considerable difficulties had a panoramic view of the southern coast of this island.

As we speeded towards Cape Fourcroy there were low thickly wooded hills or undulations of the plateau, with white and pink cliffs below, facing the sea ; these are not high, and in many places a band of vegetation shows between the top and bottom of them ; then some large sand dunes were passed and the sandy point of Cape Fourcroy rounded. The three blackboys were in the bow on the look-out and ready to help in any way. Yells of laughter came from them every time they received an extra drenching from the flying spray, and they were keenly interested in the unknown land we were passing. Carlos steered, Peter and Pedro crouched by the stays, and Mr. Brown and I clung in the lee of the little skylight. Things were better as soon as we got fairly round the cape on to the northward course, as the land gave us some shelter.

High red cliffs faced the western shore, and in the depressions close to the shore very large trees were seen, probably banyan trees and tamarinds. Tamarind trees of great size are seen here and there all along the coast of the mainland ; they are not indigenous, and the seeds must have come from the Maccassa men, who, from the dim past, have sailed down from the Celebes to North Australia (" Marega," they call it) regularly with the north-west monsoon, returning with the south-east monsoon, fishing for beche-de-mer, or trepang, as it is generally called.

We felt assured that at any rate there were some patches of rich soil on Bathurst Island. Cliffs alternated with low sandy beaches, and at about seven miles north of Cape Fourcroy we saw, on rounding a large sandhill, a small sheltered bay, where we anchored at 3.30 p.m., after the quickest run we had ever got out of the old *Venture.*

Melville and Bathurst Islands lie, roughly, between the 11th and 12th parallels of south latitude, and in the eastern longitude from about 129° 55′ to about 131° 40′. They are separated by Apsley Strait, an arm of the sea about 55 miles long, varying in width from about five miles at St. Asaph Bay, at the north-western end, to one mile at Medina Inlet, the south-eastern entrance. Bathurst Island—the western one—is roughly triangular in shape, the base along the south coast being about 50 miles, and the perpendicular distance from Point Brace, at the entrance of Apsley Strait to the south-coast, being about 40 miles. Melville Island is much larger, and is very irregular in outline ; the extreme eastern and western points are about 85 miles apart, and the greatest breadth from north to south is about 40 miles. The northern and western coasts were seen by the early Dutch and French explorers, who named some of the points—Cape Fleming, Cape Van Dieman, Cape Helvetius, and Cape Fourcroy.

I do not think that there is any record to show that any of these old voyagers landed, and the insularity of these large tracts of country was determined by Captain P. P. King, who, in the *Mermaid*, after the discovery of Port Essington, proceeded to explore the great Gulf Van Dieman, discovered and entered for a short distance by three Dutch ships in 1705.

On April 26th, 1818, King sailed round Cape Don, and says, "To the westward the land was observed trending in a north and south direction, and bore the appearance of an island."

On May 12th, sailing up from the south-west corner of this gulf, he came to the coast again, probably somewhere between Capes Gambier and Keith, and until May 31st was engaged in circumnavigating the islands, one of which he named Melville, after Lord Melville, the then First Lord of Admiralty, and the other Bathurst, after Earl Bathurst, Secretary of State for the Colonies.

In 1824 the British Government decided to form a military settlement in North Australia, the ostensible reason being a desire to encourage trade between Australia and the East ; but the real reason, no doubt, was to take formal possession of the whole of Australia for the British Crown, as it was then deemed quite possible that the French would take possession of the unoccupied portions of the island continent. Port Essington was the portion determined upon.

King, the discoverer, had described the harbor there as being equal if not superior to any that he had ever seen, so H.M.S. *Tamar*, under Captain Bremer, with the store ship *Countess of Harcourt*, sailed from Sydney on August 24th, 1824, taking a party of the 3rd Regiment and a number of prisoners—chiefly mechanics—who were called volunteers, and arrived at Port Essington on September 20th. Formal possession was taken of the north coast, and then, because fresh water could not be readily found (there was really abundance in the locality), the expedition sailed on, further west, and arrived in Apsley Strait, Melville Island, on September 30th, formed the settlement there, and called it Fort Dundas. It was abandoned in 1829.

To resume the narrative. We landed at a sandy patch between two reefs close to vivid red alluvial cliffs about 20ft. high, showing good-looking soil, with tall woolly-butt timber at the back, mottled iron conglomerate rock showed at the bottom, and the edge of the water was stained a rusty color through the excess of iron. We found two turtles' nests in a sandy bank, one containing the large round parchment-covered eggs of the green turtle, and the other the smaller eggs of the shell turtle ; we got about six dozen eggs from the two nests. We then rowed along the shore south-eastward for a short distance and landed at another very similar place—the rocks were the same—and at a short distance back from the beach we found some native wells and the recent tracks of natives. On the top of a flat rock there were two small circles formed by loose stones; quail were abundant on this place.

The night was fine and calm, but early in the morning a strong blow from the south-east made the sea so rough that we were unable to land until after mid-day. We then pulled up a creek to the north of the sheltering point, and found it to be an inlet deep enough for small craft, to a small harbor about a mile east and west by three-quarters of a mile north and south; it is not shown on the chart, and we named it "Vernon Boat Harbor." There is a sandy beach on the north side and banks of clay and rock on the south; the surrounding country is flat and well timbered. Sailed northward again; made about two miles towards Cape Helvetius, when the wind failed, and we anchored for the night. At sunrise, with a fresh wind, we passed the low and sandy Cape Helvetius, with red cliffs running eastward from it; kept on this course to near Cleft Island, and then stood in to Gordon Bay and tacked through the entrance to Port Hurd, where there was deep water, about a quarter of a mile wide. On the south side there was a sandy beach backed by large casuarinas and paper-bark trees, and two native canoes lying on the beach, making a fine picture. On the north side patches of muddy beach and some of the tallest mangroves I have seen—they must have been 50ft. high. The port is large and mangrove-lined. We stood on towards a low hill ahead, named by King "Mount Hurd," but the water shoaled so rapidly that we were nearly aground before we could work the lugger round. We returned to the entrance, dropped anchor near the beach just inside the port, and were soon ashore examining the canoes. They were 21ft. and 18ft. long, respectively, each made of a single sheet of bark, the ends being sewn up and caulked with clay, and each contained two roughly made paddles and a large shell, evidently used as bailers. There were a few barbed fishing spears on the beach near by, and some bark rain covers. A native rain cover is simply a piece of bark about 5ft. long and 2ft. wide doubled carefully across the middle, and so gives some protection to the head and shoulders Two of the paddles and one of the bailers were taken, and in order to square matters with the owners we left a stock of tobacco in a bottle, some clay pipes, and some red Turkey twill. Our boys were confident that Bathurst islanders were close about somewhere, probably watching us all the time. I hope that when they came to balance up the exchange was considered a fair one. We then pulled across to the north side, landed on some rocks, and found them to be composed of coralline limestone, with recent shells embedded. Dugong and turtle were seen near the lugger that evening, and Bubs commenced the manufacture of a turtle spear.

Under a light breeze next morning we made slow progress through Gordon Bay, and did not pass Cleft Island until about 2 p.m.; it is very small and rocky, about 40ft. high, and covered with trees and bushes. The mainland in the vicinity shows red and white cliffs, the highest point of them being about 60ft. above high-water mark, then a sandy beach northward and reddish cliffs beyond. Large banyan trees were seen near the beach, and at the back the trees seemed very high. In the afternoon we anchored almost two miles south of Rocky Point; landed and walked northward along the coast; southward a creek or inlet running inland could be seen. This part of the coast is rocky and dangerous, the water is shallow, and the sunken rocks are doubly dangerous on account of the long seaweed growing nearly everywhere. Low cliffs face the sea here; good soil is exposed in them, in some places showing 10ft. deep. The country at the back is open forest—woolly-butt, stringybark, casuarina, ironwood, and other trees, fan and fern palms. This evening Carlos got us what Captain King would have called "a good mess of fish." He uses a small circular net weighted round the circumference. This he carries over his arm and shoulder, walks cautiously along in the water, and then with a sudden twist throws it out so adroitly that it alights flat on the water like a circular disk. When rowing back to the lugger, Loman speared a very large schnapper, but as there was no barb on the spear the fish got away. I have not mentioned that at this time of the year the natives burn the dry grass, and therefore columns of smoke are always in view in one direction or another. On this particular evening the amount of smoke hanging about had a peculiar effect on the sunset; the sun looked like a huge dim, dull, red ball, and the sea was tinged a beautiful shade of purple.

Next morning we sailed early and stood well out to sea to avoid the rocks and reefs off Rocky Point, drawing into the coast again near Caution Point; then passing Deception Point and Brace Point, the northern end of Bathurst Island, sandy beaches, with well-wooded country at the back, are seen. Passing Brace Point we ran over a shoal, and in places had only 8ft. of water in our soundings. Here we saw some immense stingrays, also some turtles and a large school of soles or flounders: then we ran into St. Asaph Bay, the entrance to Apsley Strait, which at Brace Point is about five miles wide. Our course was then south-eastward, and we were soon opposite the two points of Luxmore Head—fairly high cliffs, with tall timber on top. The strait here is three miles wide and the view ahead was picturesque and interesting, with wooded points on both sides, and Harris Island standing up boldly in the middle. The wind failed, and at sundown we anchored in Port Cockburn in 10 fathoms of water.

Early next morning we stood down the strait, tacked close to Harris Island and ran into King's Cove on the Melville Island side, Garden Point on the north, and Barlow Point (named after Captain Barlow, the first commandant of the fort) on the south. At this point we landed on some rocks, with mangroves growing between, and were soon on the plateau, only about 20ft. above the sea. Nothing was to be seen but the ordinary open forest country. I may mention that in this country (I mean North Australia generally) there is no under-growth, except in swampy depressions and along watercourses. The country is practically all timbered, the trees are some distance apart and between them grows the high grass which is periodically burnt off. Palms, fern palms, and pandanus appear here and there, but the country is rightly termed "open forest country."

We stood on this plateau, with the ordinary open forest of tall trees around us, and it was hard to realise that the whole of this point had at one time been cleared of timber, and on it had been fixed the homes of 130 white people.

Soon we came to the remains of the old fort. The ditch and earthworks were in a good state, the former averages about 6ft. deep (it was originally 10ft.), and in places is faced with stone. It measures 50yds. by 75yds., the larger side being parallel with the sea frontage of the point. The circular earthworks of the bastions (for it was a two gun fort) were remaining at the two sea-front corners. Large trees were growing in the ditch, and in the middle on the land side could be seen where the entrance had been situated. Wandering on we found the well; a big tree was growing out of it, having rooted down about 6ft. from the surface. Further on the ruins of an old stone building were seen—probably the church—then returning towards King's Cove we followed what was once a road, as shown by bits of retaining wall here and there. There were also some stone enclosures, most likely used for the live stock, and at the north corner of Point Barlow the stone part of the wharf could be traced.

Fort Dundas was a settlement that failed entirely. First of all it was in the wrong place for anything but a hermit retreat; any ships that might pass would, of course, sail away to the north of Melville Island, and the navigation of both ends of Apsley Strait is very difficult, owing to the shoals at the north-west and rocks at the south-east. The garrison did practically no land exploration; they seemed to have had not the least enthusiasm or energy in finding out the possibilities of the country; they only wanted to get away from it.

It was stated that one commandant was never more than half a mile away from his house, and another one writes that he was unable to be absent more than 24 hours at a time on his land expeditions. The gallant officer might just as well have stayed at home. They were on bad terms with the natives from the very start, and I do not think I am expressing it too strongly when I say that it seems to me that by their want of tact, timidity and brutality—brutality probably caused timidity—they aroused the bitter hostility which continues in these natives to this day. Only two aboriginal women were seen during the whole four years' stay of the garrison on the island. Those who have any experience of natives will know what this means; and up to the last, just before the place was abandoned, spears would be occasionally thrown into the hospital and huts by lurking natives.

I make the following extract from a very interesting book, entitled "A Voyage Round the World," published by Dr. T. B. Wilson, R.N., who was at Raffles Bay in 1829. Referring to Fort Dundas he says, "The natives had visited the new comers (whom I have no doubt they considered unwelcome intruders) and some slight differences had occurred. The settlement, however, got on pretty well for some time; but at length hostilities commenced between the natives and the Europeans, and proceeded from bad to worse until the hatred of both parties became thoroughly rooted. From all the accounts I could collect, and I had them from various and authentic sources, I have no hesitation in stating that the civilised party was far from being blameless. It is well-known to every person who has had the slightest intercourse with savages that they are invariably addicted to thieving. It is therefore not to be denied that the natives committed many petty thefts; but the policy of being unnecessarily annoyed thereat, and the humanity of putting them to death for such offences, may be safely called into question." I do not think that any comment is necessary on this glimpse at grim tragedies, and we can see reverence for the savage English penal code of the time, when death was the punishment for most things, peeping out even in the remarks of this naval doctor, who doubtless was, for his day, a humane and kind-hearted man, indeed he must have been or he would not have questioned the "humanity" of extending the blessings of civilisation in the shape of this awful code to the ignorant islanders. Had a tactful, mild, and firm policy been persevered in, the natives would have become reliable friends, their assistance would have been invaluable in many ways, and the splendid opportunity for making a thorough and careful land exploration of the islands could have been fully utilised. The soldiers and convicts only did one good thing, they let some buffaloes go; probably this was a misadventure, and the unfortunate individual in charge duly received six dozen of the commandant's "best" for his carelessness; but they have increased and multiplied and spread all over Melville Island. We pulled across King's Cove and landed at the north side of Garden Point on a fine sandy beach, where Bubs, by one lucky shot, secured seven fine fat ducks.

This was found to be a very pretty place. A fresh water swamp extends inland, and in the wet season this would form a good stream running into the sea. A patch of jungle exists here, and the flowers were numerous and beautiful. There were many old camp fires and shells of the giant cockle lying about. A fire was started near us, and our boys declared that the wild natives were close by. We could not find the garden on that side so we pulled round into King's Cove again, seeing two turtles *en route*, and landed on the southern side of Garden Point at an old landing-place, where some timbers of a jetty were standing. Perfectly sound sawn logs were piled on the bank close by: they were about 80 years old, and had resisted decay and the white ants. Again the hunt for the garden was unsuccessful, and we returned to the lugger. Next morning we pulled across to Harris Island, about a mile. The tide was running very strongly, and it was a very hard row. The island consists of a small stony plateau, about 15ft. above high-water mark, mangroves round the edge, and trees and jungle in the middle. Some of the trees were at least 70ft. high, and parasitical ferns were seen here and there. Then we pulled across the other portion of the strait, about three-quarters of a mile, and landed on Bathurst Island at a native landing-place, where a well-beaten pad led inland. Fresh tracks of the blacks were seen in the mud. We walked on to a flat of rich black soil, in which were pools of fresh water and large paper-bark trees growing. Most of the soil seen on Bathurst Island seems good, and all the timber and vegetation generally showed strong and vigorous growth.

Back to the lugger after a long and stiff pull, and sailed up the strait, anchoring off the south point of Luxmore Head. Here we landed and ascended to the top of the plateau, about 70ft. On the beach there are some curious-looking large, black, ferruginous sandstone rocks, like masses of boiler tubes and mouldings cemented together. Then we sailed round the north point of Luxmore Head and dropped anchor close to it in St. Asaph Bay. The cliff here is almost 100ft. high. Near the bottom was found a very large barbed turtle spear. From the top there are fine views down and across the strait, Piper's Head and densely timbered country showing up northward. At the back the usual open forest extended. The place was alive with squatter pigeons. King landed here in 1818, and ascended to the top in order to take some bearings. He had a fowling piece and the theodolite stand, and Mr. Cunningham an insect net. King fired at an iguana, and then saw a party of natives approaching them carrying spears. The two white men raced down the slope in what King calls a *sauve qui peut* sort of way, leaving the theodolite stand and the insect net as spoil to the natives, nor, although they entered into parley with them afterwards, could they be recovered. King was very distrustful of them, and perhaps missed making a favorable impression. He says that the men were better formed and more muscular than any he had ever seen before.

Going eastward along the beach, we came to a mangrove-lined creek with firm sandy banks, which in King's picture I recognised as the place where he had held a boat parley with the natives. There were a lot of old camps here, with oyster and cockle shells scattered about. In a little sandy flat there was a grave enclosed by wooden slabs, partly burnt. Aboriginal markings were faintly discernible on some of them, and some posts had the wood cut away at the top, leaving two spikes like horns at the sides; others had the wood cut away from the outside towards the centre, leaving a short spike in the middle. We crossed the creek in the boat and walked northward along the beach. Near a handsome Leichhardt tree, on the trunk of which some marks were cut, there is a native well with a good supply of water. A short time after our visit a Japanese sailor from one of the pearling luggers working over the Mermaid Shoals, while filling a keg at this well, was badly speared by the natives lying in ambush.

We had bad weather next day and were unable to round Cape Van Dieman, and ran for shelter under a small sand island about three miles north-west of the cape. Here we got plenty of turtles and birds' eggs, and found the beach strewn with drift pumice stone. Next day the weather moderated, we rounded the sandspit off Cape Van Dieman, and sailed south-easterly along the north shore of Melville Island.

It is not necessary for me to continue a detail narrative; there is a general similarity between the north and east coasts and those we have already seen. Red and white cliffs alternating with sand and mud beaches, and occasional low sand dunes backed always by thickly timbered country.

The weather was bad and the coast dangerous; on one occasion we bumped on the bottom three times in a most alarming way. We landed whenever possible, but we were not strong enough to make any inland excursions. Tracks of natives and of buffaloes were seen at nearly all the places, and at night we saw the fire-sticks carried along the beach by prowling natives. On the north beach I noticed immense numbers of cowrie shells, but of course they were much sun-bleached. Wildfowl of various sorts were plentiful, also cockatoos—black and white—parrots, pigeons, quails, and numerous strange birds. "A sportsman's paradise," as my friend Mr. Alfred Searcy calls the mainland, and a most happy hunting ground for the ornithologist, the entomologist, and the botanist. By the way, Major Campbell says that wild ginger is indigenous here. All exotic trees and plants of commercial value which have succeeded on the mainland could be grown here, and perhaps better, as the native timber and vegetation seemed to me more vigorous and stronger on those islands than on the mainland. There are no hills of any importance, and the country generally is a low tableland or plateau intersected by valleys or depressions. We found no signs of minerals. On the east side the buffalo has been hunted and a large number of hides exported.

These islands look pleasant and charming from the sea, nor is the charm dispelled when you land.

6.—SOUTH AUSTRALIAN LATITUDE AND LONGITUDE.—A SHORT ACCOUNT OF THE DETERMINATION OF GEOGRAPHICAL POSITIONS OF PLACES IN SOUTH AUSTRALIA.

By C. HOPE HARRIS.

(Communicated by the Surveyor-General, W. Strawbridge, Esq., I.S.O.)

Part I.—Longitude.

The first determinations of latitude and longitude of places in South Australia were made by its discoverer, Matthew Flinders, R.N.

This distinguished navigator mapped the entire coastline from Point Fowler to Encounter Bay, including the north coast of Kangaroo Island; and has recorded, in the journal of his voyage to "Terra Australis," vol. i., 1802, the results of many astronomical observations by which the prominent features embraced in his survey were geographically fixed.

The best results were obtained with a sextant and artificial horizon on shore. Longitudes were deduced from local time, observed by altitude of sun and stars, compared with Greenwich time shown by chronometers, the accepted longitude of a lighthouse at King George's Sound being taken into account in passing; also the longitude of Fort Macquarie when Sydney was reached. Special determinations were made on a hill west of Port Lincoln, which, on comparison, are found to be in close agreement with latest Admiralty charts.

On board the sloop *Investigator* observations were taken at Holdfast Bay and Kangaroo Head, from which the position of Mount Lofty was fixed as being in latitude 34° 59′ and longitude 138° 42′. The figures are given in the journal to minutes only, but the original chart by Flinders is correct within a few seconds of the true position. Some people may regard this as only a coincidence, but it is interesting to note that the same exactitude is evidenced by the figures given for the extremity of Cape Willoughby, at the east end of Kangaroo Island, viz., latitude 35° 58′, and longitude 138° 08′, which cannot be more correctly stated at the present time.

The next important determination of longitude concerned the boundary between South Australia and Victoria.

In December, 1839, Mr. J. C. Tyers, a New South Wales surveyor, previously of the Admiralty surveying ship *Beatrice*, was appointed to fix the position of the 141st meridian, near the mouth of the Glenelg River. This Mr. Tyers did in three ways. First, by chronometric measurement from Sydney to Portland Bay on board the vessel *Pyremus*; second, astronomically, by observation of lunar distances made in the locality with sextant and artificial horizon; third, by rapid triangulation from Batman's Hill, Melbourne, to the Glenelg River. The longitude thus obtained for the eastern bank of the mouth of the river was—by chronometers, 141° 01′ 43″; by lunars, 141° 01′ 59″; by triangulation, 141° 00′ 28″; the mean being 141° 01′ 23″.3. The lunar observations (1) were considered so good that they were printed in pamphlet form as a typical example of this kind of work; but, unfortunately, the result was nearly two miles in error. The triangulation result was really the best, being within half a mile.

Further chronometric determinations to fix the boundary were also made by Captain Stanley, R.N., of H.M.S. *Britomart*, and by Captain Stokes, R.N., of H.M.S. *Beagle*, 1845, both of whom favored a point at some distance west of that indicated by Mr. Tyers' observations; so the question of deciding upon a starting point was ultimately referred to a select committee. (See British Parliamentary Papers, No. 120, vol. 29, printed March 9th, 1841; also Inquiry of 1855, Votes and Proceedings, New South Wales, vol. 2.)

SNAPPER POINT, PORT ADELAIDE; SEMAPHORE AND GLENELG.

Early in the history of the colony signal stations were erected at West Terrace, Port Adelaide, Glenelg, the Semaphore, and at the lightship, for the purpose of announcing the arrival and departure of vessels, as mentioned in the second report of the Colonisation Commissioners, 1840-41.

In 1844 the Glenelg signal station was chosen by Colonel Frome as the western extremity of the base line of an extensive trigonometrical survey, and its geographical position was consequently of great importance.

The longitude was ascertained, as far as practicable, by chronometric measurements by Admiral Crozier, 1839; Captain Stokes, R.N., 1842-5; Captain Wickham, Captain Hutchison, and more recently by Captains Howard and Goalen. A letter to *The Times*, from Mr. John Arrowsmith (reprinted in the *South Australian Register* of September, 18th, 1841), also gave valuable information on Australian longitudes.

Captain Inglis, Harbormaster, Port Adelaide, has, by courtesy of the President of the Marine Board, kindly supplied notes to the following effect:—"According to old charts Snapper Point and Glenelg flagstaff were in exactly the same meridan. Captain Hutchison considered the latter to be in longitude 138° 32′ 42″ by chronometric measurements from Fort Macquarie, Sydney. In the "Sailing Directory, 1868," Glenelg flagstaff is the observation spot. I can find no record of any special determination of Snapper Point; but in the "Sailing Directory" of 1876 it is made the observation spot, with a longitude of 138° 31′ 00″, deduced by time signals from Melbourne Observatory. This was altered again in 1883 to 138° 30′ 05″, or 9hrs. 14min. 3·37secs., as the result of telegraphic signals from Greenwich, *via* Singapore and Port Darwin."

At the request of Captain Hutchison the mast at Snapper Point was connected by triangulation with the Observatory during 1868, and the difference of longitude thus computed to be 4′ 15″·6 of arc,

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(1) By the term lunar distance is meant the process of finding the true angular distance of the moon from the sun, or from a star, by observation of their apparent distances and altitudes, which, compared with local time and certain data in the nautical almanac, gives the longitude.

equal to 17·02 seconds of time, was communicated to Captain Hutchison in a memorandum from Mr. A. B. Cooper, Deputy Surveyor-General, dated November 6th, 1868.

CAPE WILLOUGHBY.

During the year 1850 Mr. J. T. Manton, under instructions of the then recently formed Trinity House (Marine Board), determined the longitude of Cape Willoughby Lighthouse, Kangaroo Island, by 13 lunar observations, with the following results :—One, taken in August, gave 9hrs. 12min. 39secs. ; three in October gave 9hrs. 12min. 28secs. ; and nine in November gave 9hrs. 12min. 33secs. ; the mathematical mean adopted being 9hrs. 12min. 32secs. = 138° 08′ 00″, which is as nearly correct as can be calculated.

ADELAIDE OBSERVATORY.

About 10 years after the Adelaide Observatory was established, its longitude was ascertained, with a near approach to accuracy, by telegraphic time signals with Melbourne and Sydney Observatories, the positions of which had been independently fixed by astronomical observation. The longitude then adopted and printed on official memo. forms was 9hrs. 14min. 21·4sec. = 138° 35′ 19″·5.

A special feature of time signals consists in observing the astronomical local time at the precise moment of transmitting and receiving signals, and eliminating personal errors. The telegraph operator's part is so well done that any set of signals may usually be depended upon to one-tenth of a second of time ; but the astronomer's part—unless he be an expert—may contain an error for the set approaching one second of time. Sir Charles Todd gave a very clear explanation of the method in use in an address to the Institute of Surveyors, November 2nd, 1888, printed by that body in its annual report.

Twenty-four years ago, in conjunction with the Government Astronomers of Victoria and New South Wales, and Captain Darwin, R.E., the Government Astronomer of this State, Sir Charles Todd, completed from Singapore a telegraphic determination from Greenwich, *via* Palmerston, to Adelaide, Melbourne, and Sydney ; obtaining thereby for the longitude of Adelaide 9hrs. 14min. 20·30secs. = 138° 35′ 04″·5. This result was verified last year under direction of Professor O. Klotz, from America, by trans-Pacific cable to Sydney. Professor Klotz's determination places Sydney 85ft. further east than the published longitude, which affects Adelaide to the same extent.

WESTERN BOUNDARY OF SOUTH AUSTRALIA.

Parliamentary Paper, No. 137 of 1867, shows that an effort was made that year to locate the position of the 129th meridian of longitude forming the western boundary of this State. Captain Douglas, R.N., President of the Marine Board, erected an obelisk near the coast, about seven miles this side of Eucla, which purported to mark a point on the boundary line, but is now supposed to be half a mile or more too far east; whilst a line surveyed the following year by Captain Delisser, of the Survey Department, as a fixing for pastoral leases, is about one and a half miles too far west.

In May, 1880, Captain Howard, R.N., Admiralty Surveyor, exchanged time signals from Eucla telegraph station with the Adelaide Observatory. On the 4th May he found the difference of time to be 38min. 46·34secs., and on the 6th to be 38min. 47·22secs; the mean of these results is 38min. 46·78secs., corresponding to 9hrs. 41mins. 42·72secs. of time E. of Greenwich, giving longitude 128° 53′ 21″·78 for Eucla Telegraph Station.

Three years prior to this (April, 1877) the same officer exchanged satisfactory time signals with Adelaide from the telegraph station at Flinders, Streaky Bay. He made the difference of time 17min. 28·9sec., or 4° 22′ 13″, which gives longitude 134° 12′ 51″; that is about 100yds. farther west than by Survey Office data.

EASTERN BOUNDARY—NORTH OF THE MURRAY.

In order to fix the position of the 141st meridian of longitude forming the boundary between South Australia and New South Wales, the Governments of the two States concerned authorised their astronomers, Messrs. C. Todd and G. R. Smalley, to decide the position. This they did by telegraphic time signals between Melbourne and Sydney from a temporary observatory on the north bank of the Murray, where the boundary was supposed to be, using for the purpose a 4ft. transit instrument, having an aperture of 2¾in. and furnished with several vertical spider lines, and three chronometers. (See P.P. 182, vol. III., 1868-9).

A discrepancy in the accepted longitudes of the two capitals rendered the work subject to a slight uncertainty, but fortunately the brick pyramid then erected, from which the line was marked out, coincides with the true position of the 141st meridan, as obtained by triangulation from Adelaide Observatory; and by time signals, made August, 1890, between Sydney and the town of Burns (at the 134th milepost north of the river), by J. Brooks, Esq., Field Astronomer.

PALMERSTON.

Whilst the survey of Palmerston was proceeding, together with lands adjacent, in 1869, the Surveyor-General (Mr. G. W. Goyder) took several lunar observations with a portable transit and sextant. The longitude of Fort Hill thus obtained he recorded as 130° 52′ 40″, several miles nearer the true position than shown by any available chart. The correct longitude of Fort Hill, deduced from the cable station, is 130° 50′ 44″·3.

During the construction of the overland telegraph line, 1870-1, a scientific member of the party took a great many lunar observations at Charlotte Waters, and a few years later communicated the result to the writer, expressing the belief that they would ultimately be found exact. His determination was 134° 58′ 00″, now found to be 134° 55′ 08″.

In 1873 a member of the Survey Department exchanged time signals with the Observatory from Alice Springs Telegraph Station. This was done again by another officer in December, 1880. The mean of the two sets was 18′ 51″, which, adapted to the present published longitude of Adelaide, gives 133° 52′ 20″ for Alice Springs.

In 1880 one of the same officers exchanged time signals with the Observatory from Tennant's Creek Telegraph Station, the difference of time being 17min. 28secs., from which 134° 13′ 04″·5 has been adopted for the present longitude of that station, subject to an uncertainty of 300yds.

In 1880, at the time of the Herbert River pastoral blocks being offered for sale, Mr. C. Winnecke fixed the longitude of Lake Nash by occultation of Jupiter's satellites (2), and of a stone pile at the junction of the Herbert and James Rivers by observations consisting of moon culminating stars and moon occulting stars (3). The circumstances, however, were not favorable, and the longitude so obtained was not adopted. Subsequently, by chainage of pastoral surveys connecting the junction pile and the overland telegraph line, the longitude of the line where it crosses the Fergusson River, has been found to be 133° 38′ 46″.

LINE TO GULF OF CARPENTARIA.

The demarcation of the 138th meridian of east longitude, dividing Queensland from the Northern Territory, was carried out during 1883-1886 by Messrs. Poeppel and J. Carruthers, assisted by Mr. L. A. Wells, Government Surveyors of this State. The point of commencement was ascertained by chainage from the eastern boundary line in 1880-81, checked by triangulation connected with the newly determined longitude of Adelaide Observatory. The south-west corner of Queensland is, therefore, correctly fixed, and this is the more satisfactory, as the line surveyed thence to the Gulf of Carpentaria proved to be a costly undertaking, and is the longest surveyed straight line in the world—650 miles 5,700 links.

MOUNT GAMBIER.

During recent years the longitude of Mount Gambier Trigonometrical Station has been calculated from Adelaide, partly by triangulation and partly by chainage of hundred boundary lines compared

(2) *Occultation of Jupiter's Satellites.*—The Greenwich mean times of disappearance and reappearance of Jupiter's satellites are given in the Nautical Almanac, and from observation at any other place of the local time at which these phenomena occur, the difference of time, and, therefore, the difference of longitude, is found.

(3) *Moon Occulting and Moon Culminating Stars.*—By the term occulting is meant the observations necessary to compute the exact right ascension of the moon at the moment that a star in its path is hidden by the bright edge of the moon. From the difference between the right ascension so found and that given in the Nautical Almanac for Greenwich mean time, as if viewed from the centre of the earth, the longitude of the observer is deduced.

Culmination is the term employed when the moon's right ascension is found by observation of moon and stars passing the meridian nearly at the same time.

with data of the railway survey; the resulting longitude, 140° 45′ 32″, is only a few yards less than that calculated by geodetic survey from Melbourne Observatory, kindly supplied for this paper by the Surveyor-General of Victoria, Mr. J. M. Reed.

PART II.—LATITUDE.

The first South Australian latitudes by Matthew Flinders, R.N., in 1802, are in every case correct to the nearest minute.

The next reliable latitudes since that date were observed in 1842 by Colonel Frome, Surveyor-General, with a sextant, during short exploratory trips south and north of Adelaide.

Afterwards by Mr. G. W. Goyder, when Assistant Surveyor-General to Major Sir Arthur Freeling, 1857-61. Mr. Goyder's determination of the latitude of Black Rock in the north—32° 44′ 29″—is accepted as correct, that of Mount Brown as being 6secs. too low, and Mount Margaret 10secs. too high.

Since then many excellent determinations have been made by various officers of the Survey staff, of which the following are the best:—During 1879 one of the staff was entrusted with the duty of defining the north boundary of county MacDonnell, which, by proclamation in the *Government Gazette*, commenced in latitude 36° 28′ 00″. His observations were so carefully made that the point fixed by him agrees to a second with the position calculated by recent surveys connected with Adelaide Observatory. This determination was checked seven years later by another officer's observations, made 32 miles north and connected by chainage. They agree to one-third of a second.

In connection with the trigonometrical survey north of Lake Gairdner careful determinations of the latitude of three stations were made by Mr. W. Barron, with a transit theodolite and sextant, which do not differ from their calculated values more than 3secs. The middle one of these, Kingoonya, latitude 30° 57′ 49″, has been adopted as exact. Mr. Barron's observation at the 348th milepost on the New South Wales boundary line, latitude 28° 57′ 57″·5, is equally good, and agrees exactly with the intersection of the 29th parallel subsequently defined by Mr. Cameron, under contract with the New South Wales and Queensland Governments.

A more recent determination at the 134th milepost (latitude 32° 04′ 23″), connected by chainage with boundary post east of Pinery Hill, gives for the post, latitude 32° 12′ 32″. Thence, by calculation westward to Black Rock, close agreement is obtained with the latitude observed there, making Black Rock latitude 3secs. higher.

Going northward from Black Rock the latitude of Mount Serle is calculated to be 30° 30′ 15″. There the local observation is quite wrong; but calculating southward from the 26th parallel the value of 30° 30′ 12″ is obtained. The latter of these carried westward to

Strangway's Springs Trigonometrical Station, gives 29° 12′ 05″ for that place; while, by calculation from Kingoonya, situated 120 miles south, it is 29° 12′ 03″. Continuing northward, Mount Margaret works out 28° 29′ 15″, and Mount Alberga, in the Musgrave Ranges, 26° 59′ 06″, specially determined at different times by Messrs. E. B. Jones and J. Carruthers as 26° 59′ 04½″ (which is 1½secs. less than the calculated value). Carrying the computed value of Mount Margaret north-eastward to Cowarie and thence northward to the south-west corner of Queensland a perfect close is obtained on the 26th parallel. Observations for fixing the 26th parallel of latitude, forming part of Queensland boundary, were conducted by Mr. Aug. Poeppel, with a 6in. transit theodolite and two sextants. Three observers took part in the observations, which were numerous and conclusive. The line was marked in short chords westward through three degrees of longitude, the utmost care being taken to preserve its true curve.

During the survey northward of the boundary line between the Northern Territory and Queensland, 1883-86, some special sets of observations were taken, showing a remarkably close agreement between the measured and observed intervals of latitude. Notably at the Woodroffe, 311 miles 4,718 links, where the mean of 100 observations of meridian transit of stars gave 28° 21′ 06″ against 28° 21′ 05″·9 calculated. When opposite the Herbert River, a tie was made with the junction pile, 20 miles 1,526 links west and the latitude 20° 36′ 09″·07, observed by Mr. Winnecke five years previously, was now found by chainage from the 26th parallel to be 20° 36′ 09″. Crossing the high land in the region of Nicholson River the chainage showed some slight discrepancy with the observed latitude (1″ to 2″). When the Gulf of Carpentaria was reached the observed latitude—16° 30′ 25″·84—was 3″ lower than that given by chainage from the 26th parallel through a distance of 650 miles 5,700 links.

During recent years the latitude of Mount Gambier Trigonometrical Station has been calculated from Adelaide, partly by triangulation and partly by chainage of hundred boundary lines compared with data of the railway survey. The resulting latitude is 37° 50′ 30″ against 37° 50′ 32″ observed by the late Mr. Allen, of the Victorian Geodetic Survey.

CLOSING REMARKS.

Considerable discrepancies frequently occur between observed and calculated latitudes (of which no mention has been made here), due partly to local disturbances of the spirit-level from gravitational causes, and partly to inexperience on the part of the observer.

The answer to a question sometimes asked as to whether any noticeable deflection of the plumb-line has been induced by the subsidence of the Lake Eyre basin in the interior, or by the elevation of mountain masses elsewhere in South Australia, is bound up with this subject; and it is hoped that the present paper may help at some future time in the solution of an interesting problem.

Annexed will be found a schedule of geographical positions which may be accepted as correct within two or three seconds of arc.

A study of the foregoing details brings to the surface the fact that astronomically observed intervals of both latitude and longitude are longer than their measured values. This is precisely what Sir David Gill has found to be the case in the triangulation of South Africa, and indicates that either the dimensions of the earth used in calculation are not in strict conformity with this part of the globe; or that the unit of measure adopted here is slightly too long (say, one-fifteenth of an inch per chain).

This paper shows conclusively that longitude obtained by observation of lunars (occultations, and of moon culminating stars) are useless as absolute determinations for any other than nautical or exploratory purposes; whilst telegraphic time signals are so accurate that the distance between Adelaide and Melbourne observatories obtained thereby, in conjunction with latitude, agrees to within a few yards with the distance actually measured.

SCHEDULE OF GEOGRAPHICAL POSITIONS.

Name of Place.	Latitude.			Longitude.		
	°	′	″	°	′	″
Adelaide Observatory	34	55	37	138	35	04·5
Alberga, Mount	26	59	04·5	134	16	12
Alice Springs	23	40	39	133	52	20
Black Rock	32	44	29	138	48	24
Brown, Mount	32	30	21	138	00	29
Charlotte Waters Trig. and T.S.	25	55	39	134	55	08
Cornish's Base, North end of	27	34	23	138	32	52
Cowarie Trig.	27	41	58	138	19	51
Distance, Mount	29	51	03	139	14	04
Eba, Mount	30	42	32	135	11	52
Ferguson Crossing, N.T.	17	53	58	133	38	46
Gambier, Mount (summit)	37	50	32	140	45	32
Horrocks, Mount	33	55	55	138	40	29
Josephine, Mount	31	41	13	139	06	00
Junction Pile, Herbert River	20	36	09	137	41	18
Kingoonya	30	57	49	135	21	00
Lofty, Mount	34	58	29	138	42	24
Margaret, Mount	28	29	15	136	04	49
Miccolo, Mount	32	31	12	136	36	12
Palmerston Cable Station	12	28	13	130	50	37·3
Palmerston, Fort Hill	12	28	25	130	50	44·3
Pearson's Peg, on boundary	32	12	32	140	59	57
Serle, Mount	30	30	15	138	53	54
Strangway's Hill	29	12	03	136	26	49
Streaky Bay		—		134	12	51
Tennant's Creek T.S.	19	33	42	134	13	04
Termination Hill	30	15	27	138	02	51
Yarlbrinda	31	56	39	134	44	10

The official figures used herein have been quoted by permission of the Surveyor-General.

7.—IN SEARCH OF LEICHHARDT IN 1882.

By WILLIAM N. FRAYNE.

While prospecting in the country around Limmen Bight Ranges I came across a paragraph in an old paper where the New South Wales Government was offering a reward of £1,000 for any relic of the lost explorer Leichhardt, and having plenty of time at my disposal, and also well equipped with horses and plenty of rations, and being my own master, I came to the conclusion that I would make the attempt. Knowing of a tree on the divide near a small creek running into the McArthur River (by the Nicholson Creek) marked with a big "L" and other lettering, I made that my starting point; and knowing, through reading extracts of papers on the subject, that Leichhardt's destination, if possible, was the west coast of the continent, I came to the conclusion that he would naturally follow any watercourses trending in that direction.

Having reached the tree on the Nicholson Creek, we followed the trend of the water to Anthony's Lagoon, which in most seasons is a permanent waterhole surrounded with rich pastoral country. We still go west and follow the Boyd Creek, and there is another tree marked "L," and other lettering which is indistinct. Our next start was for Turkey Creek, where there are some small waterholes, with good grazing country and flooded flats with stunted gums and coalbars (a kind of boxwood), and following one of the numerous creeks down we came to a large area of flooded country extending, as far as I know, for over 60 miles long and, in places, over 30 miles wide, and the greater portion covered with a soft silt, which I know to my sorrow, for when crossing it in several places my horses used to sink into it over their fetlocks at every stride. On reaching this flooded country, and the country looking none too promising for water, and the season getting late, we came to the conclusion to camp here and wait for the wet season before proceeding further. We looked around and found the best waterhole we could get, and after satisfying ourselves about the locality we built a camp and made ourselves comfortable till the rain came, which it did in due course and with a deluge. We had selected our camp where we thought we should be safe from the flood-waters, but we found, when too late, that we were surrounded by water for miles, and that our dry ridge was gradually getting covered with water, and we were caught in the flood.

Now, this lake or swamp is where the flood-waters of the Attack, Tomkinson, and numerous other rivers and creeks empty their waters over an area of 60 miles north and south and about 30 miles east and west. The greater part of it is covered by a heavy silt that has been deposited for centuries, and the highest parts must have been at times covered with water, as the trees have got flood-marks of driftwood lodged in the branches. Westward there is some high country; some of it (around Millie Spring) is of limestone and schistose rock, with numerous caves; and still further west the country is composed of quartzite and slate formation, intersected with quartz reefs of a very promising character. There are a few caves in this district which I visited in the hope that Leichhardt reached there and left some relics in the caves, but I could not find even a tree with any marks corresponding with the others, nor could I learn anything of them except through an old native, who said that "Long time," when he was a boy, "white fellow been sit down longa water, big fellow flood come along wash him away, no more jump up," I tried to get the old blackfellow to come and show me the place, but he told me "No good that one country, debil debil sit down." I could not get him to come with me, and one can take his statement for what it is worth. I had to give up the search (after three months) through my rations getting short, and the nearest place to get fresh supplies was 400 miles away. But I still believe that in time, when that part of the country is more explored, someone might find some remains of the lost expedition, as I am convinced that Leichhardt and party perished there either by water or the natives, probably by the latter.

The country described is between Anthony's Lagoon and the telegraph line south and by east of Renner's Springs, near Powell's Creek, Northern Territory of South Australia.

Section F.

ANTHROPOLOGY AND PHILOLOGY.

1.—THE PLACE OF THE AUSTRALIAN ABORIGINAL IN RECENT ANTHROPOLOGICAL RESEARCH.

By W. RAMSAY SMITH, D.Sc., M.B., C.M., F.R.S. (Edin.),

Permanent Head of the Department of Public Health of South Australia.

"Anthropology, be it observed, is far from being a science of luxury. At this very moment it is leading to most important results, and is throwing new light upon all the sciences bearing upon man. Naturalists, physicians, men of letters, artists, philosophers, lawyers, diplomatists, travellers, archæologists, and linguists are all carrying the material wherewith to build the edifice. To those who apply themselves closely it is a somewhat arduous task, but to the great majority it is a recreation."—TOPINARD.

It goes without saying that all of us here are interested in anthropology. It is a matter, therefore, within our common knowledge that at the present time the greatest interest is being concentrated on, and the largest amount of study is being devoted to, the Australian aboriginal. The particular points that are calling for study and research, and the position and importance of these in the science of anthropology, may not, however, be so well known. I will endeavor, therefore, to set forth briefly the place of the Australian aboriginal in recent research in anthropology, and to outline what has been done, what is being done, and what still requires to be done in order to settle problems that are calling for solution. As almost every part of the anatomy of the aboriginal is being examined and re-examined with the view of discovering keys that will open up the secrets of human origin and racial affinities, I will try to indicate to scientific workers how they may aid by observations; and I also desire to show the general public how they may help by collecting materials for the investigators. Avoiding generalities, then, let us proceed to the details of practical work.

Some years ago it became known, in connection with certain criminal trials in Adelaide, that I had more than a general interest in skulls. and Mr. A. C. Thomas, now the Crown Law Clerk, presented me with a specimen. On account of the abnormality it showed in dentition, I sent it, along with another skull, to an anthropologist who was likely to make good use of the evidence it afforded—I mean my former teacher, Sir William Turner. I need hardly remind you that it was he who was entrusted with the task of describing the *Challenger* collection of osteology, and that the investigations he made and the results he published then and since then have become landmarks in the fields of anthropological research and models for future investigation. It will be evident that any opinions or inquiries coming from such an investigator are entitled to the highest respect and consideration.

In the end of July, 1899, he wrote me as follows:—"The two Australian crania, which you wrote about in March last, reached me last week, and I am much indebted to you for presenting them to the Museum. The male, with the supernumerary teeth, is especially interesting. I have one from Gippsland with a supplementary tooth behind the left upper wisdom, and another from New South Wales with a supernumerary tooth lying in the palatal plate of the left superior maxilla. The presence of three supernumeraries in one skull is, however, very remarkable, and I know of no similar instance. The female skull shows an extreme degree of prognathism for a human skull, and is valuable on that account. Anything that you can send illustrating the osteology of the Australian will be very acceptable: long bones, vertebræ, sacrum, and innominate bones more especially. I shall be glad to be made the custodian of such specimens as you may be able to send."

The description of the Morambro skull, which is the one referred to above, was published in the *Journal of Anatomy and Physiology*, vol. XXXIV., and in that account the two other skulls also mentioned in the letter are referred to as having been described by the author in his *Challenger Report*, vol. XXIX., 1884.

Quite recently Dr. R. S. Rogers, of Adelaide, whose name is mentioned in the *Challenger Report* just referred to, in connection with an "especially interesting" skull from Milang, gave me an aboriginal skull which he found at Henley Beach. It possesses two extra upper teeth. On the left side (Figs. 1 and 2) there is a completely-formed full-sized fourth molar, which has not erupted. On the right side (Fig. 3) a supernumerary molar tooth projects on the facial aspect of the superior maxilla, about the level of the third molar.

I do not find any instance of a supernumerary molar tooth erupting in such a position. Ordinary molars sometimes do. Duckworth (*Morphology and Anthropology*, p. 279) reports a skull from the Soudan with the third upper left molar similarly placed, also a skull from the Punjaub, an Australian skull in Dr. Haddon's possession, the skull of an orang-utan in the Amsterdam collection, and a prehistoric skull from Jamaica in which the third upper right molar has emerged on the buccal aspect of the maxilla.

On the occurrence of supernumerary molars, Turner says: "From the series of specimens which I have recorded it is obvious that the upper jaw is much more frequently the seat of supernumerary teeth than is the mandible." Thompson says (*The American Text-book of Operative Dentistry*, p. 48): "Fourth molars sometimes appear as supernumerary teeth, and are either fused to the upper third molar in a variety of uncouth forms or erupt separately as mere peg-shaped teeth between the buccal faces of the second and third molars, or at the distal aspect of the latter tooth. The fourth molar rarely appears as a full molar, except in some of the large-toothed races, as negroes, Australians, &c.,

and then usually in the lower jaw. Among the negroes in Africa the fourth molar is sometimes found in full form as a typical molar." It will be evident, from recent investigations, that these statements require revision.*

It is remarkable that among the skulls of all races in the *Challenger* collection, the Cambridge Anthropological Museum, and the Edinburgh University Museum, the only recorded instances of supernumerary molars occur among Australian aboriginals; and, of a total of seven extra teeth enumerated, South Australia contributes five—a goodly share. I have to add another. In a skull recently brought from the Coorong there is a single socket for a tooth behind the third left molar (Fig. 4). Unfortunately, the tooth itself has dropped out, so that it is impossible to say anything regarding the number of its cusps.

Another condition that has been attracting attention is the occurrence of "dental rudiments"—usually small masses of dentine. These are found most often between the last premolar and the first molar, and generally on the lingual margin; but I have noted the occurrence on the buccal margin in the skull of a kanaka. After long search, I am now able to record their occurrence in the upper jaw of a full-grown aboriginal which Dr. Rogers brought me two or three days ago from the Pinnaroo district. On the left side, between the last premolar and the first molar, and chiefly on the lingual aspect, there is a dental rudiment (Fig. 5) possessing the characters of a peg-like tooth, the crown being 5 mm. in diameter and the tooth projecting 6.5 mm. beyond the alveolus. On the right side, between the buccal root of the last premolar and the corresponding root of the first molar, is a small rudiment, 7 mm. long and 3 mm. in diameter (Fig. 6). It reaches only to the level of the necks of the adjacent teeth, and would probably have been invisible during life. This case possesses an additional interest, since on the one side the rudiment has the character of a mere ovoid, or slightly flattened mass of dentine; whereas on the other it is a true miniature tooth. These two specimens are among the most important, if not actually the most important, "rudiments" as yet found in the human subject.

In this connection I may quote from a description I sent to Sir William Turner in December, 1902, of an aboriginal skull found at Glenelg. "On the left maxilla there is a tooth socket which may have belonged to an extra permanent tooth or a persistent milk-molar. A large socket on the right maxilla, corresponding in position, has an evident appearance of being separate. I have seen similar appearances in other aboriginal skulls in connection with the first molar tooth; but

* Since this was written, the Secretary to this Section, Mr. Gill, the unlabelled and unadvertised repository of so much information on anthropological subjects, has brought under my notice a very interesting communication made to the Odontological Society of Great Britain by Mr. J. R. Mummery, in 1870. During an extensive examination of the skulls of the African races, Mr. Mummery found six cases of extra fourth molars in the upper jaw, two of the cases showing a molar on each side of the jaw. He says, "It is a remarkable circumstance that I met with no example of a supplementary tooth in the lower jaw; but the third molar is frequently larger than the second."

I cannot determine whether the socket in question ever contains a separate tooth or is merely the socket for one fang of a premolar, the two other fangs of which occupy a normal position in the maxilla. I have not seen such a socket in connection with any other tooth."

In August, 1905, I sent a skull of a young kanaka from New Caledonia to Professor Cunningham, asking him to look carefully at the dentition. He wrote: "The dentition of the skull of the kanaka girl is peculiar. The second premolar socket (the tooth is gone) is enormous, and has all the appearance of a molar socket; indeed, on the right side it shows three compartments for fangs. Still, it must be a premolar, I should think. I shall look more closely into the matter."

Another skull of a kanaka which I received lately from New Caledonia shows on the left side a pit-like depression internal to the second bicuspid, which was either shed early or else was abnormal as regards its roots (Fig. 7). On the right side there is a similar, but less marked, condition. One wonders whether these pits can be the altered sockets for milk molars that have not been followed by premolars.

These large sockets are remarkable as occurring in the positions where dental rudiments are commonest.

Duckworth adopts the view that these particular dental rudiments are aborted third premolars. As he points out (*Studies in Anthropology*, p. 22), the racial occurrence of these rudiments is peculiar. They are commonest in New Britain natives, Australian aboriginals, and African negroes. One hundred Peruvian skulls showed only two instances; 50 European skulls only one instance; and 300 skulls of Egyptians showed none. Among orang-utans and gorillas specimens were very common.

On this subject of supernumerary teeth it may be well to remind you that Hunter was of opinion that they were always incisors and canines, and that Owen stated that he had never seen a supernumerary premolar or molar.

The interest connected with these extra premolar or molar teeth lies in their approximating to the dentition of the New World monkeys, which have an extra premolar. This interest is further increased by the fact that a question has now arisen as to what constitutes a premolar. The view that a premolar is a tooth that takes the place of a milk molar is being questioned.*

Most workers in the anthropological field say no more about the significance of abnormalities of dentition than what I have mentioned.

*After this was written I availed myself of Dr. Stirling's kind permission to examine the series of aboriginal skulls in the South Australian Museum. In one of them there is an extra lateral incisor tooth in the left maxilla. The two laterals on this side are small and peg-like (Fig. 8). This condition bears upon the subject of which incisor has been lost in man, a question discussed by Turner, Albrecht, Wilson, Gadow, Elliott Smith, Windle, and Edwards. Windle holds that the loss of the incisors is consequent upon the contraction of the anterior part of the jaw. He is inclined to believe that the decrease in size exhibited by the jaws of the modern English as compared with Australians, negroes, and ancient British is exhibited in perhaps the most marked manner in the incisive region. The examination of even a few aboriginal skulls is sufficient to expose this error.

It would be wrong, however, to lead one to suppose that the subject of teeth in the aboriginal is connected solely with man's affinities with the monkeys and apes. It goes really much further. It raises questions about the origin of heterodont teeth and the formation of the cusps of the premolars and molars.

Works on dentistry—I speak of the best and the recognised standard works—give clear and precise and plausible descriptions of the method in which bicuspid and molar teeth are built up from the primitive simple conical forms by aggregation or fusion. Many give no hint or suggestion that there may be any other theory on the subject. It should be mentioned, however, that there is a good deal of evidence in favor of the view that the primitive molar of the mammals was a single simple cone, and that the present forms have arisen by successive additions of cusps to this cone. Some teeth that I have described in a communication to the *Journal of Anatomy and Physiology*, written at Professor Watson's instigation, show very instructive relations between cusps and those peculiar structures known as enamel tumors, which have been aptly described by Salter as "submerged cusps"; and it is very interesting to find that one of the finest of these specimens is the tooth of a kanaka that I brought from New Caledonia.

In another specimen described in the same communication the cingules of two fused central incisors have developed a cusp-like growth, strongly suggestive of the cusp-accretion theory, while the form of the roots of a canine seems to yield strong support to the fusion-of-cones theory.

I must refer in this connection to some extraordinary milk teeth in a young aboriginal subject. The milk molars beyond the crowns are ballooned to an enormous extent, and an examination of the fangs and the portions that are becoming fangs gives rise to a question as to whether the roots of these milk molars are not being developed by a process of plication of a primary simple tube.

An observation bearing on the structure of the teeth may be mentioned here. The lower jaw of an aboriginal from the Coorong had been exposed to sunlight and great heat, with the result that the teeth are "weathered" and split up into what may be termed their component parts. A "part," often, though not invariably, is seen to consist of a root and its directly superimposed cusp.

In a paper sent to the Royal Society of Edinburgh I have dealt with some aspects of the dentition of aboriginals. I may record one observation here, however, since it illustrates a statement made by Burchard (*Dental Pathology and Therapeutics*, 2nd Edn., p. 230) to the effect that "An excessive growth of hair upon the face and body has also been associated in some cases with a deficiency in number and alteration in form of the teeth. In other cases no abnormality was noticeable. In some cases the hair and other dermal structures may be normal and the teeth be quite deficient in number." Other instances have been noted by Topinard (*Anthropology*, p. 162), who refers in this connection to the influence of heredity.

Dr. Rogers was good enough to give me an opportunity of examining an aboriginal patient of his in hospital, and he pointed out the excessive growth of hair on the body. I found the man's front teeth were crowded together, and that an incisor was wanting. He stated that his mother and aunts showed a similar condition, but not his father. (Figs. 9 and 10 are photographs of casts of the lower jaw made for me by Dr. Crank.)

The upper jaw of an infant presents an interesting condition. The two maxillæ have been split asunder, and the remains of the maxillo-premaxillary sutures are perceptible, thus making evident an abnormal condition of dentition. This consists in the presence of a single cavity in each premaxillæ, between the canine socket and the intermaxillary suture. The cavities are similar, and each contains a single large developing incisor, which has split transversely in such a way as to give the appearance of one chisel-like incisor behind another. An examination of the root shows the true nature of the condition. On the right side, on the lingual border, there is an appearance that suggests that there had been two milk incisors in the premaxillæ. It would be difficult to say what the condition had been on the left side. On both sides the temporary molars have dropped out, and the bicuspids are seen deeply embedded in the bone (Fig. 11).

In the lower jaw the sockets of the two canines and four incisors are seen in front of the first milk molars, which are still present. The left lateral incisor socket is small. On the right side a permanent tooth is seen emerging in a position occupying the places of the former canine and lateral incisor. On the left side the jaw has been broken across, and shows a tooth in a corresponding position very deep down in the jaw—evidently a canine. Between this and the posterior surface of the bone is a large tooth cavity, which communicates with the socket of the lateral incisor. Further examination would involve trephining the bone, which I am loth to do until others have had an opportunity of examining it in its present condition.

In a specimen from an old adult subject there is a gap on the right side, where the canine ought to be and probably was. Above the lateral incisor, and projecting through the bone, is an apparently full-sized tooth (Fig. 12). There is also another tooth embedded in this maxilla and projecting on one side into the anterior part of the antrum and on the other into the inferior meatus. The rest of the teeth are normal. There would thus appear to be two extra incisors in this right maxilla. The left seems to be normal.

When examining a broken skull of a South Australian aboriginal that I received some years ago, I found a peculiarity in the dentition. On the left side the second and third molars would seem to have disappeared some time before death. The first molar is turned inwards (Fig. 13), so that the labial surface of the crown is horizontal, and this surface has become worn smooth against the teeth of the lower jaw. There is a similar dislocation of the corresponding tooth on the right side, but to a very much less extent, and the molar behind it is not at all displaced. All the teeth remaining in the jaw are much worn.

On this subject Duckworth says (*Morphology and Anthropology*, p. 372): "There remains for notice a peculiar condition of the teeth most frequently observed in natives of the Chatham Islands (Mori-ori) and in Maories; also, but less commonly, in Eskimo. The molar teeth are dislocated and inflected inwards, so that instead of the normal upper surface the labial side of the crown comes into use. The significance and causation of the condition are quite obscure, but it would appear to be related to the nature of the diet of the natives among whom it obtains."* These remarks probably require to be revised. Dr. Crank, of this city, informs me that the most extreme instances he has seen have been in the white subject.†

The relative sizes of the various molars, and the number of cusps these teeth bear in different races, have formed the subject of extensive research in England, France, and Germany. Much of this has been directed to Malays, Melanesians, and Polynesians, but the Australian aboriginal has been, comparatively speaking, neglected in this particular. The same requires to be said regarding the study of the shape of the alveolar border of the jaws.

Some remarks may be expected regarding the meaning of such abnormalities of dentition as have been mentioned. To show what is taught, and sometimes accepted, I may quote from a recent work on dentistry. The author writes as follows (*The American Text-book of Operative Dentistry*, p. 50): "Under the second head, *Reversion to Primitive Types*, we have a variety of interesting phenomena in the form of parts of the human teeth, which seem to be a zoological legacy. These consist of conspicuous features which reappear and seem to recall forms of the teeth observed in some of the lower animal orders, especially the quadrumana and insectivora. Among these features may be mentioned the curved upper central incisor, with the prominent cingule on the lingual-buccal ridge, making a notch which recalls the incisors of the moles; the prominent cingule on the lingual face of the lateral incisor, which is not uncommon, and recalls the form found in the insectivora and some of the quadrumana; the extra-long, curved canine, with extra-large median ridges, which recalls the large forms of this tooth in the baboons and in the carnivora; the double root sometimes found in this tooth is also a reversion to the insectivorous type; the three-rooted bicuspid is a quadrumanous reversion; the upper tricuspid molar is a primitive typal form, leading back to the lemurs and beyond them to the early typal mammals found in fossil formations; the notched and grooved incisor recalls the divided incisor of the *Galeopithecus*; the double-rooted lower incisors and canines

* This condition is referred to by Mummery in the communication mentioned above, p. 36.

† There are a good many examples of this condition in the South Australian Museum collection of aboriginal skulls, and most, though not all, of the specimens showing this peculiarity came from one locality near Adelaide. The condition is often associated with abscess of the buccal roots. Some specimens in my possession show that the lingual root remains in its normal position, while the buccal roots project in such a way that their proximal portions form wide angles with the lingual root (Fig. 14).

recall insectivorous forms; the unicuspid lower first bicuspid is an insectivorous type, and is often quite marked in man; the fifth cusp on the lower second molar is a quadrumanous reversion; the wrinkled surface of the lower third molar is like that of the orang. There are other features that might be named, illustrating the workings of the *law of atavism*, by which parts once lost in evolution may reappear and be reproduced."

This may suggest extensive culture, or reading, on the part of the author; but the statements are loose and unscientific. It is one thing for certain features in man's dentition to recall forms of teeth observed in some of the lower animal orders; it is quite another to affirm that one condition is a reversion to the insectivorous type and another condition a quadrumanous reversion. An abnormal turnip or potato may "recall" the features of some famous politician. What follows? These are not instances of atavism. Evidence does not show that man was ever either an insectivore or a quadrumanous being any more than he was a galeopithecus or a carnivore, an amphibian or a fish. An eye does not grow an ear, nor an ear an eye; monkey or ape did not evolve man, nor did man evolve monkey or ape. But as an eye and an ear were and are evolved from something that was neither eye nor ear, so man, monkey, and ape were evolved from some ancestral form that was neither man, monkey, nor ape. No doubt there are in existence certain species or varieties of plants and animals that have been derived from existing forms by modification; but such species or varieties are comparatively few. Man, monkeys, and apes have the appearances of terminal forms. The history of the common ancestor has either been rubbed out or exists undiscovered in some part of the palimpsest. When we begin to trace man's origin we must think, not in varieties merely, but in orders and classes. Some variations or abnormalities, therefore, will have a limited significance: they will be interesting when compared with conditions found among other races of people. Other variations or abnormalities will have a more extended bearing, and will be found to raise questions of the origin and affinities not only of man, but of mammals—if not of vertebrates generally.

I fear I have been degenerating into generalisations, instead of keeping to the facts of inquiry; but a digression was inevitable sooner or later, and having occurred at this stage it may be of some assistance in passing in review other features of aboriginal structure.

One important character of the skull has not been much studied lately: I mean the conditions shown at the pterion as regards the occurrence of an epipteric bone, or a fronto-squamous suture. These conditions I have found very common in specimens recently examined, much more common than I have anywhere found described. In some series about 50 per cent. of specimens examined show a fronto-squamous suture. Broca, many years ago, described the normal human arrangement (*i.e.*, the spheno-parietal articulation) as *ptérion en H*; and the normal simian arrangement (*i.e.*, the fronto-squamous suture) as *ptérion retourné*; and the condition in which the temporal and sphenoid only touch as *ptérion en K*. Hartmann (*Anthropoid Apes*, 1885, pp.

63, 111) discusses this subject at some length from the point of view of the frontal process of the squamous portion of the temporal bone, and refers to discussions regarding its appearance and racial significance. Duckworth (*Morphology and Anthropology*, p. 222) mentions this as an anthropoid condition, and figures it in a typical aboriginal skull, as do a good many other authors. He says it occurs in about 17 per cent. of cases. I believe this statement requires revision, as do also some other statements, *e.g.*, that grooves on the frontal bone are rare, that the glenoid fossa is shallow, and the styloid process very short.

One skull shows very good examples of incomplete orbits. The spheno-maxillary fissures are very large, as are also the sphenoidal fissures (Figs. 15, 16, 17). In one case the occipital bone of an aboriginal child's skull presents a rare abnormality. The occipital (Fig. 18) is somewhat distorted by exposure to the weather ; but it is quite evident, in spite of this, that there had been an extra bone at its superior angle, which is openly bifid.* The mode in which the right parietal—which was the only other bone found—articulates with this occipital shows that there was a large single or double interparietal bone extending forwards as far as to the frontal bone.

On reviewing the facts regarding supernumerary teeth, dental masses, tooth pits, dental tumors, size of teeth, number and position of cusps, milk and permanent dentitions, &c., it will be evident that the interpretation of anomalies is a subject for the expert, and that the Australian aboriginal at present is proving to be by far the most important and most abundant source of information. Not everyone, however, can say what is normal or abnormal, trivial or important, commonplace or unique, in any particular skull ; and the moral, therefore, is—Bring everything in the way of teeth and skulls under the notice of the anthropological expert.

It is scarcely necessary to remind you that anthropology does not mean merely skulls, but embraces all the structures and takes cognisance of all the functions of the body. Although it has been stated that parts of the skeleton other than the skull furnish but few materials for characterising races, this statement may require modification in the near future. Several features presented by the long bones are of interest, and the more important may be referred to in some detail.

The Humerus.—The angle of torsion of this bone in the Australian aboriginal, as given by Broca, is very small ; in fact the average is least of the hominidæ, and is less than in the gorilla. The conclusions to be deduced from this fact are not evident, for the nature of the condition is obscure, the parts affected are doubtful, and much has to be learned regarding the variations which the bone shows at various ages in the same subject.

Turner, in his *Challenger Report* (vol. XVI., p. 89), notes the occurrence of an intercondyloid (super-trochlear) foramen in both humeri of a Queensland aboriginal. I can find no other case in literature ; but I have noted this condition recently in about half a dozen specimens,

* In an adult aboriginal skull in the South Australian Museum (No. 61), a triangular bone is interposed between the parietals and the occipital.

one being the humerus of an infant (Fig. 19), in which the condition was very well marked. I do not ask you to believe that these are the only cases that have been observed, any more than I wish you to understand that they are the only cases that have occurred. But what I do wish you to note regarding this subject, and numerous other similar conditions, is that modern text-books do not mention them as occurring in the aboriginal. A vast amount of observation has never been recorded, and many records appear never to have been seen by authors. The text-books, be it noted, which profess to give general statements of what is known and recognised, are the reflex of the teaching of professors and lecturers on the subject, and they are greatly deficient, and often wrong.

Obliquity of the Forearm in Extension.—A good many years ago I had noted that the obliquity is sometimes very great in whites, especially among women. Recently I have noticed in the male aboriginal that the arm in extension may be almost perfectly straight. The significance of this obliquity is altogether obscure. In speaking of the analogical condition in the lower limb (*The Lancet*, March 11th, 1893), I said: "Normal knock-knee in women is said to be due to the greater width of the pelvis. Let it be granted that the pelvis is wider in women, as it is granted that women possess ovaries. How does width of pelvis explain knock-knee? Does width of pelvis explain the greater degree of knock-elbow in women?" Little has been done in connection with this subject. Photographs published by Klaatsch give some materials for study.

Size of the Interosseous Space.—There are few observations on this, and one cannot say that there are any results.

Femur.—In connection with this bone there are many points of inquiry; but very little has been settled. The chief conditions of importance are the curvature of the shaft, the angle which the neck forms with the shaft, the amount of torsion of the shaft, the occasional presence of a third trochanter, and the condition of platymeria.

This last-mentioned modification, when occurring at the upper portion of the femur, is often associated with the presence of great development of the gluteal ridge forming the "third trochanter." I have failed to find any reference to it in literature as occurring in the Australian aboriginal; but I have found the condition distinct and not uncommon in several aboriginal skeletons from the Coorong. In one skeleton the index was 70.9 in both femora; in another it was 72.9 in an odd femur. It occurs in young subjects as well as in old, and usually in both femora. The view that "age (*i.e.*, maturity) appears a necessary factor in the production of the character" is certainly incorrect. The condition is often associated with platycnemia.

In order to show how cautious one must be in drawing inferences, I may refer to the condition of bulging of the popliteal surface of the femur so very greatly marked in the Trinil femur found by Dubois in Java. The left femur of an Australian aboriginal described by Hepburn showed an almost exact reproduction of this abnormality. Any value that may have attached to this condition was very much discounted, however, by the nearly normal condition of the right femur of the same subject. You require to be careful in science: you never know when you will stumble on the tragedy of "a deduction murdered by a fact."

Tibia.—Here, too, several points have to be considered—especially platycnemia and retroversion of the head of the bone. But little that is definite has been done.

The subject of platycnemia* demands some remarks. This condition has been discussed in detail by Manouvrier, who considers that it is associated with the attainment of maturity. Duckworth (*Morphology and Anthropology*, p. 313, *et seq.*) discusses the subject at some length. He says, "The condition was undoubtedly common in some prehistoric races of Western Europe and Egypt. In modern times it occurs in a pronounced degree in rickety tibiæ and in the tibiæ of certain ill-fed and badly nourished Australian aboriginal tribes (*cf.* the description of the "boomerang"-tibia by Messrs. Spencer and Gillen, *The Natives of Central Australia*). Pruner-Bey attributed all platycnemic cases to Rachitis (Rickets)." Then Duckworth goes on to state the views of Broca and of Manouvrier and of Charles, and to criticise them. The lowest index he himself has found, *i.e.*, the greatest amount of platycnemia, was in a mori-ori skeleton at Cambridge, and amounted to 60. I am able to record an index of 57 in the left tibia of a young subject from the Coorong, in whose skeleton there is no evidence whatsoever of rickets or any other disease. In another skeleton the index was 57.1 on the right side and 51.3 on the left; in a third it was 65.7 on the right and 62.8 on the left. In an odd tibia it was 54.2; in another, 57.8. This gives, for six tibiæ from one locality, an average of 58.1, which shows a very much greater degree of platycnemia than in any known race, the nearest being an average of three tibiæ of the Mori-oris, which amounted to 68.†

It appears to me that this subject offers a field of fruitful study in connection with the functions of the lower extremity, and on account of the possibility of its yielding racial characters. I have to point out that the ridge that constitutes the condition of platycnemia does not correspond with the oblique line of the tibia. nor with the longitudinal ridge that separates the surfaces of origin of the flexor longus digitorum and tibialis posticus muscles. In one well-marked case the platycnemic ridge passed from its origin—about 2 cm. from the fibular articular surface—downwards and inwards, as a well-defined continuous border, to the posterior portion of the internal malleolus. The true inner border of the tibia was marked only in the upper half of the shaft. The commonly-accepted view (*Quain's Anatomy, Osteology*, p. 127; Macalister, *A Text-book of Human Anatomy*, p. 182) that the condition is due to prominence of the posterior longitudinal ridge is certainly incorrect. The bulk of the growth is sometimes external and sometimes internal to the arterial foramen.

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* This term is an unfortunate one, and gives rise to misunderstanding. It is wrongly defined in Gould's *Dictionary of Medicine*.

† See footnote on p. 569.

In the discussion regarding the relation of this condition to the function of the tibialis posticus muscle, no one appears to have noticed the peculiar fashion in which the blackfellow uses his toes, bending the knee, and passing them behind the body to the opposite hand—an act specially involving the use of this muscle.

Another point has been overlooked, viz., the relation of the platycnemic condition to the subject of retroversion of the head of the tibia. In some cases I have examined of well-marked retroversion, the condition of platycnemia has been unusually well-defined, and the additional material is seen to be arranged like a pilaster supporting the head of the tibia and the superimposed weight, much more directly than would be possible were there no platycnemic condition. From this point of view "platycnemia" would be synonymous with "pilastered tibia."*

An observation made by Topinard gives special interest to this condition. He says that a condition of the femur and the fibula (both of which I have found in the aboriginal) and the condition of platycnemia are peculiarities that belonged to one and the same race in Western Europe, and that it is remarkable that they are rarely met with in subjects showing perforation of the olecranon cavity. "The two races that have bequeathed to us the two varieties are therefore distinct." It is to be noted that Manouvrier, on the contrary, claims that all the conditions referred to are found associated in the same skeletons.

As regards retroversion of the head of the tibia, this is a condition that I have found very strongly marked in several skeletons. Theories to explain it involve a discussion of the state of the knee-joint in walking, and, as I have shown in the *Journal of Anatomy and Physiology*, vol. xxv., this subject demands a far greater amount of investigation than it has yet received, the ordinary teaching on the matter being inconsistent with the facts.

There are other points of interest connected with the tibia, for example, the facet on the anterior surface of the lower extremity, which I have found to be often present.

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* I find that Dr. Stirling, in the *Report of the Work of the Horn Scientific Expedition*, vol. 2, p. 187, gives measurements of a left tibia from Alice Springs and of two from the South-East, the indices being 73.7, 69.4, and 57.9 respectively. This gives an average of 67. Dr. Stirling discusses the condition in the body of the work, pp. 19 *et seq.*, and p. 153, where he records observations of his own and others by Professor Watson. I find no other references than these to platycnemia in the Australian aboriginal. Australian, and especially South Australian, anthropological work and specimens are not unknown in Cambridge. It seems surprising, therefore, that the results of the Horn Expedition, published in 1898, should not find a place or a reference in University works published at the Cambridge University Press in 1904, and designed to be used as University text-books on the subject. What is true of English communications would appear to be even more applicable to German researches. Dr. Hermann Klaatsch informs me that many points dealt with in this present paper have been the subject of research by him and others, and that the German literature on the subject is very extensive indeed. His own publications, which he names, are "Die Entstehung und Entwictelung des Menschengeschiechts, 1902"; "Ueber die Variationen des Menschenskelets, 1902." This adds to the gravamen of my complaint, and furnishes additional evidence of the necessity of my present communication.

The subject of the proportions of the upper and lower limbs, and of their various component parts, is one of much interest; but the measurements, having been computed on a very few specimens, are restricted in their value.

Relation of Radius to Humerus.—This has received a good deal of attention. It has recently assumed an important place in anthropology, and Turner has made a classification of human races, based on the radio-humeral index.

As in the case of other proportions, worked out by White, Lawrence, Humphry, and Broca, the results refer principally to the relation that the human subject, especially the negro, bears to the gorilla, chimpanzee, and orang. It is only of recent years that racial comparisons have been studied, and the chief work on the subject has been done by Turner, in the *Challenger Reports*, but, unfortunately, from a very small amount of material. Some years ago I sent him some additional specimens, regarding which he said, "The limb bones will also be useful in giving me an opportunity of making further measurements in my study of the relative length of the long bones in the Australian natives." He added, "Is it possible to secure examples of the innominate bones and sacrum so that one can study the configuration of the pelvis?"

The comparative anatomy of the pelvis, so far as it refers to the various races, is a recent study. Nothing on the subject is found in Topinard. Most of the work has been done by Turner, Cunningham, Paterson, and Thomson; and while the similarity of results to the results of spine study has to be noted, the great dearth of materials has to be mentioned with regret. Among 41 specimens recorded as having been measured, and belonging to races other than white, there is only one pelvis of an Australian female aboriginal. In response to Sir William Turner's request, I have been able to supply to some extent the deficiency, and in process of doing so I have brought to light some things in connection with the lumbar vertebræ and the sacrum that are new and of special interest. To these I may refer briefly.

In his *Challenger Report*, Sir William Turner notes seven examples (out of 30 skeletons) of a peculiarity of the fifth lumbar vertebra, viz., a solution of continuity of the arch immediately behind the superior articular processes, sometimes associated with non-union of the spines. This occurred in a Malay, an Andamanese, a Chinese, two bushmen, an Esquimo, and a negro. Turner also reports it in a Sandwich Islander. No abnormality in the lumbar region or sacrum has apparently been reported in an Australian aboriginal. In 1902 I found in the fifth lumbar vertebra of an aboriginal a hiatus due to the non-union of the spines. This vertebra also showed another peculiarity, since it partook of the characters of a sacral vertebra on its left side and of a lumbar vertebra on its right (Fig. 20). The fourth lumbar (Fig. 21) presented a condition of its right transverse process apparently new to anatomy. Another fifth lumbar (Fig. 22) also showed an incomplete arch posteriorily.

The condition described by Turner, in which there is a hiatus on each side immediately behind the superior articular processes, occurs (Fig. 23) in a very young aboriginal subject, whose remains were found at Garra, in the Pinnaroo district. Unfortunately, the detached piece was not found, but it is clear from the condition of the facets of the first sacral vertebra, which is separate, that the inferior articular processes of the fifth lumbar were present.

This is not all. I have been able to demonstrate all variations of the sacrum from four normal pieces, through four and a half, five, five and a half, to six. On this subject Sir William Turner wrote to me in 1903, "I propose to give the notes on the sacrum to Professor Cunningham for the *Journal of Anatomy and Physiology*. I have seen the condition found in these specimens in the sacrum of Europeans, but the very interesting modification in the position of the lumbar transverse is new to me." The specimens are described in the *Journal of Anatomy and Physiology*, vol. XXXVII., p. 359.

I have to describe two other anomalous conditions in aboriginals which occur in connection with the sacro-iliac synchondrosis. In one specimen the part of the ilium that bears the auricular surface is continued "backwards" in such a way as to cover and fit into one of the digital depressions on the posterior surface of the transverse process of the second vertebra of the sacrum, with which it forms a synchondrosis. In another specimen (Fig. 24) the supernumerary facet on the sacrum is not in a depression. It is oval in form, its axes being 12 mm. and 10 mm. respectively, and the margin being 10 mm. from the "auricular surface." This is on the right side. On the left side the diameters are 10 mm. and 5 mm., and the facet is 6 mm. distant. These facets are on the junction of the transverse process of the first and second vertebræ.

In two recent skeletons I have found, in the transverse processes of the lumbar vertebræ, all transitional stages, from the extreme instance mentioned to the ordinary and normal condition. It is somewhat remarkable that in a race in which no such abnormalities had ever been described we should find not only every known variation of the sacrum and the lumbar vertebræ, but also some conditions that have never been recorded in human anatomy. This shows the importance of examining everything.

The Spine.—As regards the single spinous process in the cervical vertebræ, said to be a simian feature in the aboriginal, my observations show that the ordinary bifid form is not uncommon.

The chief interest connected with the spine, considered as a whole, lies in the curves it exhibits. The largest amount of investigation on this subject has been done by Professor Cunningham, who has published an extensive memoir in which he shows that the Australians and Tasmanians, Andamanese, bushmen, and negroes hold an intermediate place between the Simiidæ and the whites. There is a great want of suitable materials for this important study—suitable materials meaning spines of subjects of different ages, especially with the ligaments intact.

Regarding the *scapula* aud the *sternum* I need say very little, except that the latter bone sometimes exhibits in the Australian aboriginal a condition not found in other races: I refer to the articulation of the third rib, instead of the second, with the place of junction of the manubrium with the body of the sternum.

I may refer shortly to the subject of *pigmentation*, to show how points arise for investigation. Older writers make some reference to it; but modern works on anthropology appear to ignore the subject. Professor Cunningham, writing to me regarding the tongue of an aboriginal which Professor Watson had given me to send to him, said: "I notice in the tongue an interesting point, viz., that patches of the mucous membrane are rather deeply pigmented in the lymphoid region. Is this common among natives?"

While in the Northern Territory I examined a large number of aboriginals, and found pigmentation very common and very extensively distributed on and under the tongue, on the palate, and on the inside of the cheek. On my return I examined some cases here along with Dr. Rogers, and found similar conditions. Further, we noticed that young aboriginals—of whom we examined several—showed no trace of such pigmentation. If this deposit of pigment should be found to be a late phenomenon in the individual it will prove to be an interesting observation, and one probably to be correlated with the later development of hair on the body, which is secondary to the intra-uterine and the infantile hairy condition. It does not appear to be generally known that the newly-born aboriginal is not black, but of a yellowish honey color, with narrow dark lines on certain parts of the body.

About 25 years ago, if my memory serves me aright, the question of pigmentation of the skin was investigated in reference to the subject of living in the tropics, and the investigations served to explode some physical fallacies due to the wrong inferences regarding radiation and absorption of heat. An interesting observation on this subject was made by Dr. Semon, when hunting for the ceratodus and other rare animals in the Queensland rivers. He says: "Another nuisance was the burning sun upon my bare back, which soon scorched, by its rays pouring straight down from the zenith. It was not easy to protect myself against this, for whenever I put on a light jacket this soon got wet by my going deeper into the water, and brought on a disagreeable feeling of chill as soon as the slightest wind arose. I therefore gave up protecting myself against the sun, and soon had the satisfaction of finding that my back and breast got covered by a dark-brown skin, impervious to its attack."

Another observation, which he made at Amboyna, is worth noting. He says: "When my fishermen were at sea they used to uncover the upper part of their body, keeping on nothing but the wide sack-like trousers, reaching below the knees, and worn by the Ambon men instead of a sarong. As they used to undress completely for diving, I could observe, while watching their movements below the water, how the upper portion of their body, which was daily exposed to the glowing sun, was of a far darker color than the lower. Thus we see that the sun has just the same influence on a brown as on a white skin—a fact generally hidden from our observation."

Some amount of study has recently been devoted to the muscles of expression in different races; but at the present time there is but little recorded in this connection regarding the Australian aboriginal. Cunningham and Klaatsch have both been supplied recently with materials from South Australia for investigation, so something more may be looked for.

About eight years ago I found an extra muscle in both hands of a full-grown male aboriginal. On the right side the muscle arose from the tendon of the palmaris longus at the level of the annular ligament, and passed downwards to join the tendon of the abductor minimi digiti. The nerve supply was derived from the ulnar nerve by a branch which left the trunk at the level of the pisiform bone, and passed downwards to enter the muscle at the lower border of the palmaris brevis. The muscle on the left side was similar in its relations; but I did not dissect out the nerve.

This appeared to be an abnormality of that particular body. I subsequently examined a large number of bodies of aboriginals, but found no other instance of such a condition as this.

Man is but poorly specialised in body when compared with the donkey or the deer. Like many other animal forms, he has one particular and peculiar feature that stands out prominently as a mark of distinction. The one feature, universally recognised, that marks man off from all present day forms is his brain. A highly specialised brain means less necessity for specialisation of other parts of the body. Teeth and jaws remain generalised because he can cook; his skin is smooth because he can provide means of shelter and defence. One would imagine that classifying features would be found in the development of the human brain, or in the brains of adults of the various races. Here, surely, is a fruitful field of study. What has been done in it?

Broca may be said to have led the way in the study of the brain in races. He published his results in 1880. In 1882 Miklouho-Maclay published the results of an examination of various brains, including the Australian aboriginal (*Nature*, December 21st, 1882, p. 185). In 1888 Rolleston (*Journ. Anthrop. Ins.*, p. 32) described another Australian aboriginal brain. Duckworth (*Morphology and Anthropology*, 1904, p. 423 *et seq.*) describes four brains of aboriginals in the Cambridge Anatomical Collection. But what does all this amount to, even if the descriptions were complete, instead of being merely superficial, as many of them are? The whole subject of the evolution of this organ in the aboriginal is practically untouched.

If the specialisation of brain marks man off from all other animal forms, it does not follow that the various races of mankind will be marked off from each other by cerebral characters; in fact, analogy is against such a supposition. The *fundamentum divisionis* of the genus is rarely the *fundamentum divisionis* of the species, in Deniker's words: "The physical peculiarities distinguishing man from the animals most nearly allied to him in organisation, and those which differentiate human races one from another, are almost never the same." At the same time we shall not be surprised if this statement should prove to be too exclusive, or not applicable in this particular case.

A word may be said on man's affinities. It is now regarded as fairly certain that his nearest relatives are the anthropoid apes, viz., the gorilla, orang, gibbon, and chimpanzee. He possesses about 300 structural features in common with the gorilla and chimpanzee that are not found in any of the lowest monkeys. Turner has pointed out that the simian features are not all concentrated in any single race. It has been allowed, however, that the Australian aboriginals have furnished the largest number of ape-like characters. The more one investigates the truer does this statement prove to be.

Recent advances in science have given two unexpected proofs of affinity in entirely new fields. The homolytic test puts human blood and the blood of the apes in the same class, and separates both from the blood of the lower monkeys. Again, man and the anthropoid apes are subject to a class of diseases that does not affect any other animals.

Formerly the Australian aboriginal was classed with the American negro because both possessed flat nose, protruding lips, projecting jaws, and large-sized teeth. But this is just as if one should put the echidna and the porcupine in the same order on account of their spines. The characters mentioned are very variable, not only in the Australian aboriginals and in the negroes, but in all races, and are just those characters that change very rapidly in the individual and in the race on account of changes in habits. Further, these are the characters that would become especially developed in the apes and lower human races on account of similarity of food, habits, and surroundings.

Topinard and others had concluded that Australia was originally inhabited by a race of the Tasmanian type that disappeared before a taller race that came from—somewhere. Flower and Lydekker (*Introduction to the Study of Mammals Living and Extinct*, 1891, p. 748) thought the Australians were a cross between two already formed stocks. Keane still holds that they are a blend of two or at most three different elements in extremely remote times.

Huxley held that the Australians were a homogeneous group. Finsch, from extensive observations, concluded in 1884 that they were all of one race. Alfred Russel Wallace, in 1893, pointed out the aboriginal's resemblances to certain Asiatic races, and concluded that the Australian aboriginals were really a low Caucasian type.

Dr. Semon, in his work *In the Australian Bush*, English edition, 1899, p. 237, adopts the theory that the Australians and Dravidians—primitive inhabitants of India—have sprung from a common branch of the human race, and that the Caucasians have undoubtedly sprung from the Dravidians. This makes the Australian aboriginal more nearly allied to us than the comparatively civilised Malays, Mongols, or Negroes. Speaking popularly, according to this view the Australian aboriginal, racially, would be the uncle of the Caucasian.

Lydekker, in 1898, abandoned the two-race theory, and reached the same conclusion as Wallace. Most anthropologists now accept the one-race theory. The most recent writer on this subject is Professor Gregory, who, in *The Dead Heart of Australia*, p. 176, says he accepts this view and abandons the position he took up in 1903 in *The Geography of Victoria*.

This view certainly enhances the interest in the aboriginal, and brings the subject of the ethnology and anthropology of the black nearer home to us. Some writers give the Australian even greater importance. Stratz has taken him as a central unit, a prototype, around which he groups all the rest of the races of men; and another writer, Schoetensack, holds that all the races of men were evolved in the Australian continent.

To touch upon the evidence for these theories would lead us into such subjects as language and folk-lore, customs, tools, weapons, religious ideas, &c. Such a digression is beyond my purpose. The scope of this communication does not embrace the origin or affinities of man; therefore do not expect any extensive statement of facts or theories on the subject. I have said something recently and elsewhere on certain points of aboriginal anthropology and customs.

I would refer here to only one thing more, viz., the character of the aboriginal. People have been so long accustomed to hear him spoken of as the lowest type of race that they have interpreted this to mean that he is the essence of everything that is bad. We could overlook accounts of the "Indians" of this country or the "natives of New Holland," as they were termed a hundred years ago or more; but recent descriptions of an equally untrue and absurd character are spread by people who should know better. We read of mental degradation, the zero of all anthropological analysis, the lowest of savages, no natural affections, live burial of children, wooing by club inducements, the lowest races in the scale of humanity, untrainable savages, cruel, ungrateful. I cannot close this paper without saying that I am sure that you who know the aboriginals have found them, as I have, fond of their children, kind to the aged and infirm, generous, grateful, apt to learn, good at mechanical work, equal in ability to white school children with whom they are educated, of unimpeachable honesty in things entrusted to them, cheerful under difficulties, of unruffled good temper—even in free, romping fights, and sometimes displaying remarkable shrewdness and a keen sense of the humorous or the ridiculous. I am not sure whether football is a recognised test of civilisation; but if cricket is any criterion the blackfellow has a strong claim to be civilisable. There are exceptions: of course there are. You find some aboriginals with bad mental traits, just as you find some miserably-fed individuals or groups among "pieces of anatomy" that are the finest, the supplest, the most lithesome, and of the best carriage in the whole range of creation. I think Mrs. Gunn, in *The Little Black Princess*, has given a truer picture of the Australian aboriginal than is to be found in the latest half dozen books professing to deal scientifically with the subject.

Do not find fault with me if I make no authentic statement, or even any statement at all, regarding the origin and racial affinities of the Australian aboriginal. My task is really to show what place he occupies in recent research. You will agree with me that it is an important place. You will also allow that the position of the aboriginal among the races of the world cannot finally be decided without a very great deal of research in anthropology. The people forming the great majority to whom the science is a recreation might surely unite in an effort to supply materials to those workers who apply themselves closely to what is an arduous and sometimes, unfortunately, an expensive task. I hope we shall hear no more about whole series of beautiful and rare photographic plates meeting their destiny in the melting-down furnaces of the glassworks, or accumulations of aboriginal skeletons being ground down for superphosphates.

In the universal "grab-all" for door-mats be graciously pleased to pay some respect to the altar cloths of the anthropologists.

Perhaps I ought to say, in conclusion, that the preparation of this communication has been to me a relaxation—a pleasant recreation, a labor of love, or something of that sort. It has not been any of these, and I have no reason for concealing the truth about the matter. I undertook to write the paper because I was asked to do so, and because I thought it required to be done; not because I was infatuated with the subject. It has entailed much work on me, and a great deal of inconvenience on others—particularly on Dr. Rogers, who, I think, deserves to be regarded as joint author. It has taken time and energy which could be ill spared, and which should have been devoted to other ends with other aims. If, however, by anything I have said I have succeeded in making some people repentant over lost opportunities, and resolved to do something to help Australia—and especially South Australia—to take her proper place in anthropological research, then I am content.

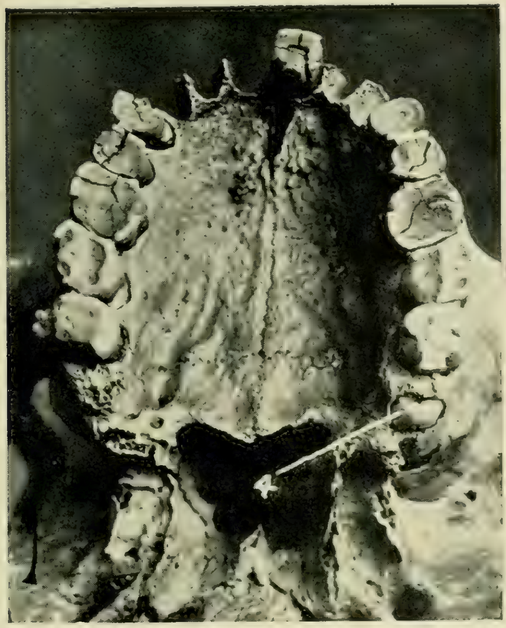

FIG. 1.—4, a fourth molar.

FIG. 2.—4, a fourth molar.

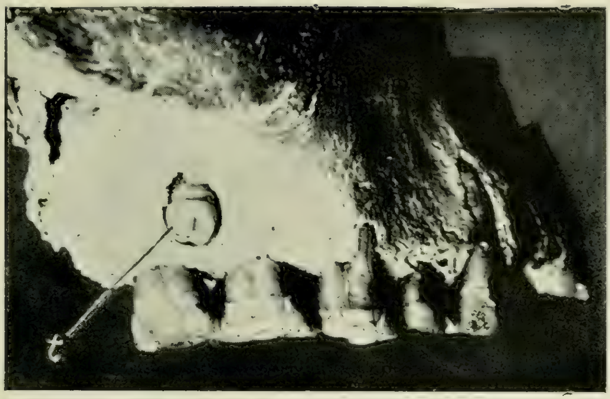

FIG. 3.—*t*, supernumerary tooth.

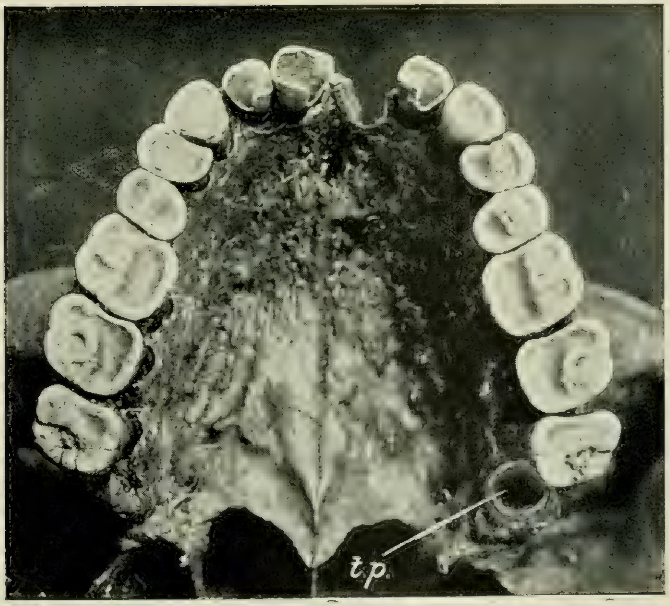

FIG. 4.—*t p*, tooth pit.

FIG. 5.—*d.r.*, dental rudiment.

FIG. 6.—*d.r.*, dental rudiment.

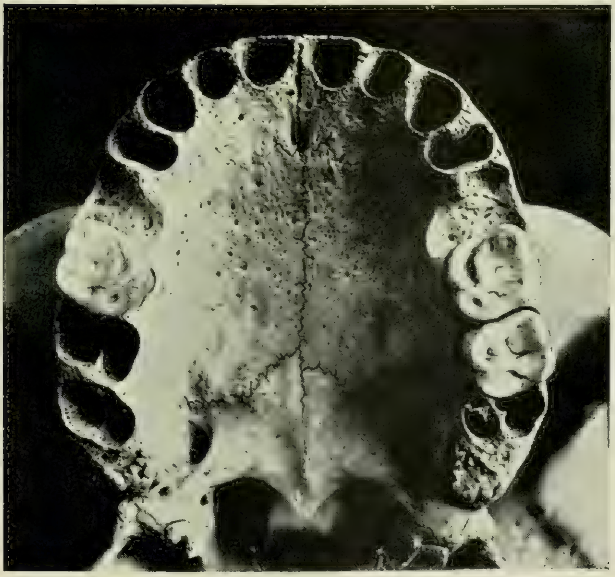

FIG. 7.

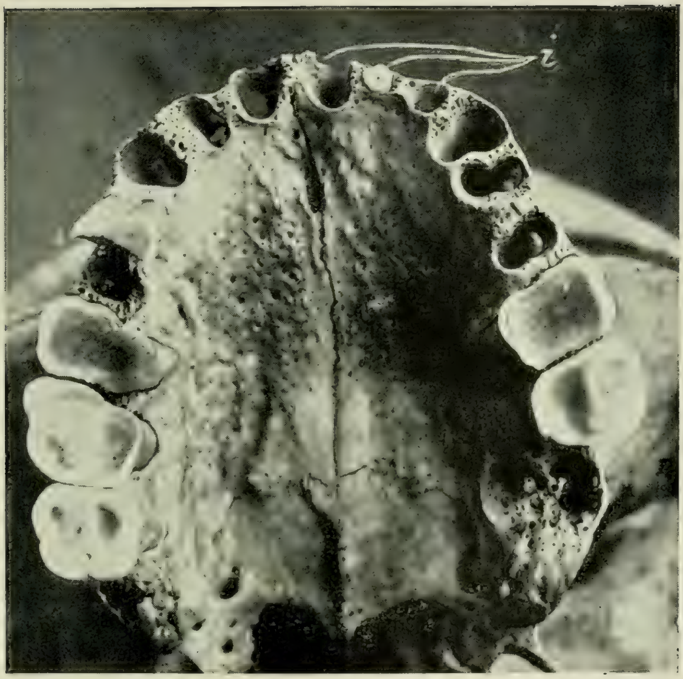

FIG. 8 —*i*, left incisors.

FIG. 9.

Fig. 10.

Fig. 11.

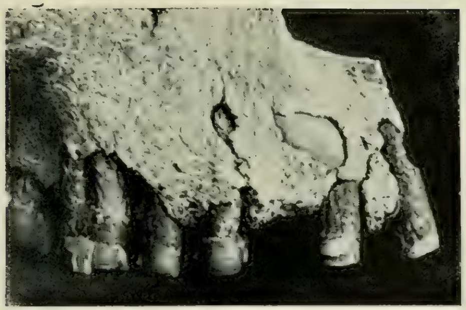

Fig. 12.

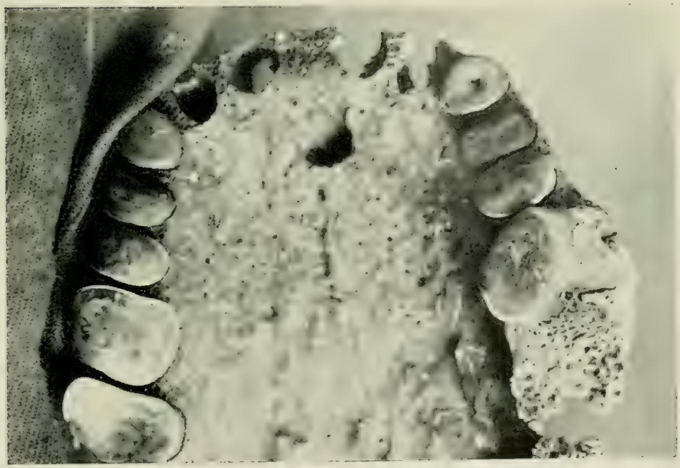

Fig. 13.

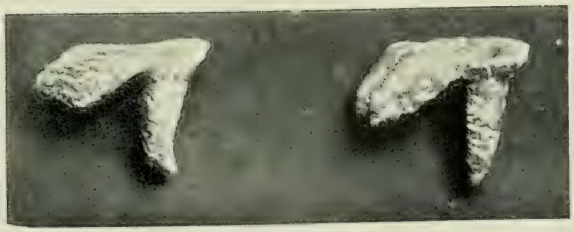

Fig. 14.

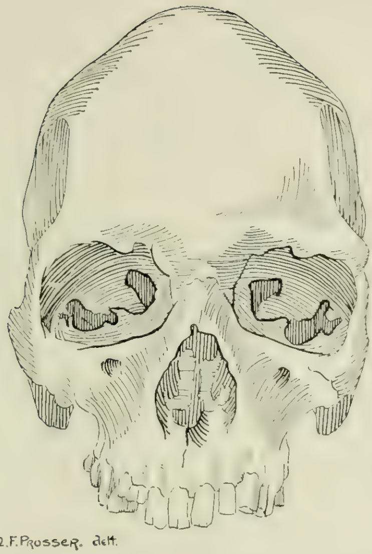

FIG. 15.

FIG. 16.—*m.*, malar; *sm f.*, spheno-maxillary fissure; *f.o.*, foramen ovale.

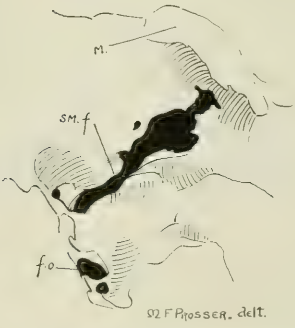

FIG. 17.—*m.*, ma'ar; *sm.f.*, spheno-maxillary fissure; *f.o.*, foramen ovale.

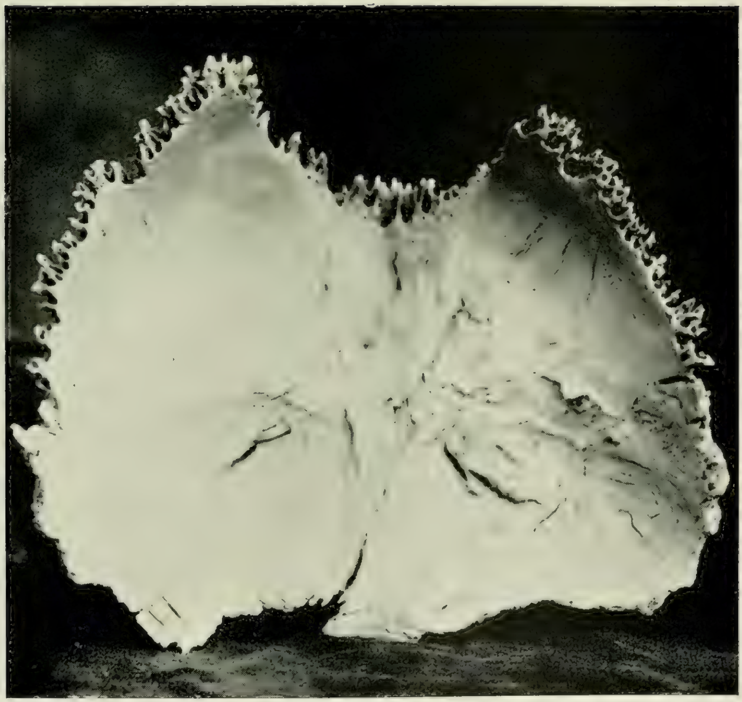

Fig. 18.

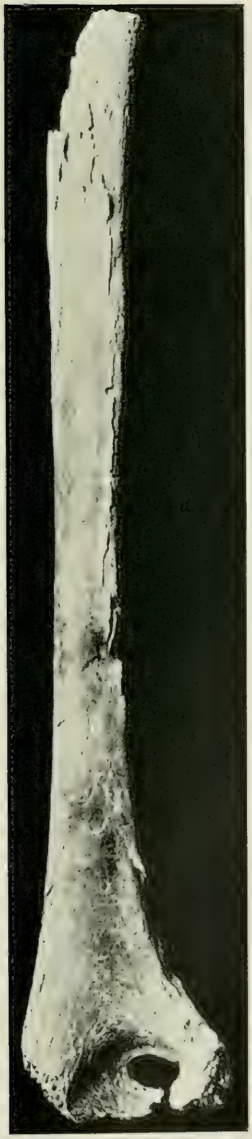

Fig. 19.

Fig. 20.

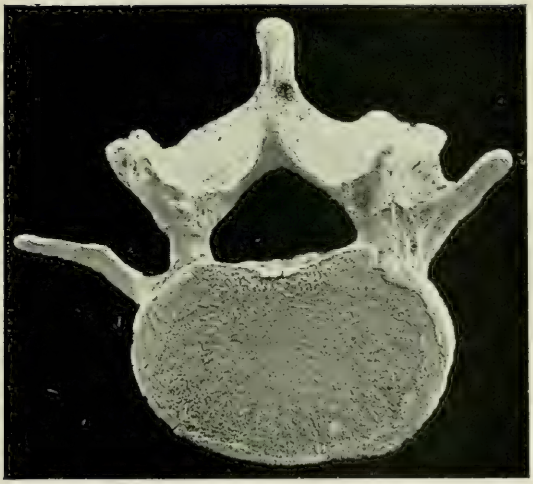

Fig. 21.

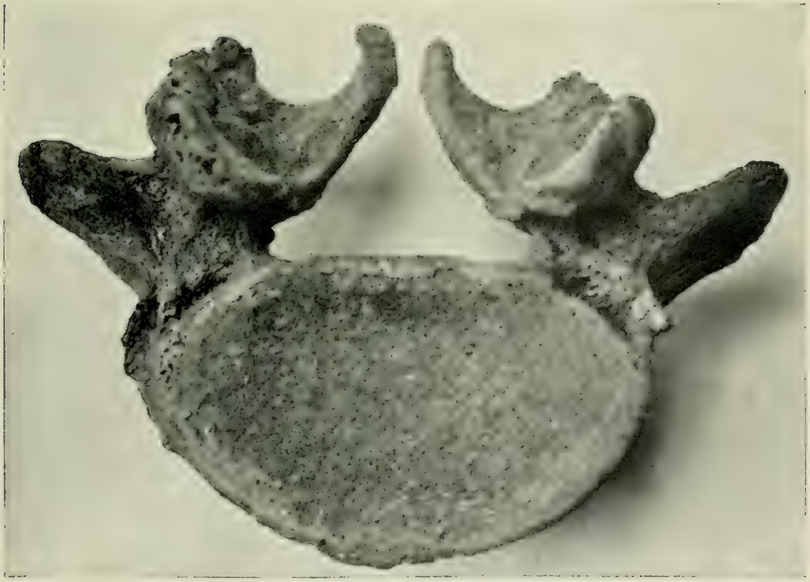

Fig. 22.

FIG. 23.

FIG. 24.

2.—SOME NOTES ON SCIENTIFIC TRAVEL AMONGST THE BLACK POPULATION OF TROPICAL AUSTRALIA IN 1904, 1905, 1906.

By Professor HERMANN KLAATSCH, M.D.

[WITH SEVENTEEN PLATES AND MAP.]

In coming to Australia it was my intention to attack the difficult problem of the origin of the Australian blacks, and of their importance in relation to the whole development of mankind. Many years previously I had begun my studies by examining skeletons and skulls, and had noted the close similarity existing between the skulls of Australian aboriginals and of those of primitive man in Europe that was first pointed out by Professor Huxley.

Having arrived in Australia at the end of March, 1904, I proceeded direct to Brisbane, where ready assistance was offered by Dr. W. E. Roth, then Chief Northern Protector of the Queensland Aboriginals. I accepted his invitation to investigate carefully his excellent collection of Queensland crania now preserved in the Australian Museum, Sydney, where I finished the descriptive paper in 1905.

My paper, entitled "Morphological Studies of the Skulls of North Queensland Aboriginals," is now in course of being printed and published by the New South Wales Government. In this some of the general ideas will be communicated regarding my theories of the importance of the Australian race in comparison with Anthropoids, the fossil man of the European Stone Age, and the now existing races of mankind. (1)

I agree with Dr. Howitt's opinion that only a land connection could explain the presence of the aboriginals in Australia, and I am inclined to accept the view of a submerged continent, from which, in one direction, have been distributed the Asiatic people, and in another the Australian blacks.

In the month of July, 1904, I began my investigations on the anthropology of the living body of the aboriginals of North Australia, in which direction very little had been previously done. My first experiences with the natives in a primitive stage was in the Gulf of Carpentaria. The Queensland Government placed the sailing-ship *Melbidir* at my disposal for a period of six weeks, which gave me the opportunity of visiting some of the rivers of the gulf coast of the Cape

(1) My publications on this question before I came to Australia are very little known to English authors, from their not having been translated into that language. In the paper indicated my other publications are mentioned, which are to be found in the "Zeitschrift für Ethnologie, Berlin," and in the Reports of the German Anthropological Society. A more general review is given in my paper on the Origin and Development of Mankind, in the popular work, "Weltall und Menschheit," II., 1902, Berlin.

York Peninsula and the Wellesley Islands, a number of which had, since the time of Flinders, only recently been visited by Dr. W. E. Roth in the *Melbidir.*

On Bayley Island I spent some days in friendly contact with a tribe of natives. At the Archer River I assisted in the foundation of a mission station, in company with Mr. Arthur Richter, of the Mapoon Mission Station, Batavia River. The mouth of the Archer River is wrongly depicted on every map of Australia, for it enters the sea by two distinct and navigable channels separated by an island. They both extend into bush country never before touched by white men. The confidence of the blacks, who had proved very treacherous and dangerous before our arrival, was won as the result of a successful operation performed by me on the breast of a woman. Having visited the Normanton and Burketown districts on the Leichhardt River, where I collected relics of the giant fossil marsupial *Nototherium*, I returned to the coast of North Queensland and remained from November, 1904, until February, 1905, in the districts of Cooktown and Cairns.

A most important field for investigation proved to be the Bellenden Kerr Mountains inland from Cairns, where a great number of half-civilised and free-living tribes are located. Some of these were found to be in a good condition, but others were in a state of decay, largely owing to the introduction of opium by the Chinese. One of the best specimens collected here was the mummy of an old chief, "Naicha," of "Boonje" (Upper Russel River), which had been perfectly smoked eight months after death. The negotiations with the relatives for the possession were difficult, but successful. From Cairns I proceeded to Sydney, where I arrived at the end of March. During my studies in the Australian Museum I was very kindly assisted by the curator, Mr. Etheridge.

I left Sydney at the beginning of September, 1905, for a 14 months' trip around Australia.

On the south coast I visited Warnambool, Victoria. I found the sandstone formation near Warnambool more interesting than I expected after the unfavorable opinions expressed by some scientific authorities. Various footprints of animals in the sandstone rocks have been known for many years, but very little attention has been given to the fact. I discovered the footprint of a giant bird, which I suggest may belong to *Genyornis newtoni* (Stirling), remains of which, found in Callabonna Lake, are preserved in the Adelaide Museum. I published the results of my investigation in one of my reports to the Anthropological Society of Berlin. (2) I came to the conclusion that the human-like footprints, saved by Mr. Archibald, the late director of the Museum, very likely indeed belong to a juvenile human individual of the Tertiary period. (3) I next proceeded to Perth, and

(2) Zeitschrift fur Ethnologie, 1906.

(3) After a consultation I had with Prof. E. David, of Sydney, I have every reason to hope that the locality of Warnambool may now be studied more profoundly by the Australian scientists.

after a short stay there and on the Island of Rottnest I followed the north-western coast, which proved to be a most prolific place for study, having been previously practically untouched from an ethnological and anthropological point of view. Intimate connection was established with the Niol Niol tribe in particular, among which the Roman Catholic priests have a mission station at Beagle Bay. Generous help was rendered by these missionaries. The Niol Niol proved to be a kind and intelligent people, who have preserved the old customs and traditions, having been only in contact with white people for some 12 years. Their language has been studied by the Trappist monks, who founded the mission station. The tribe possesses a great variety of weapons and ceremonial decorations, many of them reminding one much of the specimen described by Spencer and Gillen in their excellent works on the Arunta and the North Central Australian tribes. I secured a fine collection of sacred wooden slabs or churingas, which name (following Spencer and Gillen) I accept as a term for the whole of Australia. In the north-west the churingas have different names according to their size. Amongst the Niol Niol every man has two churingas, a large one and a small one, called respectively " Minber " and " Mandaka." They consist of wooden material and are carefully ornamented with quadrangular figures. Every real churinga in the Broome district is perforated at one end that it may be used as a bullroarer. They are absolutely restricted to the male individuals. The women have smaller sticks of similar shape, called " Lara," which have not any sacred or secret importance, but are carried round by the lubras as charms.

There are doubtless some local differences between the north-western and central districts of Australia, by which the different results of investigations are easily accounted for. So far as I have studied the question in the north-west, my attempts to establish a complicated system of totems similar to that described by Spencer and Gillen for Central Australia has been completely unsuccessful.

The dances I saw performed (but only by night) reminded me very much of the pictures published by Spencer and Gillen; but at Beagle Bay they are not connected with " totems." For instance, an old man, who beautifully imitated a dugong, had nothing to do with anything like a dugong totem. There was no reason for the aboriginals to conceal a totemistic system, because both the missionaries and I were very intimate with them, and, showing and explaining to them the pictures of " sacred ceremonies " in the papers of Spencer and Gillen, we were able to question them very closely regarding the totemistic laws and performances, but they denied absolutely the existence of such a system. (4)

I hope to be well understood that, by stating the facts as regards the Broome district, I do not contradict in any way the correctness of the statements made by Spencer and Gillen for Central Australia.

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(4) One of the old intelligent fellows of that tribe is always inventing new dances—" catching them from a hollow tree "—and such new dances are communicated to other tribes.

The only thing I am missing is a clear definition of the word "totem" as applied to Australian conditions. The scope of the use of this system is very wide in the papers of Spencer, and it includes some subjects which I never would accept as totemistic. Regarding the "Wellungua totem" ceremonies of the Warramunga tribe, Spencer and Gillen (5) admit that "there is no idea associated with them of securing the increase of the Wellungua, nor apparently have they any desire to do so." The idea of the giant snake inhabitating "sacred" waterholes is a general one, extending from the west to east of Australia, but without being connected with a totem. In the Broome district the snake is called Wallanga, reminding us of Wellungua, the same name occurring in the Molonga corroboree described by W. E. Roth. (6)

The same idea is found in North Queensland. The volcanic lake Eacham in the Bellenden Kerr Range is believed to be inhabitated by a dangerous giant snake; the rainbow was the reflection of its brilliant skin. The latter suggestion is also found near Broome. In one of my excursions in the Wyndham district I came across a "sacred" lagoon supposed to be inhabitated by the dangerous snake "Noujuwarra." (7)

The common belief of a powerful snake over the whole of Australia is important, regarding the origin of a similar belief in ancient religions of Asiatic nations. (8)

It was very difficult to get absolutely accurate information from the Niol Niol regarding their belief in the reincarnation of the soul. But, clearly enough, they accept the existence of the soul before birth. The name given to soul in this stage is "Rai." The "Rai" are supposed to be sitting in trees, like birds, and to enter the body of a woman independently of sexual intercourse. They also accept the existence of the soul after death, as spirits called "Njer," which may be useful to the living relations, but may also sometimes tease them. I never could find out if the "Njer" are transformed into "Rai.' The belief in the three entities of the soul is very remarkable in connection with its similarity to the ideas of African religion, and of savage and of cultivated nations. (9)

No sign is to be found of the present or past existence of message-sticks in the Broome district.

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(5) Spencer and Gillen.—"The Northern Tribes of Central Australia," London, 1904, p. 227. I was very pleased to learn from Mr. Gillen that he is inclined to introduce the term "Kobong," used by Grey, for south-west Australia in the place of "totem."

(6) W. E. Roth.—"Ethnological Studies amongst the North-West Coast Queensland Aboriginals," 1897.

(7) Cf. Herbert Basedow, Trans. R.S. of S.A., vol. 28, p. 36.—In the Musgrave Range.—"The waterhole Würmikattidinji is inhabited by a huge snake, which, however, no native remembers having ever seen."

(8) W. G. Streeton.—Roy. Soc. South Austr., 1893.—"Customs, Rites, and Superstitions of the Aboriginals of the Gulf of Carpentaria." Describes from McArthur River, Borroloola, that the eclipse of sun and moon is believed to be caused by a "big-fellow snake." The excellent paper of Mr. Stretton seems to be not valued enough; it is not mentioned by Spencer and Gillen.

(9) See S Laing.—"Human Origins," London, 1897, p. 119.

In one expedition to Pender Bay, near Cape l'Evêque, I observed natives in preparation for a corrobboree using a green color for the decoration of their bodies. This is a vegetable matter derived from the young leaves of eucalyptus, which are masticated, the resulting liquid giving a brilliant green color. That is the only real vegetable color ever observed amongst the Australians.

The customs of circumcision and subincision are practised over the whole north-west. The subincision is properly an Australian custom, the reason for which until now has never been explained. The suggestion that this peculiar mutilation is intended to restrict procreation has been successfully contradicted by Dr. W. E. Roth. (10)

In the countries where the practice is in vogue every male is introcised, and the women must have undergone a corresponding ordeal, which has been elsewhere described. As Roth clearly explains, this mutilation of the male does not necessarily prevent fertilisation. (11)

In these remarks the idea is given, for the first time, of the introcised man as an artificially made woman.

During my stay in the Broome district (November-December, 1905, May-June, 1906) I received information of the real significance of subincision, which at first I refused to accept as correct.

Constat in agro qui Broome uocatur iuuenes eosque pueros qui uel iam facti sint puberes uel mox futuri, uidelicet decem nati annos usque ad quattuordecim, mutuo inter sese masturbari solere. Sacerdotes autem Christiani qui apud Beagle Bay habitare solent, ita in rem omnium turpissimam ac foedissimam et inuecti sunt et inuehuntur ut uix sani sit negare rem ita fieri. Quippe in tribu Niel-Niel nominata uiri puerique inter sese quiddam paciscuntur eique pacto etiam lingua sua possunt nomen dare. Nam et uiri, siue initiati siue pene incisi, nomine Wamba, et pueri, priusquam initiandi ritus facti sunt, nomine Walebel uocantur : quod nomen Walebel negatiuam habere significationem syllaba 'le' interposita satis demonstrat.

Ille uero qui nomine Wamba utitur suum quisque Walebel aut habet aut habuit ea condicione ut amicus amico uictum paret cottidianum : quae duorum marium condicio non dissimilis uidetur esse matrimonio cuidam quod post certum tempus possit dissolui, quippe quae usque eo maneat donec puer, pene incisus, nomen et ipse habeat Wamba.

Me quidem percontantem quaenam ratio sit inter Wamba et Walebel masturbandi, quidam ex indigenis, homo non insulsus, qui apud East Kimberley erat natus, certiorem fecit, rem ipse imitatus : pueri profecto penem cum primum erigi coeptus sit in uirilis penis foramen, quod ad id auctum usque ad intimam scroti partem pateat, inseri solere ; puerum humi supinum iacentem uiri pene manibus comprehenso (quasi extrema digitalis tegumenti parte frices digitum), suum circumfricare penem usque eo dum utrique effundatur semen.

(10) Roth.—Ethnol. Studies N.W. C. Queensland, 1897.

(11) Cf. W. E. Roth, *l.c.*, p. 179.

Quae equidem bene scio esse uera ex eo quod, dum uiri cuiusdam, pene incisi, cadauer inseco atque aperio, intellexi illud urethrae foramen, inter initiandi ritus factum, ita posse augeri ut pueri cuiusuis penis facillime posset inseri.

The explanation of this custom is the difficulty experienced by the younger members of some tribes in getting young women, who are possessed by the old men. The mayor of Broome, Mr. Warden, who has lived there for 17 years, informed me that great jealousy is shown by the Wambas regarding their boys, and that more of the fights which are very common amongst the black people of Broome have their origins in the boys than in the women.

I only intend to state the facts, which may be easily proved by every other scientist visiting the country of Broome and Beagle Bay. I suggest as possible that the primitive significance of the horrible custom of subincision may be explained by conditions formerly existing in which the difficulties regarding the possession of women by the young men were extremely great. This condition being variable and easily changed, I believe that in many tribes the subincision has become a custom which is only performed because the ancestors did the same, and without any practical importance. Therefore the contradictions which I anticipate against the statements I have made will be without any value.

Dr. Roth at first, of course, was not inclined to accept my idea; but later, by a letter, he called my attention to his observation in the Boulia district. (12)

From Broome I made a trip to Java, where I contracted a serious infection of malaria fever.

During my visit to Java I had an opportunity of inspecting the locality where Dr. Dubois (1891-1893) discovered the remains of Pithecanthropus. Digging at that place, on the border of the Bengewang River, I secured some fossil relics of *elephas*, *rhinoceros*, *bos*, and *cervus*. The fragment of the skull of Pithecanthropus shows some peculiar features by which it is near connected with the Australian type of cranium. I am inclined to consider Pithecanthropus as a very primitive form of real Tertiary man, connected in one direction with the ancestor of the Australian and Tasmanian aboriginals, and in the other direction with the fossil man of the European Stone Age (the type of Neanderthal, Spy, and Krapina).

(12) In connection with what you told me as to your new views about introcision, please look at sec. 321, p. 180, of my ethnological studies. It is certainly interesting that the Boulia name for a "whistler" is the *vulva possessor*.

December 18th, 1906, R.M.S. *Omrah*. Dr. Roth.

Mr. Herbert Basedow, in his "Anthropological Notes made on the South Australian Government North-West Prospecting Expedition, 1903," made the following interesting observation: In the Tomkinson Ranges members of the Ullparidga tribe were observed to dance about a man who had killed a kangaroo, and all the while to hold their subincised urethras to view, ... and widening the slit to its utmost extent. Transactions of the Royal Society, Adelaide, vol. XXVIII., 1904, p. 3.

Another interesting connection between Java and Australia is proved by the great similarity of the Australian dingo with the wild dog of the Tengger Mountains of East Java. I visited this locality, in which the real *Canis tenggeranus*, described by Kohlbrugge, is only represented to-day by some specimens which are not completely pure bred, but show clearly the characters of the appearance of the dingo. (13)

These facts concerning man and dog corroborate the idea that a common centre has existed, a now submerged continent which was connected with Java and with Australia.

There is not any connection of Pithecanthropus with the recent Malay population of Java. I investigated the Malay race for comparative studies with the Australians.

There is no trace of a palæolithic population of Java. The only stone implements found are of neolithic type and recent. I was digging in some caves of the southern mountains of Java, the only part which is not volcanic. My inquiries regarding relics of an old population were unsuccessful. The rumors of an extinct aboriginal people of Java, for which even a name has been invented ("Kalangs") are baseless and purely mythological.

I returned to Broome (May, 1906) in a very bad state of health, and had to stay for some weeks in the hospital. After recovering I made a second trip to Beagle Bay. In the beginning of July I proceeded to Wyndham, on the Cambridge Gulf, a place which had been prominently before the public in relation to Dr. Roth's report regarding the ill-treatment of the natives there.

I am sorry to have to sustain the correctness of Dr. Roth's allegations, for, during my stay there of two months, I found the relations between the whites and the blacks so unfavorable that it was impossible for me to get into friendly touch with the numerous wild tribes around Wyndham, every white person being regarded with the dread that the natives attached to police officers, who, in their mind, were likened to dangerous animals. Excellent material for investigation, however, was found in the prison, where 70 to 80 aborigines were confined. I measured over 70 of them very exhaustively, taking a much greater number of measurements of the body and of the head, combined observation of the complexion and structure, than have been made before. I also secured a very fine material for pictures of the living bodies.

Nine miles inland from Wyndham I discovered a native quarry, which is not known to the blackfellows of to-day. A field of 100yds. diameter in the bush was covered with the relics of the old manufactures. The intention had been to get material of a dark-colored metamorphic sandstone rock with which to make the spear-heads. On digging I found the traces of human handiwork for a depth of nearly a foot. A half-civilised aboriginal near Wyndham completed some of the samples of the quarry to the form of the leaf-shaped stone heads, which are now imitated in glass.

(13) I collected a good deal of anatomical material of the Australian Dingo, which I have sent to Prof. Studer, at Berne, Switzerland, for further investigation.

At Wyndham I got sick again by complications following the attack of malaria, but recovered before proceeding to Port Darwin, where I arrived at the middle of September. In the Northern Territory the most friendly relations exist generally between the whites and blacks; and, strange to say, in this State exists the least comprehensive legislation dealing with the aboriginals, which are physically and mentally of a superior type. Close association was secured with the Kunandja or Kunandra tribe (Alligator River tribe). Before my arrival Mr. Herbert Basedow, that gifted young scientist, made a profound study of the customs and weapons of the tribes of Palmerston and of the Daly River. His paper will shortly be published. I need only mention here an observation I made at Port Darwin, viz., a native from Port Keats (14), Victoria River, who had a very interesting foot-formation reminding one of a hand. The extreme shortness of this man's big toe in relation to the second toe proved the atavistic repetition of the ancestral stage of mankind in which the foot was handlike. On my arrival in Adelaide I heard that Dr. Ramsay Smith noted the same phenomenon before me, but he took no stereoscopic photograph nor a cast in plaster of Paris, as I did.

From Port Darwin I made a trip to Melville Island for a fortnight, in a 2-ton vessel, accompanied by Mr. Joe Cooper, a buffalo hunter.

The natives on this island are absolutely preserved in the primitive stage, and are stated to be dangerous and treacherous. (15) Unlike almost all other parts of the Australian coast, these black people of Melville Island have never been disturbed by white immigration since the only white settlement, Fort Dundas, founded in 1827 by Captain Bremer, was abandoned in the year 1829. Left to themselves for so long, their number did not decrease, being now approximately more than a thousand. Joe Cooper and his brother are the only white men who can venture to go inland, where, in the very centre of the island, they have a camp, from which the hunting operations for the buffaloes are undertaken. Mr. Cooper, who was speared in the neck 10 years ago, has introduced for defence purposes a small company of mainland natives.

The buffaloes (16) represent an enormous increase of the herd introduced from Timor by the old settlers. It may be mentioned that the natives never attempted to spear the buffaloes, and that they had to be taught to appreciate their meat.

I left Palmerston September 18th, Tuesday night, the small cutter being fairly crowded by seven aboriginals; two of them were natives of Melville Island. Cape Gambier, on the south-east corner of Melville

(14) This aboriginal was one of the murderers of the party of Mr. Fred. Bradshaw, who was killed near Cape Scott, in his launch, together with the Russian engineer Eggeroff and two other white men, Nov., 1905.

(15) See Report on the Geological Expedition of the year 1905, by the Government Geologist, Mr. H. Y. L. Brown.

(16) See Journal of the Geographical Society, London, vol. IV., 1829. Major Campbell.—"Geographical Memoirs of Melville Island and Port Essington on the Coburg Peninsula."

Island, was not reached till Thursday, September 20th, owing to contrary winds and rough sea. Anchor was dropped off Cape Gambier, and four of the natives in the boat were landed to make their way across the island to Cooper Bros.' camp, and arrange that horses should be at the landing-place to meet the party. Whilst the boat lay at anchor 17 full-grown native men and two boys came off. They proved to be of the best type yet seen by me in Australia. The description given by Captain Bremer in the year 1824 is correct even to-day: "These natives were of about medium height and well formed, possessing wonderful elasticity, and not stoutly built, the stoutest having but little muscle. Their activity was astonishing, their color nearly black, their hair coarse but not woolly, and tied occasionally in a knot behind, while some had daubed their heads and bodies with red or yellow pigment. They were almost all marked with a kind of tattoo, generally in three lines, the centre one going directly down the body from the neck to the navel, the others down from the outside of the breast approaching the perpendicular line at the bottom." (17) The manner in which they came to my boat reminded me absolutely of the picture published by Captain King, vol. I., p. 112: They "sprang into the water and made towards the boat with surprising celerity, jumping at each step entirely out of the sea, although it was so deep as to reach their thighs" (p. 113). "The men were better formed than any we had seen before; they were daubed over with a yellow pigment . . . ." (p. 114). Even the features of their face seem to have been well preserved for three generations. Major Campbell noticed "the eyes small, sunk, and very bright and keen." The supraciliary ridges are well developed in many individuals. This character is also mentioned by Campbell ("the eyebrows are extremely prominent").

The humorous propensities (18) of this happy black people have not diminished during 80 years, and it was on account of this good humor that I always had the best relations with the Melville Island natives, who seem to be a well-disposed people if they are treated kindly.

Surrounding the boat the 17 male individuals examined everything with the greatest curiosity. They were very pleased with the gifts we presented to them, and I received some of the beautiful spears, which are almost the most artistically barbed specimen in the whole of Australia. In spite of being very heavy, they are thrown without the wommera (throwing stick), and are only used for fighting. The only implements they use in making them are sharp pieces of shell, because there is no material on the island for making stone implements, which never have been introduced from the mainland.

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(17) Bremer's report on his expedition to Melville Island with H.M. ship *Tamar* is reprinted in "The Genesis of Queensland," H. S. Russell, Sydney, 1888, p. 30 *et seq.* Some particulars have been communicated to Capt. King by a letter from Lieutenant T. S. Roe. "King's Narrative of Survey," etc., vol. II., London, 1827, p. 233 ff.

(18) King.—Vol. I., p. 112: "The whole tribe began to shout and laugh in the most extravagant way."

The presents they appreciate most are the iron tomahawks, just as in the time of Captain King (19) and Bremer (20).

The scars by which they decorate the body are totally different from the ornamentations on the mainland. They seem to imitate leaves arranged on a branch; but I make the suggestion that they are connected with the arrangement of the barbs on the spears.

Our conversation was mostly restricted to signs, but some interpretation of words was managed by the two Island boys we had on board.

On several points of the coast I had the opportunity of meeting natives of the island. After crying out for them "Pongi, Pongi," which means "good friend," they nearly all came to the ship, and I never had any bad experiences (21).

After leaving our black friends we made another landing on Buchanan Island, near the southern entrance to Apsley Strait, where our natives secured a good supply of turtle eggs. Next day (September 21st) the narrow Apsley Strait was entered, and in the afternoon anchor was dropped off the old settlement of Fort Dundas, the relics of which are well described in the Government report, 1905 (22). Some hundred yards south from this place I came across an excellent specimen of a grave decorated by monuments, as discovered and briefly mentioned by Captain Bremer, but never scientifically described.

The grave was surrounded by nine wooden pillars arranged in an elongated oval, each post differing in size and shape from its fellow. The longest was about 6ft., and each was variously painted in yellows and reds. Some of the pillars were capped with water vessels made of bark and perforated by two openings, the borders of which were carefully fixed with stringwork. The meaning of this arrangement was explained to me by one of our Island boys. The water vessels indicate that there a woman was buried, and the perforations of the vessels show that she has been speared.

There must be something in the arrangement of the painted symbols on the pillars indicative of the position in which the corpse lies. One of our Island natives, on being requested to do so, without the slightest hesitation dug down at the west end of the enclosure and discovered, at a depth of about 2ft., the skull, which proved to be that of a very young lubra.

After cutting off the upper part of one of the pillars we returned to the boat, very likely observed, but not attacked, by the natives. But at night, as we were lying at anchor near Luxmore Head, firesticks carried by natives were seen moving about among the timber; therefore it was decided to run no risk, and the intention to obtain water was postponed till the following morning.

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(19) King.—Vol. I., p. 111: "After a short parley with them, in which they repeatedly asked for axes by imitating the action of chopping . . . ."

(20) Bremer and Campbell made often the experience that axes have been stolen by the natives.

(21) Cf. Government report, 1905, *l.c.*, p. 28.

(22) *L.c.*, p. 27.—A view of Fort Dundas, taken from Garden Point, 1824, is published in King, vol. II., p. 237.

The relics of a monumental grave destroyed by fire were described by the Government expedition, 1905, near Luxmore Head: "In a little sandy flat there was a grave enclosed by wooden slabs, a portion of which has been burnt. Aboriginal markings were faintly discernible in places on the wood, and some of the posts had the wood cut away at the top, leaving two spikes like horns at the sides; others had the wood cut away from the outside towards the centre, leaving a short spike standing up in the middle of the post." In some examples the slab was so carved out that the upper part was only connected with the lower by two thin pillars, or on others the top was mushroom-shaped.

It is easy to see that the natives used the fire for this work of sculpture, scratching away the burnt parts with pieces of shells.

Captain Bremer (23), 1824, found the grave of a native on Bathurst Island: "The situation was one of such perfect retirement and repose that it displayed considerable feeling in the survivors who placed it there, and the simple order which pervaded the spot would not have disgraced a civilised people. It was an oblong square open at the foot, the remaining end and sides being railed round with trees of 7ft. or 8ft. high, some of which were carved with a stone or shell, and further ornamented by rings of wood also carved. On the tops of these posts were placed the waddies of the deceased. . . . . At the head was placed a piece of a canoe and a spear, and round the grave were several little baskets made of the fan palm leaf, which, from their small size, we thought had been placed there by the children of the departed. Nothing could exceed the neatness of the whole: the sand and the earth were cleaned away from the sides, and not a shrub or weed was suffered to grow within the area." These little baskets of fan palm leaf are to-day generally used by the Island people (though they also occur on the mainland). During my stay at the central camp I obtained a large collection of the baskets made by the young Melville Island girls, with a pointed bone of kangaroo. The description of the grave by Captain Bremer proves that in this case a male, and very likely a good warrior, was buried, as indicated by the waddies and the spear (24). The same

(23) Russell, *l.c.*, p. 34.

(24) There are not many cases mentioned in which the Australian aboriginals were accustomed to decorate the graves with the implements or weapons of the deceased. Grey made a remark regarding south-west Australia. Mr. Alex. Morton (Hobart), "Notes on a Visit to West Australia," Royal Soc. of Tasmania, 1898, says from the Murchison River—"If it is a man it is usual to place at the head of the grave a womerah, the property of the deceased." Cf. Herbert Basedow, *l.c.*, p. 24, regarding a grave of a woman in the Musgrave Ranges—"The grave in which the corpse had been buried a few feet below the surface had been filled up with earth and a circular mound erected over it to indicate the spot. On the summit of the mound the implements of the gin—a yamstick ('wanna') and a cooleman ('mika')—had been stuck in the sand in an upright position, almost as a tombstone might be erected." (Pl. VI., fig. 1).

Regarding the question as to how far the pillar grave monument are distributed over Australia I got very little information. The only comparable thing is a simple small painted slab from a grave of MacArthur River, preserved in the Adelaide Museum. Some gentlemen at Port Darwin asserted that they had seen similar things in the Northern Territory, but without definite statements.

idea is confirmed by Major Campbell's report (1892): "It appears to be the custom of the natives to bury their dead in retired spots, near their most frequent camping grounds. The burial place is circular, about 10ft. to 12ft. in diameter; it is surrounded by upright poles, many of which are formed at the top like lances or halberds, 14ft. to 15ft. high, and between these spears and waddies of the deceased are stuck upright in the ground.

On Saturday, the 22nd September, the long sandy point of Cape Van Dieman was doubled. Near Cook's Reef two natives were sighted. They followed the ship, making the most funny jumping movements as a reply to our invitation, by "Pongi, Pongi," to come near the boat. As we intended to go ashore they cleared out rapidly. Cooper suggested that they belong to the tribe which speared a Japanese sailor (25) from one of the pearling luggers some months ago, and that they feared punishment.

After sailing all night the cutter arrived about midday on Sunday at Lethbridge Bay (26), at the mouth of an uncharted river, which has been named by the Coopers the Jessie River (27).

More than a dozen mainland natives were waiting here, who all crowded on board—men, women, children, and three dogs. The river was narrow, with mangroves growing so closely and thickly on either hand that at several points a passage had to be cut for the boat. Every branch falling down emptied a nest of green ants over our heads.

After continuing up the river for about five miles a halt was called for the night, and fires were lighted on shore. I camped there, but I did not sleep, because I never felt at one time such countless hordes of ferocious mosquitoes as were met with on this river. An early start was made the following morning, and after travelling two miles the thick belt of mangroves gave place to a wide expanse of swampy country swarming with many varieties of game, buffaloes, and birds, especially wild geese which, with long swan-like neck, strong bony prominences on the head, and the webbed feet only partially developed, seem to be identical with the species from southern New Guinea that I saw in Java.

Approximately 10 miles from the coast the water voyage ended, and we had to travel on horseback over a tableland from 100ft. to 200ft.

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(25) Government report, 1905, p. 28.

(26) Captain King says (vol. I., p. 108): "The country appeared verdant, and the hills are thickly wooded; at the bottom of the bay a shoal opening trends in between two hills, over which, in the evening, seven natives were observed to cross in a canoe. This was called Lethbridge Bay."

(27) Government report, 1905, p. 22.—" . . . Although there appears to be an abundance of fresh water on both islands, no rivers were observed to open out on either of the north, south, or west coasts." But on the map a "Johnston River" is marked opening in Brenton Bay. We did not proceed so far eastwards, and the Johnston River is not identical with the Jessie River, the origin of which is in the very centre of the island. This river, geographically undescribed, ought to be termed by a definite name, for which I would suggest that of Cooper River.

high for another 10 miles to the central camp. At the landing-place a great number of Melville Island natives were awaiting, including many women and children. They all helped to carry the luggage and provisions. We left the boat without any protection in the river.

The soil on the tableland shows the laterite formation, the surface being covered with small pebbles of ironstone—the usual ferruginous concretionary claystone. A similar formation is found on the top of Luxmore Head (28). The high land was not well timbered, but as we descended to the valley, in which the central camp is situated, I was surprised by the luxuriant vegetation and the big timber which renders the little valley cool and shady on the hottest day, the whole forming a striking contrast to the parched appearance of the surrounding country. This fertile condition was due to the presence of several springs which practically form the source of the river up which our party had ascended. One of the springs forms a large waterhole containing water of great freshness and purity, and forming the most invigorating and glorious natural bath conceivable. This picturesque valley is the present headquarters of the buffalo shooters. There are two camps, one tenanted by the mainland blacks—the bodyguard of the Coopers—the other by the Island natives, who distinguished themselves funnily enough as the "Myalls," or wild blackfellows. Both camps have the most friendly relations with each other. I remained two days, making some interesting observations, and exchanging tobacco, axes, calico, &c., for many ethnographical specimens. There were a good number of very comely young girls and pretty children. They spend much time in decorating their faces by a peculiar method of painting, which I did not observe on the mainland. Some parts of the face round the mouth or below the eyes are surrounded by a colored line, generally red; the interior of this marked field is dotted with spots of another color, for instance, yellow. I have seen similar decorations on pictures of women from Hula, British New Guinea. The forehead is painted almost yellow, the region of the eyes red.

The most interesting spectacle was offered every night by the corrobborees, especially by the dances of the Island people, these being totally different from those of the mainland natives, who performed a "devil devil" dance, using dancing sticks made of paper-bark. The Myalls walked first in Indian file; then surrounding in a half-circle two men, who were the only performers—the others providing the spectators and the orchestra—in a most singular way, never observed in the mainland, by beating both hands on the bare buttocks. So far as I know such realistic music has never been described, but Major Campbell (1829) makes a remark connected with this matter regarding the Melville Island natives: "When they express joy they jump about and clap their hands violently on their buttocks, and in showing contempt they turn their back, look over their shoulder, and give a smack upon the same part with their hand." Very rightly the same

(28) Government report, 1905, p. 23.

author remarks that "they are good mimics, have a facility for catching up words, and are gifted with considerable observation." In the corrobborees I witnessed they not only imitated animals such as alligators, turtle, sharks (29), as was done elsewhere, but they had adopted the antics of the old Fort Dundas sailors in rolling and pulling on ropes, and even the actions of the man in command of sailors so engaged. The performers are painted most beautifully with white clay, and very likely this decoration is an imitation of white men's apparel. The hands and feet being devoid of coloration, the impression of a white dress is conveyed. The dances ended regularly with jumping of a most violent description.

Some of the women and children took part in the dance, stamping in the circle with the characteristic high step movements, holding a piece of paper-bark in the hands to cover the genital parts, and producing a most ridiculous effect.

I was sorry to leave this peaceful place, in which the air is filled by day and night with the happy laugh and song of a yet undisturbed black people. The moonlight in the dense scrub mingled with the glare of many camp fires made the most poetic impression I ever met with in "Black Australia."

Returning to the mouth of the Jessie River (September 27th), after a second painful mosquito night in the mangrove swamps, I discovered another grave on Radford Point—at least I supposed that place to be a grave, although I was unable to obtain any proof. Our digging between the monuments was unsuccessful; perhaps the skeleton had decomposed, perhaps displaced. There were only two monuments, 5ft. to 6ft. high, which are figured in Plate 17. On the inner side of every pillar a waddy was implanted, showing the male sex of the deceased. The paintings in red and yellow were beautifully done. I cut away the upper part of one pillar, taking it in the boat. Near the place I found two small sticks, which are used for beating time in the corrobborees.

On the same day I was fortunate enough to discover another grave, in which the skeleton was preserved. We tried to call at Karslake Island, but the water was so shallow that our boat became fixed on the coral reef. I travelled 600yds. over the shallow stony ground to the island, in which our blackfellows opened a grave. It was surrounded by nine pillars, the most of them being damaged by fire; but the same variation of shape was noticed as I have described. The skeleton was partly decomposed, but the skull fairly well preserved. It was that of a strong male individual of perhaps 50 years of age. The teeth

(29) In imitating the shark the two performers kept sticks in their arms, one in the right placed with one end against the shoulder, the other in the left. The right arm represented the snout, the left the tail of the fish. Moving forwards, with the right arm in front, they turned and jumped about most furiously, as if they were trying to catch game.

are completely preserved (30). The supraciliary ridges were very prominent. The whole feature of the skull reminded me very much of a beautiful specimen from Victoria belonging to my collection, thus proving the unity of the race from south to north, only the width of the face is a little larger in the Melville Island specimen than in that from the south coast.

On the return journey through the Apsley Strait we experienced some turbulent weather, and I tried to protect myself against the icy cold rain by jumping into the tepid seawater.

In St. Asaph's Bay I had the last meeting with the aboriginals. An excellent old fellow and two young men came on board, and we had a great laugh and entertainment without words together.

From Port Darwin I returned directly to Sydney at the end of November, 1906. The last scientific work of my trip was done in Tasmania, where I was most kindly assisted by Mr. Morton, curator of the Tasmanian Museum. I investigated the skulls of the extinct Tasmanians, which reminded me of the studies on the same matter I made some years ago in Paris and London. I was pleased to find Dr. Noetling in Tasmania, and to learn that we may expect from him an exhaustive publication on the primitive stone implements of the Tasmanians. I collected myself a good number from a native quarry near Melton-Mowbray, northwards from Hobart. The soil is filled with relics of human manufacture for a depth of 18in., which proves a long continuance of work, especially if we consider that the locality is the summit of a hill, in which soil is increasing slowly. I am obliged to Mr. Morton for the donation of many fine specimens of stone implements, which I hope will be useful in the acute discussions taking place in the old country regarding the Eolithic problem. I discovered primitive stone implements of Tasmanoid type in many old camping grounds in North Australia. There is no cardinal distinction between those from Australia and from Tasmania. It is wrong to call the Australian Neolithic on account of the half-polished stone axes, which are scarce compared with the primitive stone implements. These implements show great variations which offer some similarities with those of the Palæolithic and Eolithic stages of stone technique of Europe. Many Australian tribes have preserved a stage which is lower even than some Eolithic types of the old country; many used only shells.

Deeply regretting the extinction of the Tasmanians, I think everybody will agree with me if I suggest that a more enlightened treatment of the Australian aboriginals is justifiable on scientific grounds alone, apart altogether from humanitarian questions. My object as a scientist is not to blame any person or any institution, but to enlist the services of the white Australians in suggesting more improved methods of treatment of their black brothers—methods which I feel will be forthcoming when the existing conditions and the problems which have to be faced are better known.

(30) According to Major Campbell the custom of knocking out one front tooth was practised among the Island people; but I observed nothing of that custom, nor of circumcision or subincision.

EXPLANATION OF THE PLATES.

Plate 1. Bark Canoe and Native of Bayley Island, Wellesley Group, Gulf of Carpentaria.

Plate 2. Wellesley Island Natives on Bayley Island ; the fourth figure from the left is the principal old man, " Aliget."

Plate 3. Native Camp, Archer River, North Queensland.

Plate 4. Native Men of the Bellenden-Ker District, North Queensland.

Plate 5. Mummy of Native Chief, Bellenden-Ker Mountains, North Queensland.

Plate 6. Natives of Cairns District, North Queensland, preparing for a fight.

Plate 7. Natives of the Niol-Niol Tribe, Broome District, North Queensland, decorated for a Corrobboree.

Plate 8. Natives of North-West Australia decorated for a Corrobboree.

Plate 9. Native Prisoners, Wyndham Gaol, North-West Australia.

Plate 10. Three Native Prisoners in chains, Wyndham Gaol, North-West Australia.

Plate 11. To the left, Victoria River Native ; to the right, feet of same, showing abnormality of toes (see text).

Plate 12. Group of Natives of Melville Island at the Landing-place, Jessie River. On the extreme left, a typical Melville Islander ; in the background Joe Cooper, the buffalo-hunter.

Plate 13. Natives of Melville Island dancing.

Plate 14. Women of Melville Island at Central Camp.

Plate 15. To the left, Natives of Wellesley Island collecting Nardoo ; to the right, Dance of Melville Island Natives.

Plate 16. Central Camp, Melville Island—Mainland and Island Natives.

Plate 17. On the left, the upper part of a carved Grave Monument (" Wondorolla "), from Radford Point, Melville Island, on which a Native rests his arm ; on the right, four Natives and two Grave Monuments.

18. Map of Melville Island, showing author's route.

PLATE 1. BARK CANOE AND NATIVE OF BAYLEY ISLAND, WELLESLEY GROUP, GULF OF CARPENTARIA.

J. TAYLOR, COLLO

PLATE 2. NATIVES, WELLESLEY ISLAND.

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PLATE 3. NATIVE CAMP, ARCHER RIVER.

PLATE 4. NATIVE MEN OF THE BELLENDEN-KER DISTRICT, NORTH QUEENSLAND.

PLATE 5. MUMMY OF NATIVE CHIEF, BELLENDENKER MOUNTAINS, NORTH QUEENSLAND.
(FRONT AND SIDE VIEWS.)

J. TAYLOR. COLLO

PLATE 6. NATIVES, CAIRNS DISTRICT, QUEENSLAND.

J. TAYLOR, COLLO.

PLATE 7. NATIVES, N. W. AUSTRALIA.

J. TAYLOR, COLLO.

PLATE 8. PREPARING FOR A CORROBOREE. N. W. AUSTRALIA

PLATE 9. NATIVE PRISONERS, WYNDHAM, W AUSTRALIA.

PLATE 10. NATIVE PRISONERS IN CHAINS, WYNDHAM GAOL, NORTH-WEST AUSTRALIA.

J. TAYLOR, COLLO.

PLATE 11. NATIVE OF VICTORIA RIVER. FEET OF SAME NATIVE SHOWING ABNORMAL TOES

J. TAYLOR, COLLO

PLATE 12. NATIVES OF JESSIE RIVER, MELVILLE ISLAND.

J. TAYLOR, COLLO

PLATE 13 NATIVES DANCING, MELVILLE ISLAND

J. TAYLOR COLLO

PLATE 14 NATIVE WOMEN, MELVILLE ISLAND.

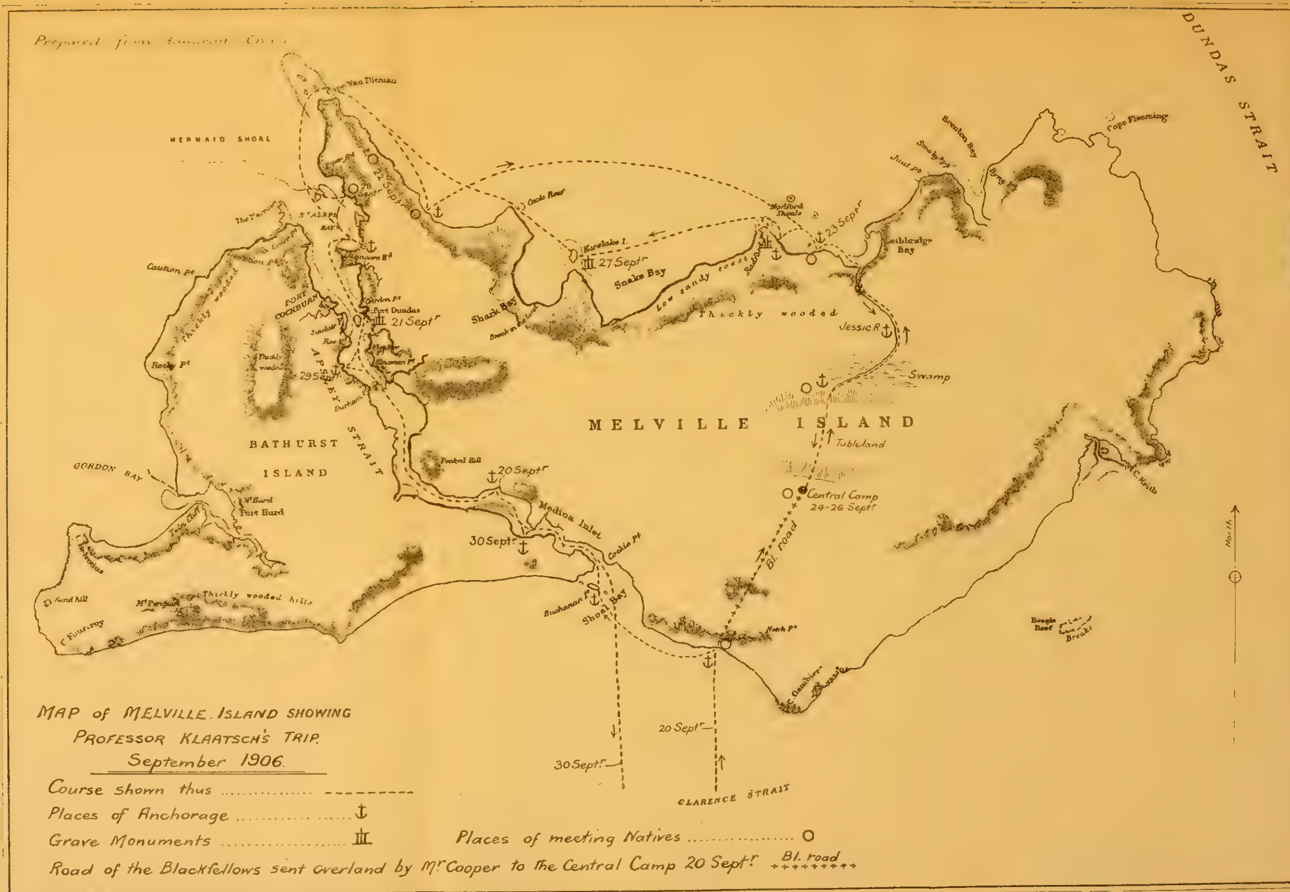
TAYLOR COLLO

PLATE 15. NATIVES GATHERING NARDOO, WELLESLEY ISLAND. NATIVES DANCING, MELVILLE ISLAND.

PLATE 16. CENTRAL CAMP, MELVILLE ISLAND, MAINLAND AND ISLAND NATIVES.

PLATE 17. UPPER PART OF A CARVED GRAVE MONUMENT, FROM RADFORD POINT, MELVILLE ISLAND, ON WHICH A NATIVE RESTS HIS ARM.

FOUR NATIVES AND TWO GRAVE MONUMENTS, MELVILLE ISLAND.



SURVEYOR GENERALS OFFICE, ADELAIDE. A Vaughan, Photo-lithographer

3.–HOW CAN TROPICAL AND SUB-TROPICAL AUSTRALIA BE EFFECTIVELY DEVELOPED?

By MATTHEW MACFIE.

It is no exaggeration to say that in the marvellous variety of soil and climate with which this island continent is endowed—throughout an area of 2,946,691 square miles—we possess sources of potential wealth unparalleled in any equal extent of territory on the surface of the globe. But the important geographical fact seems to be very imperfectly realised by the majority of our population, and immigrants from Europe, that we occupy 12½ degrees of latitude within the tropics.

The distinguished meteorologist, Professor Alleyne-Ireland, of the Chicago University, in his great work "The Far Eastern Tropics," says—"If we draw across a map of the world the northern and southern isotherm of 68° Fahrenheit, that is to say, a line passing through those places in the Northern and Southern Hemispheres which have a mean temperature of 68° Fahr., we cut off a belt of the earth's surface 3,600 miles across, roughly lying between 30° north latitude and 30° south latitude. This belt is called, for the sake of convenience, 'the heat belt.' It is clear that the climate of a country determines to a great extent the labor conditions which prevail there." (Pages 3-6.)

We accept extreme cold as a bar to civilisation, and refuse to accord a similar influence to extreme heat. Any limits we care to set to the development of Terra del Fuego on account of its climate will be received without remark, but if we attempt to assign bounds to the progress of Borneo and Sumatra, through which the equator passes, hostile voices are raised in protest. Yet open-air labor is as really incompatible with the enjoyment of sound health and with the attainment of old age by white people who continuously reside within the tropics and sub-tropics, as would be the case under similar conditions in the frigid zone. How often, in like manner, do we find indiscriminate and false comparisons made between Canada and Australia as fields for white immigrants, as if no account need be taken of the wide climatic difference between the Dominion and the Commonwealth. Nevertheless the stern truth remains that Canada, from north to south, is wholly a white man's country, being, for the most part, 48° from the equator, and 18° from the limit of the heat-belt—which is 30° from the equator—while Northern Australia extends to within 11° of the equator, and covers 19° of the heat-belt.

The marvel that the wide differences in climate and race which prevail throughout the British Empire should escape the attention of intelligent Englishmen is enhanced when we remember that out of 413,000,000 subjects of His Majesty King Edward, only 52,000,000, or only one in eight, are white—seven out of eight being colored. Out of 16,000,000 square miles of British territory, comprising over a fourth of the globe, only about a fourth of this total British area lies outside the tropics. Lady Lugard, in her great work on Nigeria, reminds us that "tropical labor is colored labor," and that "we have not yet faced the question of organising colored labor." The duty of effective tropical administration becomes daily more urgent when we realise that only a fourth of the empire is non-tropical.

The fact cannot be ignored that out of the entire 30° of latitude in which Australia is situated, 19° of latitude has a climate which inflicts injury more or less severe, and sooner or later, on whites who attempt to work continuously in the open field all the year round. Victoria lies between the 34th and 39th parallels of latitude, New South Wales between the 28th and 36th, Queensland between the 11th and 29th, South Australia, including the Northern Territory, between the 11th and 38th, and Western Australia between the 14th and 35th. Thus it appears that Victoria is the only State in Australia situated wholly outside the heat-belt, while a small section of New South Wales is included in it. Queensland is entirely within it, but Western Australia has 16°, and South Australia has 19° of latitude within the climatic area which specially tends to produce fatal effects upon whites, who are indigenous to the temperate zone, and who consequently lack the protection of a dark skin with which nature has expressly equipped the natives of the tropics and sub-tropics for protracted labor in those superheated areas. It is only right to say, however, in correction of Professor Ireland, that there is one degree less heat in the Southern Hemisphere than in the Northern Hemisphere, in the corresponding latitude of the former. But this makes very little appreciable difference in our actual sensations in both latitudes. As a forcible writer has truly said, "The white man can no more run the equator than he can run the North Pole."

It is not, however, to be supposed for a moment that I call attention to the neglected fact of the heat-belt extending from 30° north to 30° south of the equator with the object of depreciating, in the slightest degree, the enormously rich productiveness of any section of our country. On the contrary, I hold with Mr. Benjamin Kidd, in his able book entitled "Control of the Tropics," "That as the white races of mankind increase from year to year, there arises an absolute necessity for utilising the tropics and sub-tropics as sources of food supply for the dense and growing inhabitants of the temperate zone." He contends that there is a new rivalry destined to arise between leading civilised nations, not so much for the mere possession, but for the control and economic development of tropical countries. There is a progressive conviction that it contributes pre-eminently to the highest advantage of intelligent communities possessing large areas in different latitudes to devote themselves to those forms of production for which nature affords their respective countries special climatic advantages. The prevailing doctrine in the parent country of the British Empire is—*not* that there should be an indiscriminate protection of all national industries by high tariffs merely for the financial benefit of local agriculturists, manufacturers, and their employés. The prosperity of the United Kingdom is due to free trade, which involves the free interchange of products between different producing countries, according to the exceptionally favorable conditions which happen to fall to their lot respectively. The paramount consideration in deciding whether there should be a free exchange of indigenous products between nation and nation ought not to be the securing of large profits to local producers, and high wages to their work-people. The claims of the two classes last named are, of course, by no means to be ignored. But the interests of consumers, who constitute an overwhelming majority, should be the supreme "objective," and the question as to what branches of trade should engage the chief attention of capitalists and work-people in any country—at least in the first instance—*should be determined by the natural advantages possessed by the particular countries in which they live.*

When England left protective duties behind, she based her enlightened fiscal policy, adopted in 1846, on the broad foundation of her extensive coal and iron mines, and her abundance of available skilled labor in these manufactures. To these, combined with the great shipping facilities afforded by her insular position in the temperate zone for the establishment of numerous convenient ports for export and import trade with all parts of the world, she owes the supreme position she has attained in manufactures, mercantile shipping, and free interchange of products with those of other nations. The vast export trade she carries on with her scattered dependencies and foreign countries enables her to purchase and import goods from them in return under advantageous conditions in the interest, primarily, of consumers, while furnishing ample and remunerative occupations to all classes of her population. No nation in the last 60 years has more rigidly adhered to the cardinal principle I have laid down—that the profitable, economic, and financial development of a country's resources mainly rests on the fixed economic principle that supreme care should be bestowed on industries whose success is specially guaranteed by suitability of indigenous products, soil, and climate. Systematic efforts should be chiefly directed to the production of commodities which can find large markets at a convenient distance, and which can readily undersell competing countries.

The climatic position of Australia is that of 2,946,691 square miles, which it comprises, 2,203,265 square miles are within 30° south of the equator. This leaves only about one-fourth of the entire area outside the heat-belt. In illustration of the magnitude of the combined trade of the United States and the United Kingdom with tropical countries proper, which are within 23½° of the equator, it is estimated that 44 per cent. of their total collective trade is done with regions within that zone.

As regards the comparatively undeveloped natural resources of three-fourths of Australia within the heat-belt, the area over which these resources mainly extend, virtually remains, up to the present, "a waste howling wilderness." Excluding, for the moment, the incalculable latent wealth of Queensland and Western Australia, both of which possess varied tropical and sub-tropical resources—capable of supporting a population of hundreds of millions—let us take for example a section of country which is the most sparsely inhabited part of our continent, despite the prodigious extent of its undeveloped tropical and sub-tropical riches. I refer to the Northern Territory of South Australia, which extends from latitude 26 to latitude 11, covering about 15° of latitude and 9° of longitude. It is about 560 miles wide by 900 miles long, containing an area of about 523,620 square miles—or 335,116,800 acres. The Northern Territory is about two and a half times the size of France, and four and a half times the size of Great Britain. It has a frontage of 1,200 miles to the Indian Ocean, intersected by numerous rivers, including the Roper, the Adelaide, the Daly, and the Victoria, which are navigable from 20 to 100 miles from the sea. As a South Australian Government report on the region, which was published in 1902 ("The Land-grant Railway Across Central Australia," pages 10, 11) remarks—"The number and volume of these great rivers may afford some indication of the fertility of the country through which they flow. Along the extensive northern seaboard there are many valuable harbors, of which Port Darwin is equal or superior to any other in Australia. Situated as it is in a commanding geographical position with regard to India and the East, at no distant time it must become one of the greatest emporiums of the Southern Hemisphere . . . . Doubtless when the transcontinental railway is completed from this port to Adelaide the principal mail traffic from Europe will take this route, and prove a powerful factor in the development of the Territory."

The carrying capacity of the country to the north of Barrow Creek alone—within the tropics—for horned cattle may be imagined when it is remembered that 200,000 square miles of that area exist which can easily provide pasture for 2,000,000 cattle at the rate of 10 head per mile. Yet so rich are the grazing lands on the rivers that this is considered an extremely low estimate. Drawing a line east and west of Barrow Creek, another 200,000 square miles of country running southward from this boundary is peculiarly adapted for sheep, and here an average of 50 sheep to the mile would give an aggregate of 10,000,000. An annual wool clip, valued at 2s. 6d. per sheep, would give an annual return of £1,237,500. Horses, camels, and ostriches could also, with immense advantage, be introduced into certain sections of the region. Coming to agricultural products, the Northern Territory is exceptionally favorable for the growth of cotton. This fibre, although not indigenous, is found growing wild throughout the jungles in many varieties, and Dr. Holtze, when Director of the Botanical Gardens at Port Darwin, was strongly of opinion that there is no place in the world better suited for its successful cultivation. In a paper read before the Geographical Society in Adelaide, a few years ago, that gentleman mentioned—speaking only of one suitable area out of many—that a belt of 80 miles round the coast would give an area of 80,000 square miles, or upwards of 51,000,000 acres, capable of yielding large quantities of diverse tropical products in addition to the one just named, and of employing many hundreds of thousands of hands in tropical culture.

The high authorities already quoted recommend that the growing of rice should be specially encouraged, as the Territory is found to be pre-eminently adapted for this product, "being the only known country in the world where the rice plant is indigenous." ("Land-grant Railway," &c., p. 16.)

The Territory is a promising field for the cultivation of sugar, coffee, tea, tobacco, cocoanuts, indiarubber, jute, ramie, sisal hemp, Manilla hemp, arrowroot, tapioca, maize, peanuts, spices, medicinal plants, African oil, cotton, ginger, and many other tropical and sub-tropical products. Yet, in the face of these proved facts, Sir John Forrest, in his budget speech as Federal Treasurer, made the following unpatriotic and misleading statement :—"I am not carried away by the cry of some persons that Australia is capable of carrying a population of many hundreds of millions. I know very well that the interior is arid." If Sir John's reputation as an Australian explorer rests on this sweeping indictment of the country, I fear his name will hardly be venerated by posterity as that of a true prophet. But Dr. Holtze and his son, Mr. Nicholas Holtze, both emphasize the fact that, for the profitable cultivation of the products enumerated, colored labor suited to the climate is indispensable.

These statements are, of course, only preliminary to the vital question which forms the chief topic of the present paper. That question is—How can the tropical and sub-tropical area which constitutes so vast a proportion of Australia be most effectively developed ? I venture to maintain that the territory included in the heat-belt cannot be effectively developed without the introduction of labor from largely populated countries situated somewhere within that zone, and adapted, by nature, for doing open air work under a vertical sun. In choosing colored workmen I should be disposed to give the preference to our Indian fellow-subjects, although in some respects it is believed by many that Chinese and Japanese are more efficient in field labor.

This may appear a bold assertion to those who are more familiar with the cry of a "White Australia" than with the teachings of science on the subject.

Within the last few weeks a report by Dr. Ramsay Smith, Chairman of the Central Board of Health and permanent head of the Health Department of South Australia, was presented to the Chief Secretary of the State, giving the results of a hasty four weeks' sojourn in the Northern Territory. The document seems extraordinary from a strictly scientific point of view, and is totally at variance with the collective testimony of numerous high authorities. Dr. Ramsay Smith's statements only bear relation to the subject I am dealing with in so far as he propounds the novel doctrine that "there is nothing in the whole science and practice of medicine to show that white men, as individuals and races, cannot live in the tropics." He further contends that "the acclimatisation of the individual takes usually about two or three years," and that certain white races, including Jews, Gipsies, the nations of Southern Europe, and even the people of Northern Europe, can bear the climatic severity of the tropics with greater immunity than colored people. I can find, however, no shadow of proof in the doctor's report for this affirmation. The theory is totally opposed to the universally accepted belief of anthropologists, viz., that the skin-color of human races is determined by their proximity to or distance from the equator, as the case may be. There is a consensus of opinion among all recognised authorities on the subject that the sole *raison d'etre* for the evolution of a pigmented skin, in different degrees under natures law, is that the colored races are near or at a certain distance from the equator. Any other interpretation of the matter is absolutely incompatible with the facts. Possessors of the blackest skin are always indigenous to equatorial regions or descendants of those who are. In countries near tropical limits, the natives who have lived in that area for many generations are mostly brown. Between $23\frac{1}{2}°$ and 30° their color is still lighter. As we pass from 30° to 50°, and still further north and south—where there is no need of the protection given by a colored skin—we reach the region chiefly occupied in Europe, North America, and latitudes corresponding in the Southern Hemisphere, by white inhabitants.

Dr. Ramsay Smith would seem to imply that whites are even better able to withstand unfavorable climatic influences in the tropics than Kanakas. He adduces statistics to show that the death rate among whites in Queensland is only 11.56 per 1,000 against 36.39 among Kanakas; but the statistical basis of his calculation is unsound. The bulk of the Kanakas have been living in North Queensland, and it is unfair to make a comparison between a colored race chiefly confined to the tropics and the vastly more populous white race residing chiefly in South Queensland. Another point still more fallacious is the assumption that the alleged higher death-rate among Kanakas, as compared with whites, is necessarily due to climatic causes, when, on the contrary, it is a rule that the change in a colored man's diet, habits, and general environment, when brought in habitual contact with civilisation, has the effect of generating diseases to which he is not liable at a distance from the virus of white civilisation. There is no evidence to prove that the death-rate among Kanakas, in their native islands, bears so high a proportion from the causes which are so fatal to them in Queensland. The conclusion to be drawn, therefore, is that the higher death-rate prevailing among them in North Queensland is ascribed to the wrong cause, and has nothing to do with climate. Consequently the assertion that whites can bear a tropical climate with less risk of disease from that source falls to the ground. Besides, the attempted comparison between the effects of climate on whites and Kanakas is vitiated by the admission of Dr. Ramsay Smith that it is extremely rare "for whites to remain for lengthened periods in the Australian tropics." So that, on every ground, the argument for the greater power of resistance to tropical heat being with whites utterly disappears. But even if that race could be perpetuated in the tropics more effectively than the colored races, this advantage could only be secured to the whites by nature's protective method of pigmentation. Such an event, according to the theory of Dr. Ramsay Smith, would be followed in time by the once white inhabitants, after they have become colored in the course of generations, being subdued as an inferior race by a fresh influx of whites from temperate latitudes.

The first competent writer on the subject I will cite in favor of colored labor in the tropics and sub-tropics is Major Charles Woodruff, a surgeon in the United States Army. He has conducted elaborate investigations in the Philippines and in the Southern States of America bordering on the heat-belt, and has published the results of his labors in an able book on the effects of light on white men in the regions referred to. His contention is that the disorders which, sooner or later, afflict our race in tropical and sub-tropical latitudes are caused, not by excess of heat, but by excess of light. It is well known that those actinic rays which are of a short wave length—the violet, indigo, and ultra-violet rays—are highly penetrative, and produce what amounts to a chemical action on the human body. Referring to the chemical phenomena produced by those waves, Sir William Crookes, a former president of the British Association for the Advancement of Science, says, "We have actually touched the borderland where matter and force seem to merge into one another." Dr. Woodruff holds that tropical and sub-tropical exhaustion, loss of memory, tropical and sub-tropical asepsia, neurasthenia, several obscure skin diseases, and some curious fevers are due to the action of the actinic rays on a body which has not sufficient pigmentation to resist them. The same writer found in the Philippines that a large proportion of Americans from northern cities in the United States, who become residents in those islands, and who at first praise the climate, are themselves numbered amongst its victims within two years after landing. In proof of the marked sensitiveness of the white man's constitution when transferred from the temperate zone to even the fringe of the sub-tropics, Dr. Woodruff shows that the Scandinavians who have emigrated to the northern States of America become liable to alarming disorders and nervous irritability, and die out in the third generation. The main line of his argument—which seems impregnable—is that the world is divided into color-zones, and that *each climate is exactly suited by natural law to the particular human racial type evolved under its influence, but cannot be adjusted to any other.* He denies that in a permanent change of residence from a temperate to a tropical or sub-tropical zone, acclimatisation is possible, except after a long period, and then only by the very rare "survival of the fittest." Nor, in this case, is the "fittest" the healthiest or the most adventurous, but the darkest man.

Ten years ago, von Schmaedel, in a paper read before the Munich Anthropological Society, stated that the black man's skin has, in the process of evolution, developed the dark tint as nature's protection against the disease-bearing actinic rays. Animals, too, unless provided with thick pelts or black skins, cannot resist the short actinic rays, and avoid the light. According to the same authority, a blonde skin is adapted to a northern climate, where the sunlight is pale and where many of the short rays are absorbed in the tropical sun. Even brunette races, in sub-tropical climates, exclude as much light as possible from their houses, and in the Southern States of America—which only in a single instance approach as near the north tropical boundary as about the twenty-third parallel of latitude—negroes sleep as much as they can in the intervals of labor by day, and hold their revels by night.

The American author already quoted arrives at the conclusion—which will doubtless be pronounced extreme by many—that the white race in the United States must ultimately die out in all except the most northern cities of the Republic. If this be not strong presumptive testimony in favor of the extension of the heat-belt to latitude 30, words cease to convey ideas. He also ascribes the declining birth rate in the tropics and sub-tropics to insufficient pigmentation of the skin, and, on this ground, insists that only a few of the German immigrants to South America in the corresponding zone will see the third generation. The decrease in the Australian birth rate, with the nervousness and exhaustion of many native-born Australians, he ascribes to their exposure to the penetrative rays of light incident to most Australian latitudes.

Professor Baldwin Spencer, whose personal knowledge of large sections of the Northern Territory certainly qualifies him to express his views on the subject, wrote to me last year approving the central steppe lands for settlement, but he adds—" Whether the more northern part of the Territory is a white man's land is a very different matter. From personal experience during a summer in the gulf country, I should say that the coastal parts of the Northern Territory are not suited for white men—at least not if anything like hard manual labor has to be undertaken. In my opinion there is a belt of country in tropical Australia—northern territory of Queensland—which can only be worked with the aid of colored labor."

Dr. W. Hartigan contributes to the " Journal of Tropical Medicine " an article on " Fit and Unfit Persons for Residence in Warm Climates." The writer says—" While living in China I had often noticed how many more or less delicate men had been advised ' to go out East, as they would be sure to improve.' Now, when examining in London for various Far-Eastern firms, I have frequently to reject applicants as ' unfit ' who had likewise been told that they ought not to remain in England, but would get on capitally in China or Burmah or Peru, as the case may be. Such advice has usually not been given by those who have had tropical experience or made a special study of epidemiology . . . . The weedy, narrow-chested, undersized, anæmic applicants, with their sandy or fair hair, pale, pinched features, too clear or high-colored complexion ; and likewise the gawky, undedeveloped, lanky skeleton, with straight, lustreless, dark hair, probably bright eyes, but sallow, jaundiced features ; or, again, the physically well-built middle-sized man, uncertain and slow of speech, with a dull, heavy expression and face of unhealthy colorless hue . . . . are, all unsuited for the tropics. The former become early victims of tropical anæmia . . . . loss of energy, and inability to work, and readily succumb to prevalent intestinal diseases. Another type to be avoided is the overstrung, exuberant, active, good-all-round 'admirable Crichton,' who burns the candle at both ends . . . a tropical climate does, undoubtedly, 'get on the nerves,' . . . . while the victim of any of the neuroses is generally unfit for work or residence in hot climates . . . . This prohibition applies also to the epileptic—even if only suffering from *petit mal*. Likewise the man of bibulous habits is most unsuitable. The slave of the pipe and the cigarette are recommended to stay at home."

I wonder how much care is taken by the Agents-General for the Commonwealth States in London to explain to intending emigrants climatic differences between the tropical, sub-tropical, and temperate zones of Australia.

About the year 1868 a company advertised the wonderful capabilities of a district in Brazil for the growth of coffee and sugar. Some hundreds of Englishmen and their families were induced to emigrate thither. Their numbers were gradually reduced to nominal dimensions by disease and death, traceable to the climate. After years had passed, accounts appeared in the newspapers of the trials, privations, and deaths of another group which had been tempted to emigrate from Wales to the same district, and succumbed to fatal climatic influences. Sir Charles Bruce, a retired ex-colonial governor of varied tropical experience, in a paper which he read before the Royal Colonial Institute, in March, 1905, on "Crown Colonies and Places," is most explicit in enunciating his views on the labor suitable for hot latitudes. He says —"In temperate regions, where the white man could work under the same conditions as in Europe, he has himself replaced the native . . . In our tropical colonies it is otherwise. *Experience has proved that their resources cannot be developed by the manual labor of the white man.*"

Sir George Le Hunte, the present Governor of South Australia, has had considerable experience of the tropics as the representative of his Sovereign in Fiji, the West Indies, and the Mauritius. Being familiar with tropical conditions in these British settlements, His Excellency was deputed by the South Australian Government to visit the Northern Territory and report on the kind of labor most suitable for its effective development, and he did not hesitate to coincide with all having a scientific and practical knowledge of the subject. Not only did he pronounce colored labor in that region and in all corresponding latitudes in Australia to be indispensable: he also affirmed, in reply to the baseless objection of white trades unionists, that such labor "would not compete with the corresponding class of white labor, but would afford a large field for the employment of white-skinned supervision and management."

Mr. H. Y. L. Brown, the Government Geologist of South Australia whose professional duties lately necessitated a lengthened residence in the same Territory, addressed a reporter of the Adelaide *Register* upon his return in the following words:—"The place is going down hill fast. Chinamen are being drained out of the country, and no one is allowed to come in to take their place. The whole thing hangs on colored labor. *The white man cannot work in that sun.* There is no doubt about that. There are so few Chinamen left that they will only work for a European for high wages." At present the dwindling population amounts to about 3,000, of whom only 800 are whites, the rest being colored.

A letter was addressed some time ago by Dr. Spencer, of Enmore, New South Wales, to the Sydney *Daily Telegraph*, in which he relates his experience as a medical man in Northern Australia. The letter was considered sufficiently important to be quoted by Senator Dobson in the Federal Parliament. The writer narrates numerous cases in which he witnessed men falling victims to a climate for which nature had not adapted them, and proceeds as follows :—" Let capitalists be invited to rent tracts of tropical Australia upon specific conditions of investment. Let the lessees be authorised to import colored labor for agricultural purposes upon condition of repatriating every imported laborer on the expiration of his indenture. No capitalist will employ white men at tropical labor, for which only the colored man is fit. If one maintains that the agricultural riches of tropical Australia can be developed by white labor, he is either a deluder or is deluded."

Mr. C. B. Shawe, a trustworthy citizen, writing to the Melbourne *Argus*, twelve months ago, said :—" I have lived 40 years in the tropics, and know that the white man cannot personally work the land. He can guide, direct, supervise, and profit by it when worked by colored labor. A third generation of pure whites in the tropics is a feeble rarity, and a fourth is unknown. How, then, is the white man going to colonise tropical Australia ? If necessary, a color line could be drawn, south of which these immigrants are not to come."

In opposition to the visionary and unscientific absurdities of Messrs. Barton, Deakin, Reid, Kingston, Forrest, and other self-interested partisans of the " White Australia " movement, I place the opinion of Mr. Coghlan, formerly Government Statistician of New South Wales, and now Agent-General for that State in London. In his " Seven Colonies of Australia, 1899-1900," he says—" A considerable area of the continent is not adapted for colonisation by European races. The region with a mean summer temperature in excess of 95° Fahr. is the interior of the Northern Territory of South Australia north of the 20th parallel, and the whole of the country, excepting the seaboard, lying between the meridians of 120° and 140°, and north of the 25th parallel has a mean temperature in excess of 90° Fahr." In another paper the same writer says—" The climate of the Northern Territory of South Australia is extremely hot, except on the elevated lands. Altogether the temperature of this part of the colony is very similar to that of North Queensland, and the climate is equally unfavorable to Europeans." To condense the statistics of Mr. Coghlan on page 5 of the volume referred to, Australasia, in the winter months, has 1,649,500 square miles with a temperature ranging from 60° to 80° Fahr., and in summer 2,810,800 square miles with a temperature from 60° to 95°. But Professor Alleyne Ireland, the highest living authority on climatology, in his "Far-Eastern Tropics," maintains that the white race cannot do field work continuously without seriously undermining health and shortening life nearer the tropics than latitude 30°, under an average heat of 68° Fahr.

When presiding at the reading of a paper on "The Products of Australia," by Mr. J. G. Jenkins, Agent-General for South Australia, before the Royal Colonial Institute, Sir George S. Clarke, a former Governor of Victoria, said—"While the settled portions of Australia are not yet fully developed, tropical Australia, full of great possibilities, is practically in a state of nature . . . . I do not believe that legislation can alter the laws of nature, and the experience of the world is that white field labor is impossible in the tropics. It must be remembered that the whole of the United States, and all except a little strip of Argentina, lie outside the tropics. I have never heard any valid reason why what Mr. Jenkins calls 'suitable labor' should not be employed in the tropical part of Australia, and rigidly limited to that part." In the discussion of the same paper, Lord Brassey, also an ex-Governor of Victoria, said—"I feel persuaded that the aid of the tropical races might be very valuable in those tropical parts; and I do not see why that kind of labor should not be engaged under conditions which are perfectly free and voluntary, and which involve no degradation of any kind to those concerned."

The late Herbert Spencer, England's greatest philosophic thinker of the nineteenth century, in his "Study of Sociology," expresses his views on the subject in the following decisive terms:—"Men having constitutions fitted for one climate cannot be fitted to an extremely different climate by persistently living in it, because they do not survive generation after generation. Such changes can be brought about only by slow spreadings of the race through intermediate regions having intermediate climates to which succeeding generations are accustomed, little by little."

In his forcible work entitled "Europe and Asia" Mr. Meredith Townsend remarks—"Those who say, with Mr. Frederick Boyle and Mr. Bates, that whites can thrive and develop in the tropics, only dream. History is opposed to them . . . . That must have been a most operative law which originally divided mankind so that the white race was confined to Europe, that the black race populated Africa, and that the huge bulk of Asia, the most fertile and tempting of all the continents, was filled with yellow and brown men . . . . The white people flourish best within strictly temperate regions. Hot lands do not, with all their natural advantages, ever tend to produce energy . . . . The first generation of white settlers in such countries suffers terribly from unaccustomed diseases; from the depressing effect of a change of climate, and from the shock involved in a violent change of daily habitudes as to diet, hours of labors, and general social life. This suffering, involving much mortality, would discourage the average colonist to such a degree that he would not remain for the time which even Mr. Boyle admits to be necessary to secure him complete acclimatisation . . . ." (pp. 343-4).

Dr. T. E. Scholes, in his learned and unanswerable work, "The British Empire and Alliances," published in 1899, holds the view (p. 383) that "nearly all the malaria which attacks white men in tropical Africa is due to the action of the sun, and that the pigment on the colored man's skin is the only true antidote . . . . While whites within the heat-belt become the victims of jaundice, disordered vision, shattered nerves, and sometimes subverted reason, and are compelled to be birds of passage, the black man can live under the severe climatic conditions mentioned with absolute immunity from the risk of such distressing ailments." The author last named classes the prejudice against colored races—so indispensable to the development of tropical and sub-tropical regions—in the same category with witchcraft and sorcery.

Hæckel, the greatest living German writer on anthropology, has deemed the subject of sufficient importance to devote some attention to it in several of his works. In his "History of Creation" (vol. I., pp. 150, 151) he states that as early as 1813 Dr. W. C. Wells, in a paper which he read before the Royal Society, remarked that "negroes and mulattoes are distinguished from the white race by their immunity from certain tropical diseases. One race, for example, in the middle regions of Africa would thus be developed better fitted than other races to bear the diseases of the country. That race would consequently multiply, while others would decrease—not only from their inability to sustain the attacks of disease, but from their incapacity to contend with their more vigorous neighbors." "The color of this vigorous race, I take for granted (says Hæckel) from what has been already said, would be dark . . . . a darker and darker race would in course of time occur; and as the darkest would be the best fitted for the climate, this would at length become the most prevalent, if not the only race, in the particular country in which it had originated." The same eminent author, in the work already quoted (vol. I., p. 243), adverts to skin pigment and its uses in these words—"The want of the usual coloring goes hand in hand with certain changes in the formation of the other parts—for example, of the muscular and osseous system . . . . Very frequently albinos are more feebly developed, and consequently the whole structure of the body is more delicate and weak than in colored animals of the same species. The organs of sense and the nervous system are, in like manner, curiously affected where there is this want of pigment. White cats with blue eyes are nearly always deaf. White horses are distinguished from colored horses by their special liability to form sarcomatous tumors. In man, also, the development of pigment in the outer skin greatly influences the susceptibility of the organism to certain diseases. So that Europeans with a dark complexion, black hair, and brown eyes become more easily acclimatised to tropical countries, and are less subject to the diseases there prevalent (inflammation of the liver, yellow fever, etc.) than Europeans of white complexion, fair hair, and blue eyes." Again Hæckel states the interesting fact that "the kittens of a pair of black cats produce black hair before they are born, and we have no reason to doubt that the black pigment in their integumentary structure is originally referable to the action of the sunlight. In many instances creatures living for generations in darkness become white, pigmentless, and they regain the pigment when exposed to light. The white, colorless Proteus from the caves of Adelsberg become clouded grey, and ultimately become black when kept in a tank whence light is not strictly excluded. Blindness is a very general characteristic of creatures which dwell in darkness." In his "Evolution of Man" (vol. II., pp. 180–183) Hæckel strikingly points to the analagous methods of nature in providing colored skins for the apes—from whom man is believed by all leading modern ethnologists to be descended—indigenous to the tropics and sub-tropics respectively. He writes—"Both the African man-like apes are of black color, and, like their countrymen, the negroes, have the head long from back to front (dolichocephalic). The Asiatic man-like apes, on the contrary, are mostly of a brown or yellowish-brown color, and have the head short from back to front (brachycephalic), like their countrymen, the Malays and Mongols. The largest Asiatic man-like ape is the well-known orang, or orang-outang, which is indigenous to the Sunda Islands (Borneo and Sumatra), and is brown in color."

Mr. Benjamin Kidd, in his "Control of the Tropics" (pp. 48–50), says—"The attempt to acclimatise the white man in the tropics is a blunder of the first magnitude. All experiments based on the idea are mere idle and empty enterprises foredoomed to failure." Elsewhere in the same volume the author remarks—"In South American republics the pure white population appears unable to maintain itself for more than a limited number of generations without recruiting itself from the outside. The prospect is that ere long these countries will be almost peopled with black and Indian races." In a recent contribution to an American periodical, the same writer foreshadows coming events thus—"As the economic pressure of civilisation to develop the tropics continues, the cry is everywhere going up for races able to sustain the burden of the development which the tropics are destined to undergo. In response to this pressure it is possible that we shall witness in the future almost as large movements of population in the tropics as history has already witnessed in the temperate regions."

Indorsing the views of the eminent scientific and practical authorities already cited, Mr. Chamberlain, when Secretary of State for the Colonies, expressed his belief that "the life and health of our administrators in colonies where *civilisation and the development of resources can only be carried on by the labor of colored races working under European supervision is a national asset.*"

In the Melbourne *Argus* of November 30th, 1906, appeared a letter from the manager of a large sugar mill in North Queensland, who writes as follows:—"We engaged 10 gangs of canecutters, 10 in each gang, and three gangs of white canecutters, making in all 130 men. We offered the best terms offered by any mill. A gang of Chinamen working in similar cane cut three-quarters of a ton more cane per man per day than the best white canecutters from any part. After about three weeks' cutting we had one or two warm days—84°

in the shade—and then the white cutters commenced to give trouble. Twenty-seven were paid off in one week. A whole gang, on one occasion, laid down their knives and took a holiday. A very common thing was—and still is—for the whole gang to stop work about some little grievance they might have against one of themselves. At the end of four or five weeks there was not a single gang that had not changed its ganger or members. Nine thousand reliable men are required for the mills. Where are they ? I have not 50 reliable members. I really do not think that importing European labor will help us much. No European with any self-respect or regard for his health would cut cane from choice. It was never intended that whites should do outside manual work in the tropics. The black man has a skin provided by nature to resist the heat. *It has been proved that the white man does not get inured to the sun.* Look at the white residents of India, or of any other tropical country. My idea of relief would be to allow the natives of New Guinea to come on the plantations for coffee, tea, sugar, spices, cotton, &c., and let them be returned to their homes at the end of the term of their agreement. Or let the 'Tamils' of India be introduced and confined strictly to the plantations. . . . This (1906) season, up to October 27th, the mill lost 168¼ hours, and we are only about half way through the season, with our greatest troubles ahead when the weather becomes warm. Some of the canecutters are earning £4 to £5 per man per week, exclusive of rations or bonus."

Mr. A. L. Anderson, a sugar-planter from the Herbert River, North Queensland, interviewed at Brisbane, said he had tried white labor in the canefields, and had come to the conclusion that the sugar industry without black labor was impossible. North of Mackay the white labor in the north was not only scarce but utterly unreliable, and, as a result of that and uncertainty as to the future of the industry, the farmers were not increasing their acreages.

Mr. George Kerr, a Johnstone River farmer, when interviewed, said the crop in his district next year would be a record one. He remarked that most of the statements of the conference of white labor delegates should be taken with a grain of salt. The majority of the people on Johnstone River were opposed to white labor. They would never have sufficient white labor to take off the crop necessary to keep the mill going.

Not the least important and gratifying incident connected with the conference of the United Australian Chambers of Commerce, held at Perth a few months ago, under the presidency of Mr. Knox, was that the first resolution passed on the occasion urged "the necessity for developing the tropical parts of Australia by suitable labor, white labor being deemed impossible."

The collection of opinions I have quoted against the insane policy of excluding from the enormous tropical and sub-tropical area of Australia the only kind of labor adapted by nature for its effective development would be incomplete without including the sentiments expressed by Asiatic peoples on the subject. Smarting under the indignities to which they are subjected by the Immigration Restriction

Act, British Indians resident in Australia sought redress for their grievances by forming themselves, at the beginning of 1903, into a body called the "British and Indian Empire League of Australia (affiliated with the National Congress of India and kindred bodies in Great Britain)." Soon afterwards they memorialised the Indian Congress, held in Madras in the same year, to espouse their cause. The following are a few extracts from their petition :—"As loyal subjects of King Edward, all we ask is that the very limited number of British Indians who seek access to Australia should not be excluded by restrictive legislation, so long as they duly respect the laws of the country and the rights of their fellow-subjects of British origin, avoiding all interference with the established customs and interests of European residents. The astounding anomaly of which we complain is that about one-half of Australia lies within the tropics. The races indigenous to extra-tropical countries are endowed with a lighter complexion than those who inhabit tropical territories. The obvious physiological cause of this difference is that it was deemed necessary by the author of our existence to enable natives of the tropics to live and labor in that region with comparative immunity from danger to health. They are, accordingly, afforded special protection from the scorching rays of a vertical sun by a different dermic organisation from that of natives of extra-tropical countries. Yet this wise provision is profanely condemned and resented by the dog-in-the-manger policy of the Commonwealth restrictionists. Those whites hostile to us cannot work in the tropics without serious inconvenience ; yet they insist on prohibiting their Indian fellow-subjects, whose physical constitution is expressly adapted to a tropical climate, from developing a vast British country, whose increased products would contribute to the convenience and comfort of the civilised world. The plan of the Creator is contemptuously defied by a majority of Australian legislators, who retaliate against Him for giving us the only kind of complexion by which we could withstand climates that would imperil the health and lives of Europeans. His handiwork is denounced by the Bartons, Kingstons, Deakins, and their followers as a 'curse,' threatening the contamination of the white population. . . . Christian missionary societies profess solicitude for our conversion from the faith of our fathers to their religion on the plea that Christianity is the sole passport to eternal felicity. But it militates greatly against our desire for the society of the professed adherents of that system in the future world that we should be subjected to such ignominious treatment by Australian fellow-subjects of British descent, and that their clergy and the public press should remain silent while we are doomed to unmerited contumely by so large a class of Australian politicians and citizens, although ruled by the same sovereign as themselves. . . . The British Government must be asked to declare before the world whether it is for or against our cause."

In response to this appeal the National Congress of India, at its annual meeting in 1903, passed the following resolution :—"That this Congress views with grave concern and regret the hard lot of His

Majesty's Indian subjects living in the British colonies, the great hardships and disabilities to which they are subjected by colonial governments, and the consequent degradation of their status and rights as subjects of the King, and protests against the treatment of Indians by the colonies as backward and uncivilised races; and it prays that, in view of the great part the Indian settlers have played in the development of the colonies, and the economic advantages which have resulted, both to India and to the colonies, from their emigration to and stay in the latter, the Government of India will be pleased to ensure to them all the rights and privileges of British citizenship, in common with the European subjects of His Majesty, by enforcing, if necessary, such measures as will render it impossible for the colonies to secure Indian immigrants except on fair, equitable, and honorable terms; and that, in view of the great importance of the principle of equal treatment of all His Majesty's subjects, His Majesty's Government should devise adequate measures to ensure that position in all British colonies."

It should not be forgotten that the Indians, in pleading for their rights, take their stand on England's pledge, when she took over their country from the East India Company, after the mutiny of 1857. Her Majesty, the late Queen Victoria, in her proclamation of 1858, said—"No native of the said territories (India), nor any natural-born subject of Her Majesty resident therein, shall, by reason only of his religion, place of birth, descent, color, or any of them, be disabled from holding any place, office, or employment under the said Government, and it is our further will that, as far as may be, our subjects—of whatever race or creed—be freely and impartially admitted to offices in our service, the duties of which they may be qualified by their education, ability, and integrity to discharge."

Mr. Kingston, the first Federal Minister of Customs, in a speech at Brisbane, proclaimed his own incompetency to occupy a seat in the Commonwealth Government by the following discreditable utterance:—"If there was an industry that must have the 'yellow agony' or the 'black curse' to keep it alive—a proposition which he did not admit—then it must be swept off the face of Australia, which was a white man's land." By the "agony," he evidently meant the Chinese and Japanese, and by the "curse," the kanakas. The Japanese Consul-General of Australia, at a social function, subsequently replied to the insulting language of Mr. Kingston in terms of faultless courtesy. "He would like to say a few words concerning fears entertained by some people . . . in regard to a danger they termed the 'yellow peril.' A little reflection would show those fears were groundless. Since the beginning of the present Japanese dynasty, which had continued in an unbroken line for over 2,500 years, they have never been an aggressive race. They had centuries of undisturbed peace. . . . The great desire of Japan was to pursue the arts of peace; to live in friendly communion with the whole world."

The following is the translation of an ominous paper from *Triabem*, the official gazette of Tokio, of April 18th, 1904:—"Here (Japan) is an energetic industrious nation sadly needing fields of labor. Nations that are growing will assert their right to find room wherever there is room, and untilled fields will be seized by the right of might if not thrown open in some other way. People are not to hold land without making use of it. If the Australians will not open their eyes and listen to reason they may, some day, be surprised to find themselves in trouble from which the mother country may refuse to extricate them."

As regards the kanakas, designated the "black curse" by Mr. Kingston, who were captured and brought to Queensland by force sanctioned by the State Government, we have the kindly-expressed valuable testimony of Dr. J. P. Thomson of the Queensland Government Lands Department—an official who has had many years' experience of these Polynesians. In a paper read by that gentleman before the Royal Colonial Institute (November 24th, 1903), he says—"In intellectual capacity the Polynesian is on a far higher plane than the Australian aboriginal; he is superior to the African negro, and to many of the tribes of further India, and is capable of reaching a high step on the ladder of civilisation. In perceptive powers he is keener than many of the colored races, and is very readily impressed. He is highly receptive, easily taught, and can reason clearly, but is somewhat emotional, with a clear idea of right and wrong. . . . . Being naturally domesticated, he is sympathetic, honest, and trustworthy. I have found them invariably superior to white men for the class of work. . . . . more loyal, equally intelligent, and far-less troublesome. . . . . During a period of family bereavement I had more affectionate care and sympathy from my Polynesian boys than from my European neighbors — including those professing Christianity. In the dense tropical jungle, heated by the air of a solar furnace, or in the steaming canefields, the kanaka, if properly treated, will cheerfully toil from day to day: from daylight to dark, if need be. . . . . I have tried whites at the same kind of work, with most unsatisfactory results. . . . . His deportation will undoubtedly inflict great hardship, as well as prove a serious setback to tropical Australia. . . . . There is no use shutting our eyes to the fact that much of the continued prosperity of the sugar industry of Queensland depends on colored labor."

All attempts to reply to the varied and numerous authorities I have cited in defence of the necessity of employing colored labor in the Australian tropics and sub-tropics amount to little more than an evasion of the real point under discussion. Mr. Walter James, ex-Agent-General for Western Australia in London, read a paper on April 10th, 1906, before the Royal Colonial Institute on "Australian Immigration." The author informs us that the Immigration Restriction Act, passed in 1901, "was intended to protect the policy of a white Australia. To that policy (he says) we almost unanimously agreed: *It was conceived and enforced long before the Labor Party came into existence*, and it stands, to-day, too strongly entrenched to be affected by the opposition or advocacy of that or any other party."

With dogmatic prejudice he prophesies that, "No serious objection will ever be raised to it," and in the same bigoted spirit he adds that, "In its broad sense, the policy of a 'White Australia' represents the one question upon which the Commonwealth is inflexibly and earnestly united." Yet nothing could more distinctly emphasize the flagrant inaccuracy of such a statement than the enlightened testimonies I have quoted, including the resolution unanimously passed by the United Australian Chambers of Commerce which assembled in the very capital of Mr. James' own State last year, previously quoted by me, declaring the impossibility of developing the agricultural resources of Northern Australia by white labor. Mr. James then proceeds to illustrate the hollowness and inconsistency of his own attack upon colored labor by admissions mutually destructive of each other. He says—"The white man never troubled about the yellow until the mineowners thought fit to use the yellow man as a threat to bring down the price of labor. A few attempts to do this laid the foundations of the bitter hostility of Australians to Chinese . . . and of Australian exclusion laws." It is frankly confessed by the same authority that the arguments subsequently employed as to the Chinese being socially undesirable was an afterthought, to win the support of whites not interested in the wages question in favor of the exclusion of Asiatics. The Labor Party confessedly wanted to expel them, from a dread of them as possible competitors in work. A new and false issue, according to Mr. James, was then raised. Every Chinese camp was specially declared to be a "festering sore in the heart of the community into which all that was foul and low in human character drifted." Mr. James then completely neutralises the force of his argument once more by acknowledging that "the moral lepers were not all yellow. Even some degraded whites drifted to the camps." He further states, nevertheless, that "the Chinaman to-day, in Australia, is a decreasing force; that 'the camps' are disappearing in the old mining centres," and that in the cities the Chinaman "is becoming quite European in his dress, and growing more European in his tastes and modes of living." Mr. James unconsciously maintains with startling inconsistency that there are filthy whites as well as filthy Chinamen, but that the former are to be tolerated in their squalor, while the Chinamen, who appear to be gradually adopting habits of European civilisation, are to be excluded as a moral plague, notwithstanding their marked sanitary and social improvement and their special suitability for tropical labor.

In like manner Mr. James takes exception to "brown-skinned low-caste men from India," on the illogical ground that "they are still Hindoos or Mohammadans, and keep apart from the national life." The fallacy here is that one must be a believer in the popular creeds of a country to be a loyal citizen. Yet the late Sir Leslie Stephen, one of the ablest philosophical thinkers of the nineteenth century, was an avowed Agnostic after resigning the clerical office in the Church of England, and, in the eighteenth century, one of the greatest intellectual giants of his age, and one of the most exemplary citizens and loyal patriots in the United Kingdom was David Hume, the philosopher, deist, and historian.

Mr. James also, with equal lack of discrimination, objects to East Indians because "they hawk through the country districts cheap fancy goods mostly rubbish;" as if all white men were above suspicion of being hawkers, cheats, and loafers. Our attention must not be diverted by these manifestly irrelevant and exaggerated charges against British Indians from the supreme question, viz., "Are the fabulous agricultural riches of three-fourths of Australia to remain undeveloped and neglected to gratify a senseless whim that the colored races, who alone can accomplish the task effectively, should be rigidly excluded from the very parallels of latitude to which they practically belong by birth, and in which they alone are capable of open-air work without risk of fatal disease?"

The only answer Mr. James dare venture to make to this is a feeble assertion—not only without a particle of proof but in audacious defiance of centuries crowded with evidence of the martyrdom of whites by a climate to which they were not indigenous, in India, the West Indies, and other tropical and sub-tropical countries—a climate which tends to sweep all but colored races into a premature grave. Mr. James can only reply—"Australians believe that white labor can people this country, and have strong grounds on which to base that belief. The assumption that the white man cannot live and work there equally as well as the black or the yellow is perfectly gratuitous." But not the faintest attempt does he make to substantiate this false affirmation. The attitude of Mr. James in this matter is as absurd as if he were to deny the whole vast accumulation of evidence in support of the Copernican theory that the earth revolves round the sun, and as if he were to cling, at all hazards, to the ancient and defunct Ptolemaic system of astronomy. He strives to uphold the long-exploded theory that the white man is just as well suited to bear tropical heat as the man of color by quoting Mr. Gregory, formerly of the Melbourne University, but now Professor of Geology in the University of Glasgow. Equally in gratuitous contradiction of a long array of irrefutable proofs, the professor contends that "there seems to be no adequate reason why Australia should not in time all be occupied by white races." But this assertion is unsupported by an atom of proof. The professor fears the invasion of "an Asiatic deluge," if the artificial legislative barriers now erected against it be removed. But protection from such an imaginary disaster could be effectually provided, as already stated, by legally restricting Asiatic immigrants to their own latitudes, and by having the management of large tropical and sub-tropical agricultural undertakings promoted by white capitalists and superintended by men of the same race. It is wholly by raising evasive issues, expedient fallacies, and mean equivocations that the vital question of this controversy is shirked. These evasive issues include the alleged unreliability of colored workers in defending the country from attack, and the denial of the proved impossibility of developing the latent wealth of the Australian heat-belt by white labor.

DISCUSSION.

The President intimated that the subject was open for discussion. Some of the members suggested that it would be necessary to adjourn the meeting, since the discussion was likely to occupy a great deal of time. Others suggested that the various scientific points in the paper should be taken in detail. One member proposed that the subject of pigmentation of the skin might be taken up first. After some general conversation, Dr. Ramsay Smith said: Mr. President, will you allow me to open the discussion on this subject?

It has been most refreshing to listen to this paper. It takes us back to the beginnings of science—back, even farther, to the beginning of the study of logic and to the mental recreations of the early philosophers and logicians. We remember, when following their footsteps, the ratiocination that proved that there is no such thing as motion: "A thing cannot move where it is: a thing cannot move where it is not: but it must move either where it is or where it is not; therefore it cannot move at all." The ancients said, "*Solvitur ambulando*"—so we walked, moved about, under the firm intellectual conviction, all the while, that motion was impossible.

The paper reminds us, too, of the beginnings of scientific societies, and the problem propounded to the Royal Society by King Charles: "Why is it that, if a living fish is placed in water, the weight of the whole is not increased, whereas if a dead fish be so placed the weight of the whole is increased by an amount equal to the weight of the fish?" After prolonged discussion, someone was sufficiently disloyal to suggest that the statement should be tested by experiment. You know the result. The members of the society found that His Majesty was amusing himself; in vulgar language "the King was having the loan of them."

I remember how Professor Guthrie Tait used to devote five minutes at the beginning of the lecture hour to answering students' questions submitted to him in writing. Sometimes he would read a question: "How do you explain so-and-so?" and he would reply, with a smile, "Gentlemen, I deny the fact." He impressed upon us that in science it was necessary to be clear about the existence of the fact before attempting any scientific explanation of it.

These historical references are very pertinent to the present subject. We have been listening to a large number of very cogent and conclusive, and, apparently, scientific reasons why white men cannot live and work in the tropics. Recently I read Lord Roberts' "Forty-one Years in India." I find to-day that the book must be removed from the class of biography to the shelf reserved for the literature of the imagination. Perhaps Mr. Macfie may think that this is straining his thesis to the breaking point. But, if he does not mean this with individuals, he does lead us to believe he means it with reference to races. We have been taught that the Spanish in the Philippines have been in possession for 300 years, and that the Dutch in Java and Africa have existed for several hundred years, and have thriven. We have learned to-day that we have been dreaming, that we are deluders or deluded, and that this so-called history must be relegated to the realm of fiction. At Manila I found that the American ladies there begin card parties at 8 o'clock in the morning, continue them at intervals during the day, attend the theatre, hold suppers after, and finish off the day or the night with balls, &c., and then, at the end of about two years of this life, they begin to complain that they feel the climate trying. They may now feel assured, on the strength of Mr. Macfie's paper, that the tropical climate is not merely trying—it is impossible.*

I would select and examine a few illustrations to show the sort of logic and science employed by Mr. Macfie in support of what I take to be his thesis: that the tropics, or certain large tracts thereof, cannot be exploited by white labor.

1. In referring to a report of mine, he says it contains nothing in support of an assertion I made. What was the assertion? According to him† it was that "there is nothing in the whole science and practice of medicine to show that white men, as individuals and races, cannot live in the tropics." Now, what sort of support does Mr. Macfie wish me to bring forward for my assertion? I am at a loss to imagine, unless he expects me to embody a whole treatise on tropical hygiene in the compass of a short report. If, on the other hand, he refers to a supposed contention or affirmation about the ability of certain white races to bear the climatic severity of the tropics with greater immunity than colored people, which he attributes to me, I have to say that I do not recognise my sentiments in the garb in which he clothes them. Elsewhere he refers to what he calls my admission, that it is extremely rare "for whites to remain for lengthened periods in the Australian tropics." The words he professes to quote do not occur in my report. I have never used them anywhere. I did say something about the length of time certain classes of people remained in the Northern Territory; but that had nothing to do with the subject of disease or inability to work there, nor had it any general reference to the Australian tropics.

* On this subject I should like to add that Major-General Wood, Governor of one of the Philippine provinces, says, "A moral life, with plenty of hard work, will be found to counteract in most cases the so-called demoralising effects of the Philippine climate." The Commissioner of Public Health for the Philippines writes thus, "Cantlie observes that about two years are required for acclimation of the white man in the tropics, after which good health is a reasonable expectation. Calvert makes a similar observation. These views seem to be borne out by statistics of the Board of Health for the Philippine Islands." Again, he says, "Americans connected with the public service, whether engaged upon work in offices or upon work requiring their presence in the open air, have probably, on the average, accomplished more in the Islands than is ordinarily accomplished at home in similar lines of work."

† The words in my report were:—"The broad question is often put, 'Can white men, as individuals or races, live in the tropics?' There is nothing, so far as I can find, in the whole science and practice of medicine to show that they cannot. On the contrary, all the facts of hygiene tend to prove that they can." It is customary for scientific people, when conducting a scientific discussion, to put a writer's or speaker's actual words within the inverted commas when commas are employed. Such a custom tends to maintain a proper understanding in relation to the subject under discussion. I believe this custom is not unknown in literary circles.

2. In referring to statistics which I quoted of whites and kanakas, in Queensland, he says the comparison is not valid, and that we ought to be guided by statistics of the death rate of kanakas in their own islands. I took pains to state that the statistics of whites and kanakas in Queensland are not on all fours, and I was, and am, prepared to make all necessary allowances in order to arrive at a true estimate of the conditions. He refers to the kanakas in their own islands, and asks for a comparison. I say, "If there are any facts or figures regarding these death rates let us have them." I know their trend. He talks of the kanaka at home. I have seen and studied the kanaka at home. Does he work like a white man? Does he work in the New Hebrides as he works in Queensland? In the Pacific Islands, where half an hour's labor will supply his wants for a week, and where he can live all the year round on a little more than nothing, the kanaka does not see why he should work. Neither do I. Nor have I yet seen any cogent or logical reason brought forward by anyone why he should work. The tropics are not conducive to labor, to bodily or mental exertion, in either the white or the black. I do not deny that the black can be made to work, and to work hard. He can be fed, and on good "feed" can be made a better man for the contractor; but for how long? and is he a better man for himself or anybody else, as we regard a man?

3. Malaria.—Mr. Macfie argues or quotes with apparent approval, from what he characterises as a learned and unanswerable work, that the black is free from malaria because the actinic rays cannot pierce his pigmented skin. The statement in this explanation is very refined, very scientific looking, quite in accordance with the latest discoveries in physiology and optics. But what is the real fact that is being so scientifically explained? The truth is, science has now shown that the black possesses no immunity from malaria; he is saturated with it from his picanninyhood to old age, and is in a condition to pass the disease on, through the medium of the mosquito, to the white man who is foolish enough or ignorant enough to give him the opportunity.

I had occasion to refer yesterday, in this Section of the Congress, to the subject of pigmentation, and I quoted Dr. Semon's experiences in Queensland, and his observations at Amboyna, that pigment developed in the white subject in the tropics according to requirements. I have no fault to find with Mr. Macfie's quasi-theological quotation or statement to the effect that the Creator put pigmented races in the tropics, and non-pigmented people in the cooler regions. It has a historical look about it; but it is not history. The assertion can neither be proved nor disproved, and is therefore outside the scope of science. The scientific counterpart of the statement is that persons, whether indigenous to the tropics or immigrants to those regions, will develop pigment naturally. As to the assertion that the white man was never intended for work in the tropics, and the assumption or inference that, therefore, the black was — where is the scientific evidence for such reasoning, or what is the logical validity of it? It may be true that the white was not so intended, and it may yet be proved that he cannot work; but the evidence adduced to prove this, and the valid arguments founded upon it, tell with manifold force against the assumption of the intention regarding the black and the ability of the black so to work. It is surprising, well, perhaps it should not be so surprising after all, that people claiming to share the counsels of the Omniscient regarding divine intentions should have such a limited acquaintance with the more humble facts of science.

4. Albinos, says Mr. Macfie, being without pigment, are liable to disease from which pigmented persons are free. Are these diseases to be ascribed to the mere want of pigment? The fact is that the albinism itself is due to a constitutional condition of the body, on which the diseases enumerated also depend.

5. Suppose we grant, what Mr. Macfie says a forcible writer has truly said, that "The white man can no more run the equator than he can run the North Pole"; I ask, by what canon of logic or by what method in science does it thence follow that the black man can run either or both?

6. Mr. Macfie raises an interesting question by his quotation about third and fourth generations of whites in the tropics. Apparently, he has no difficulty in drawing a conclusion from it, and building a superstructure on the foundation of the inference. I would remind you that about 20 years ago Dr. Cantlie said the same thing about Londoners in almost exactly the same words. Third generations of pure Londoners were not of much account, and all his quests to discover a fourth generation Londoner had been barren. I do not find that on that account anyone has proposed either to abolish London or to bring in another race—black, white, yellow, or brown—to supplant the English in that city, as being more fitted according to "scientific" arguments to live and flourish there. I imagine there is something in the logic of vital statistics that Mr. Macfie has not mastered.

7. Mr. Macfie refers to a certain report on the Northern Territory, in which the writer states that he shares the opinion that tropical agriculture in the Northern Territory cannot be developed with white labor. I have read that report carefully and critically, and I fail to find anywhere, either expressed or implied, an intimation that this impossibility of development is due to the inability of the white man to live and work in that region. I repeat that the question of white and black labor in the tropics is a commercial one, not a health one. It is becoming recognised more and more that the subject of colonising the tropics by white individuals is synonymous with the prevention of endemic and epidemic diseases, a matter within the power of the settler. No fact established by science has ever been of so great commercial and political value as this recent discovery.

I would sum up the relation of the section to Mr. Macfie's paper thus:—The question is, "Can the white man live and work in the tropics as well as the black can?" That may be answered without reference to any theories of science, simply as a matter of evidence. If the answer is "No," then the question, "Why can he not?" is within the sphere of science.

I hold no brief for a White Australia. To me, as a member of this Section, commercial and political considerations are immaterial;

they are unworthy of our attention when investigating a scientific question, and I do deprecate any attempt to support any side of a commercial argument by bolstering it up with bad logic, scientific fallacies, and arguments founded on misquotations.

I would add one thing more: When the abscess over Zadig's eye broke in opposition to the opinion of the doctor, the doctor wrote a treatise proving that it ought not to have broken: which was—What? Certainly not science.

The meeting was adjourned till 2 o'clock to allow other members to resume the discussion, but none attended.

4.—ORIGIN OF THE MELANESIAN AND POLYNESIAN RACES.

By Rev. ISAAC ROONEY, F.R.G.S.

The peoples of the Pacific represent two distinct migrations, and, although possibly from the same original stock, the migrations were so far apart and the divergence is so marked that to-day they may be treated as two races: (1) The Melanesian or Papuan inhabiting the islands of the western Pacific from Fiji up to New Guinea; and (2) the Polynesian inhabiting the various groups of the Pacific east of a line running from New Zealand to the Sandwich Islands.

(Polynesians are also found on some parts of the coast of New Guinea and other islands, descendants of those who settled down at the temporary stopping-places when the race migrated eastward).

I.—POINTS WHICH DIFFERENTIATE.

1. Polynesians are brown in color, with straight black hair.

The Papuans are dark (various shades), with frizzy hair.

2. The Polynesians, physically and intellectually, are a superior race. R. L. Stevenson, who lived many years among them, bears this testimony: "The race is perhaps the handsomest extant. Six feet is about the middle height of males. They are strongly muscled, free from fat, swift in action, graceful in repose; and the women, though more fleshy, are still comely."

Count Pfeil, the German Governor of New Britain—a gentleman who had travelled extensively in every part of the world except Polynesia, who had lived five years among the Zulus, and always spoke of them with enthusiasm as physically the finest race in the world—coming in contact one day with a Polynesian chief, asked me whether I considered him a fair specimen of the race. I replied in the affirmative. "Why," said he, "that is the handsomest man in the world. My Zulus cannot be compared with him."

The Papuans, doubtless through long residence in a malarial climate, have deteriorated physically. This does not apply to the Fijians, who have preserved a magnificent physique. But malarial fever is unknown in Fiji.

3. The Polynesians are ruled by hereditary chiefs, who exercise despotic power over the lives and property of their subjects.

The Papuan form of government is patriarchal. Fijians an exception.

4. Polynesians are polite, respectful, generous, hospitable. They despise meanness and treachery.

The Papuans on the other hand are mean, treacherous, and avaricious.

5. The Polynesians had a hereditary priesthood who preserved the traditions of the tribe and the genealogy of the chiefs.

The Papuans have no hereditary caste, and no privileged class.

6. As rank among the Polynesians comes through the mother, woman is held in the highest respect.

Among the Papuans the woman is a chattel, a slave, a beast of burden, sold to the highest bidder.

7. The Polynesians, though scattered over the Pacific from New Zealand to the Sandwich Islands, have one language, with dialectical variations.

The Papuans have many languages. In the New Hebrides, Solomon, New Britain, New Guinea every island has its own language, and on a large island several different languages will be spoken; all belong probably to the same stock and have the same grammatical structure, but with differing vocabulary and requiring a different alphabet to express the sounds.

In all these points of differentiation, except the first and the last, the Fijians must be regarded as an exception. In color, hair, and language they belong to the Papuan race. In all other respects—physique, powerful chiefs, hereditary priesthood, position of woman—they should be classed with the Polynesians.

II.—ASIATIC ORIGIN.

Both races are of Asiatic origin. That the dark race came from India we have many proofs; but we have no clue as to the time when they arrived in the Pacific—probably thousands of years ago.

The brown race represents a later migration from the same motherland. They found the islands of the western Pacific already peopled by the black race; hence few permanent settlements were effected till they reached the Friendly Islands and Samoa.

PROOFS.

1. Polynesian Traditions.

Polynesian traditions collected by Judge Fornander, of the Sandwich Islands, traced their origin through India to the head of the Persian Gulf, and beyond. They came through Beluchistan to India, mixed with the brown Dravidian race in Southern India, and thence into the Malay Archipelago. About the beginning of the present era they were driven out by the Malays from the mainland. About one thousand years ago they left Fiji and sailed to the east, peopling Tonga, Samoa, and other groups to the eastward. Savaii, in Samoa, appears to have been their great centre. Eight hundred years ago they arrived in the

Sandwich Islands. One hundred years later they peopled New Zealand. "Their universal tradition is that they came from the west, and when they die they return to Avaiki. Avaiki is the Sanscrit name of Hades, and to this day it is the Hades both of the Buddhists and the Brahmins." —*Fornander.*

On the western end of every island there is a "naithombothombo," a jumping-off place, where the souls of the departed follow the setting sun to the home of their fathers.

2. Names of Places.

The recurrence of names like Rewa and Poonah, in places far apart as India and Fiji; Nusa, Papua, and Rotumah in western and eastern Polynesia, thousands of miles apart. Savaii, Manua, Upolu, Tonga, &c., found in the Western Pacific are referred to in the ancient songs of the Eastern Polynesians. Hawaii, in the Sandwich Islands, and Savaii, in Samoa are simply different pronunciations of the same name. Hapai (Fijian Sapai or Savai), Hawaiki, Sawaiki are other forms of the name, and all represent Java iti, *i.e.*, Little Java, or as we should say, New Java.

The Maori tradition is that they came from Hawaii, but Hawaii is simply the Maori pronunciation of Savaii, in Samoa.

3. Language.

The Polynesian and Papuan languages appear to be of Aryan origin, with Semitic and Turanian elements. The Rev. George Pratt, 40 years resident in Samoa, in preparing a grammar of that language, was struck by the many points of similarity between the Hebrew and the Polynesian, so far as the grammar of the two languages is concerned. The Rev. Dr. Macdonald, of the New Hebrides, found so many Semitic words in use by the people of that group, that he regarded their language as of Semitic origin. I, on the other hand, could trace many of these words to Aryan roots; which is simply another proof of what is now an acknowledged scientific fact—the common origin of all languages.

The Aryan of Polynesia is pronounced by Judge Fornander to be pre-Vedic, less highly developed—hence more primitive than Sanscrit.

The word Aryan is derived from $\sqrt{}$ *ar*, to plough. Another derivation of the word signifies "the noble." The Polynesian word for noble or chief is "*Ariki*" or "*Ari'i.*"

The pronouns afford a good illustration of the Aryan element in these languages.

First person—Aryan form, *agam;* Sanscrit, *aham;* Greek and Latin, *ego;* Malay, *aku;* Maori, *ahau;* Samoan, &c., *a'u;* New Britain, New Ireland, and Duke of York Island, *iau;* Fiji, *au* (second person, *iko* = *ego*).

Second person singular—Aryan base, *yu;* Greek, *ὑ-μεῖς*, *ye.* New Britain, *u* and *iu* (= *yu*); New Ireland, *iu* and *ui;* Duke of York Island, *u* and *ui;* New Guinea, *oi;* East Polynesian, *oe* and *koe.*

Third person singular, pronoun—Base *i;* Sanscrit, *i-dam;* Latin, *is*, *ea*, *id;* New Britain, New Ireland, Duke of York Island, and New Guinea, *i* and *ia;* East Polynesian, *ia;* Malay, *ia*, *iya;* Hebrew, (M) Hu (F) Hi.

Throughout Polynesia the pronouns are more numerous and more precise than in English. The Polynesians have singular, dual, and plural, with inclusive and exclusive forms, according as you include or exclude the person addressed.

The Papuans or Melanesians have singular, dual, trial, and plural, with inclusive and exclusive forms in personal and possessive pronouns. There are six different sets of possessives by which you indicate exactly whether the article referred to is food, drink, or otherwise, and whether you include or exclude the person you address. The same system of pronouns is found among the Kaffirs of South Africa.

Aryan √ *ki*, to rest, repose; Latin, *civis;* Goth, *haims;* German, *heim;* A. S., *ham;* English, *home;* New Britain and Duke of York Island, *ki*, to sit, dwell, wait.

√ *sta* and *stu*, to stand; *sta* is used in the European languages; *tu* (= *stu*) is the form used throughout the Pacific (both races).

√ *pa*, to protect—hence paling, palisade, &c.; Maori, *pa*, a fort; Fiji, *ba*, a fence or fort; New Britain and Duke of York Island, *pal*, a house, bark, skin; Fijian, *vale*, a house; Tongan and Samoan, *fale;* Sandwich Islands, *hale*, a house; Maori, *whare*, a house.

√ *wad*, to wet = Duke of York Island, *bata*, rain; also √ *ud*, to wet; Sanscrit, *ud-an*, water; Greek, *ὑδ-ωρ*, water; Fiji, *utha*, rain.

√ *wak*, to speak; Sanscrit, *vach*, to speak; Latin, *vox, vocis;* Fijian, *vosa*, word, speech; Fijian, *vaka*, to say, speak.

√ *pu*, to beget. Latin, *pu-er*, a boy; *pu-ella*, a girl; *pullus*, the young of an animal. New Britain, *bul*, a boy; *te-bu-an*, a woman (literally one who brings forth); *wa-pu-era*, to bring forth plentifully.

Hindustani, *kana*, to eat; this word is found throughout the Pacific.

There is a well-defined interchange of consonants in Polynesia—l and r; t and k; h, f, v, and w; j and t; j, h, and s are interchangeable. *Roto* is the Maori word for lake, as *roto-mahana*, the hot lakes. *Roto* is the Maori pronunciation of loko = Italian, *lago*, loch, lake.

Rotumah, hen, a woman = Persian *zen*, a woman.

Ruma is the Malay word for house. The same word is used on New Guinea and Duke of York Island.

Sampan is the Chinese for boat.

Tampang is the Duke of York Island word for boat.

Mat is both Arabic and Persian, and is the word used throughout Polynesia for death. We have it in English, checkmate = Persian, *Shah mat*, the King is dead.

The decimal system of notation is found throughout Polynesia among both races.

4. Another proof of the Asiatic origin of the Polynesians we find in the fact that the Hovas, the ruling race of Madagascar, are proved by their language, traditions, physique, &c., to belong to the same race as the Polynesians.

Leaving India, the one branch sailed away to the south-west, and eventually conquered the dark race already in possession of the island. The other branch sailed to the east, and found a home in the Malay Archipelago, and eventually in the eastern Pacific.

I would venture the opinion that the Sakalava, the Betsileo, and other coastal tribes of Madagascar, differing from the Hovas as the Fijians do from the Polynesians, will be found eventually to be closely allied with the people in the western Pacific.

5. Religion.

At some time in their history the Polynesians came in contact with the Hamitic race, and throughout the Pacific we find traces of the Cushite cult.

Sabaism.—The early Polynesians were sun worshippers. "*Ra*" was the sun-god of Egypt. *Ra* or *la* is the word for sun throughout Eastern Polynesia. "*Sin*" was the Akkadian moon-god; "*Sinu*" the moon-god of the Babylonians. *Masina* is the Polynesian word for moon, and "*Sina*" is the woman in the moon. *Singa* is the Fijian for sun. *Pele*, the goddess of fire of the Sandwhich Islands is the Polynesian pronunciation of *Bel* or *Baal*, the sun-god of the Phœnicians. New Britain, *Pila*.

Stone Worship.—Phœnician *batulia* = Fijian *vatu*, a stone; New Britain, *wat.* Stone worship is found in Fiji and other groups of the west Pacific.

Circumcision.—Practised by the Fijians and Polynesians.

Human Sacrifices.—Common among the Polynesians.

Ancestor Worship.—Practised by the Papuans.

6. Manners, Customs, Folklore, Etc.

1. *Exogamy* (marrying out of the clan).—In New Britain, *e.g.*, for marriage purposes, the people are divided into two clans, called *Pickalaba* and *Maramara.* A man must not, on pain of death, take a wife from his own clan. Same custom among the Australian aborigines, the Brahmins of India, and the North American Indians, *et al.*

2. *Totems*.—The totem of the Athenians was a grasshopper. The totems of the New Britain clans are two species of grasshopper, the "*kam*" and the "*ko kilalei.*"

3. *Descent through the Mother* (Matriarchy).—Prevailed among the early Arabs, Akkadians, *et al.* The same custom is found among the people of the New Britain group. The children belong to the mother's clan, not to the father's. Among the Fijians and Polynesians, rank depends on the mother.

4. *Land Laws.*—On New Britain, a man's land descends, not to his own children, who belong to the mother's clan, but to his sister's children, who belong to his own clan. In this way the land always remains in the same clan.

5. The Hindu law, that a wife must not eat with her husband, prevails throughout Western Polynesia.

6. The system of kinship among the Polynesians is the same as that prevailing among the races of India, *et al.* (Fison.)

7. Witchcraft, as practised by the people of the western Pacific, is identical with that of the ancient Babylonians.

In my belief in the Indian origin of the Polynesian and Papuan races, I am incidentally supported by Mr. F. J. Gillen, F.A.S., of Moonta. Listening to his lecture on the Customs and Beliefs of the Aborigines of Central Australia, with phonographic reproductions of songs and corroborees, I could imagine myself back among the islanders of the western Pacific. Mentioning this to Mr. Gillen next day, he said, "Oh, we trace these Australian aborigines to India." "That accounts for it," I replied, "as we can trace the islanders of the Pacific to the same source." Now, these people are separated by thousands of miles of land and water. They have been separated for thousands of years. The fact that they have the same beliefs, the same manners and customs, the same corroborees, can be accounted for only on the ground of a common origin. If the aborigines of Australia have come from India, we have much stronger proof that the peoples of the Pacific have come from the same mother-land.

Another proof of the common origin of these races is found in the mode of cooking. A paper recently read by John Philip Gell, Esq., on the South Australian Aborigines, quoting from a work published in Adelaide, in 1840, by two Lutheran missionaries, gives a description of a native oven:—"The larger game and vegetables are cooked in the following manner: A hole is dug in the ground and a fire kindled in it, upon which stones are laid to be heated. During the time these are being heated they prepare the game or vegetable, and then remove the stones and larger remains of wood; and if they stew a kangaroo, they first fill the inside with part of the hot stones and leaves of the gum tree. The kangaroo is then put into the hole and covered with leaves, the remaining hot stones, bark, and earth. It remains there for an hour or more, until steam escapes from the different parts. When this takes place, the meat, or whatever is cooking, is sufficiently done." That description of a native oven in Adelaide, 67 years ago, will stand as a description of the native mode of cooking throughout the Pacific.

An objection to the Aryan origin of these people might be founded on differences in color, features, and hair. Such differences can be traced to environment. Climate, temperature, food, habits, occupation, and similar causes, working through successive generations, will account for all known variations.

Medical men who have had large experience in tropical countries, tell us that a hot dry climate will in the course of ages, turn the skin brown; a hot humid climate will turn it black. Examples: White and black Brahmins; white, brown, and black Jews; the Portugese in south India (three centuries), now as black as negroes.

Other variations produced by the intermarriage of different races.

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Section G (I.).

SOCIAL AND STATISTICAL SCIENCE.

1.—THE LIMITS OF STATE INTERFERENCE.

By W. M. HUGHES.

The fundamental and primary principle underlying the relationship between the State and the individual is that the former is justified in interfering with the individual's freedom of action only when this freedom is incompatible with that of other individuals, or when it is restricted or threatened by some act on the part of other individuals.

The number of those whose freedom is thus affected is not material. It would be easy to quote cases where laws have been made, and properly made, to protect the interest of a mere handful of individuals; and where a grave injustice has been done the law has been amended in the interests of a single person. And, of course, the law very frequently protects small groups of persons to the detriment of the general community.

This is the basic principle, and the State ought not to interfere with the individual's freedom of action in any direction for any other reason. Now, this principle extends to all acts of the State, and includes interference in the industrial sphere. There is a prevalent idea that though this is very right and proper in other spheres of social activity it is altogether out of place in the industrial sphere.

It is not difficult to understand how such an opinion has arisen. Those persons whose freedom of action the State restrains very naturally object to any interference which curtails their opportunities for profit, while others not now so situated, but who hope to be so, help to swell the chorus of indignant protest.

At first sight, too, this protest seems well founded. Interference by the State in these matters is an innovation, and is the more irritating because it is not hallowed by precedent. The State, according to the individualist school of economists, ought to confine itself to keeping order, and allowing the combatants in the industrial ring to fight their own battle. The result of such a struggle, it is said, is the survival of the fittest. This result makes for the general good of the nation—the elimination of the unfit, the triumph of the strong, the energetic, the provident, the inventive, and, in turn, means the direction of the nation by such men, and the transmission of these qualities to their progeny. As a consequence, too, it operates as a check upon the fertility of the unfit by reason of the absence of those easy conditions which make for increase in population.

Any further interference by the State must be at the expense of the best and most useful citizens. The talented and energetic are handicapped. The industrial machine is slowed down to suit the least active. The independence of the individual is sapped: ambition dies, invention is discouraged, progress gives way to stagnation.

All these effects must—according to the individualist school—inevitably follow from the intrusion of the State into the domain until recently left almost entirely to individual enterprise.

The position assumed by these persons is very natural: self-interest and ignorance of certain principles in connection with the development of society explain and excuse their attitude. It is, however, in my opinion, both unscientific and illogical.

I have said that the State ought to interfere with the individual only when such interference is necessary for his own happiness or that of his fellow citizens. It ought not to interfere because it is strong, or in pursuance of some plan to make people happy in its own way. The individual ought to be permitted to be happy in his own way. In the opinion of some this way may not be the best; but unless the happiness of others is materially disturbed, or their scope of action seriously restricted, the individual ought to be allowed to go his own way. To compel people to wear a particular kind of dress, live in a certain kind of house, eat certain foods, and drink, or abstain from drinking, certain liquids, are all unwarrantable interference with their liberty. Only one reason can justify interference in this or any other direction—that the freedom and happiness and welfare of the general community cannot be secured without it. The State has no right to interfere at all apart from this. On the other hand, the individual has no rights superior to or independent of this right of the State to interfere for the benefit of the community.

Once postulate that such interference is desirable, and it is not the right to interfere that is then in question, but only the method and extent of such interference.

The right of personal freedom is the basis of all individual liberty, yet nothing is more clearly established than the right of the State to restrain by imprisonment this freedom. There are no individual rights which, in a proper case, the State cannot and does not invade. It can inflict corporal punishment, and even take away life itself.

These facts are so familiar that they are in danger of being overlooked. The State may, and does every day, restrain the liberty of the individual in a hundred ways. In countries governed upon a democratic basis all those interferences have the approval of the majority of the citizens. In all countries certain acts of the State have the sanction of the people. No one, for example, except, perhaps, the criminal classes, doubts that laws for preventing theft and murder are very necessary, although there may be differences of opinion as to the most effective way of doing this.

I come now to another point of great importance, and one frequently forgotten. The sphere of State activity is not definite and immutable. On the contrary, it is ever changing, and in modern society ever extending. Acts permitted in primitive communities without restraint are in a more advanced state of civilisation subject to the most rigid regulations, or not allowed at all.

Sanitary laws may be quoted as illustrations of this tendency in the ordinary sphere, and factory legislation in the industrial sphere.

In primitive or sparsely settled communities each individual deals with waste material according as his own fancy or convenience suggests. The growth of population creates new conditions, which make uniformity desirable, and disposal with due regard for the health of the community essential. Therefore, the individual can no longer have his own dust-heap up against his own door.

In the industrial sphere modern methods of production have created new conditions. Where hundreds of persons whose duties are to attend to machines are grouped under one roof, it is found that the right of the employer to pay such wages as he pleases, to work his hands such hours as he thinks fit, under unhealthy sanitary conditions, and danger from unguarded machinery, particularly with regard to women and children, were no longer compatible with the general welfare of the community. His freedom of action has been restrained, and this restraint is extended as the development of the methods of production calls for.

Such laws were quite unnecessary under primitive conditions of production, but very few will deny that they are very necessary to-day, although at the time they were first introduced the outcry against them was very considerable.

These two instances of changing conditions necessitating further State interference might be multiplied almost indefinitely, but they will serve sufficiently to illustrate a most interesting and important phase in social evolution.

Another point here requires notice. Not only is the sphere of unregulated individual activities curtailed by the increasing complexity of modern society, but also by the gradual modification of those crude conceptions of the functions of the State and its relation to the individual which formerly were current. The conception of the State as a distinct entity, which exists for the protection of the individual, is only of recent date. The idea that there is a general consciousness as well as an individual consciousness, a national as well as individual life, was only possible with a wider diffusion of knowledge and increased facilities for intercourse.

It has followed from these things that the State now either does itself, or compels the citizens to do, many things which formerly he was free to do or leave undone, as he pleased. Education is a good example of this new field of collective effort. It is to be noted that in such matters the State does not merely interfere with individual enterprise; it makes compulsory actions which were formerly optional. A parent must send his child to school. A citizen must pay his quota towards educating all children, whether he has children of his own or not, and irrespective of whether he pays for their education by some private teacher.

The modern State, considered as an organism, exhibits those marks which invariably accompany higher development. It responds more readily to stimuli, it specialises functions, and it has evolved new organs, or, what is the same thing, rudimentary organs have developed until they perform functions entirely new, or formerly very imperfectly performed by the individual.

The critics of the principle of State interference in industrial matters overlook these elementary but very important facts.

They speak of the State and the individual as though a clear line of demarcation could be, or ought to be, drawn between the spheres of their operations. As we have seen, this is not the case; the State is justified and ought to interfere wherever and whenever the industrial, social, physical, and moral welfare of the individual demands it. There is no fixed line beyond which the State must not go. Such an idea springs from a complete misconception of the nature of the State, and ignorance of social evolutions. While some acts fall more properly within the scope of State action, and others within that of the individual, yet the State, like the individual, may do all things.

The development of society has been so rapid that already many of those principles governing the relations of the State and the individual which were regarded as immutable in the middle of the nineteenth century are now admittedly no longer operative. To confine the State to keeping a ring clear for the industrial combatants is no longer regarded as sufficient, even by those who do not consciously favor collectivism at all. The narrow individualism of Herbert Spencer finds few, if any, advocates. Public libraries, baths, parks, schools, municipal gasworks, trams are now recognised by most people as falling within the legitimate and proper sphere of collective action.

It is now generally accepted that the physical and mental health of the citizens concern the State vitally. Democracy, which entrusts the duties of government to the people, makes it imperative that the people should be fitted to govern. To this end the State endeavors to promote the physical health of the individual citizen by sanitary laws, operative both in workshops and homes, and his mental health by State schools either wholly or partly free to all. In England they have gone so far as to feed all children who need it, recognising that food comes before education, and that without sufficient food of the right kind neither health nor efficient education is possible.

Coming now to the industrial sphere, we may usefully note that compulsory arbitration in industrial disputes adopted in Australia is slowly making headway elsewhere. The principle here involved is that in the interests of the general public the parties to industrial disputes should not be permitted to disorganise society. Production is a social process, a national, not an individual, function, and individuals ought not to be permitted to create confusion merely because they are unable to agree as to terms. It is in the interest of the State that production should proceed in orderly and effective fashion, and the State should see to it that neither party is treated unjustly nor shirks his responsibilities.

It is contended, however, that, in spite of the grave consequences which in most cases follow from these disputes, the State ought to do no more than compel the parties to keep the peace. No reason that will bear examination can be advanced for such a contention. There is no fundamental distinction between anti-social industrial acts and any others. The man who brawls in the street, who steals, who assaults another, who commits a nuisance, and he who throws out of gear the industrial machine by ceasing work, or by refusing to allow men to work, are alike enemies of the State. There is only one standard by which any act of an individual can be tested. Does it disturb the peace or affect the welfare of the community, or limit the scope of action of other individuals to such an extent as to affect their happiness or welfare in any definite way. If so it ought not to be permitted. And the fact that such an act falls within the industrial sphere is quite immaterial. Nor is the principle affected if such acts have been, owing to the dominance of a certain section of the community who have interests in common, hitherto regarded as lawful, though obviously operating in many cases with great harshness. Private ownership of land, carried to a point where it becomes a monopoly of a limited and essential factor in production, is an example of this class of acts.

It follows, then, from what has been said that the State may in a democratic community do whatever is necessary to be done to promote the welfare and secure the happiness of the citizens, and that there is no class of acts which individuals may perform with which the State may not in a proper case interfere. This interference may be of the slightest, or it may go to the length of absolute prohibition. The State may forbid the individual to do any of a certain class of acts at all, but may do them itself. The police powers of the State are an illustration of this class—the public executioner an extreme instance. Here the State may actually kill the individual. But under no circumstances is the individual permitted to kill another. These powers were not always exclusively the prerogative of the State, but were also exercised by a number of individuals. With the development of society the specialisation of function, always a phenomenon attendant upon development, has resulted in these matters being brought under the exclusive control of society in its collective capacity.

In no branch of social activity has development been so marked as in that of the industrial. Modern methods are so enormously superior to those which they have superseded as to have effected a revolution in production. The quantities of goods, their variety, their cheapness, the productivity of the laborer, the extraordinary increase in the amount of capital employed, have combined with other factors to create a situation entirely novel in character. To attempt to deal with the phenomena of modern industrialism in the way that served the requirements of primitive production is obviously absurd and impossible. Yet there are not wanting some hardy spirits who are continually bewailing our departure from what they term "first principles" in these matters.

The number of these critics and the energy of their criticism is, however, becoming less each day. Facts are too much for them. Insensibly they bend to the blowing gale. They admit exceptions to the general application of their much-lauded "first principles." And these exceptions daily become more numerous and more important.

In the face of those latest developments of modern industrial methods, "trusts" and "combines," it is, indeed, no longer possible logically to do otherwise. Reluctantly they concede the right of the State to interfere, to regulate—in some cases to own and control—industries where free competition no longer exists, or where, as in the case of railways, telegraphs, water, and other services, ownership by individuals practically amounts to a monopoly. Having conceded so much, however, they still continue to insist that any further departure from "first principles" will and must be disastrous. Apparently they fail to realise that they have given away the whole case by the admission that there were occasions on which their doctrine could not be safely applied.

I propose shortly to show not only must exceptions be made, but that the basic principle of their theory is both unscientific and illogical.

First let us take the facts of the case. Competition is no doubt a law of nature, but so is co-operation; and the one is as general and important as the other. It may be admitted that to competition between individual organisms is due the present highly developed types. It is also true that amongst men the effects of this competition has been everywhere modified by persistent efforts to protect by co-operation the weak from the strong. The elimination of the unfit by competition has never been permitted to go to those extremes which a logical application of the law of the "survival of the fittest" demanded. Society has always recognised its duties to the so-called unfit, and the rigors of competition have never been permitted to operate without some check.

Competition, perhaps, is the primary law of life, but co-operation is certainly that of society. Amongst primitive communities the State generally protects the individual but slightly. With civilisation the restraint of the individual for the benefit of the community becomes more marked. Life and property are protected from the operations of the strong and unscrupulous. The weaker individuals by co-operation prevent the stronger from exercising their strength against the rest of the community.

Society has always handicapped the strong. Nature has always handicapped the weak. The handicap imposed by society has at times been insufficient, at other times unjust. This has arisen in most cases through the government being in the hands of a minority, which naturally acted in a manner conformable to its own interests. Where the government has been in the hands of a class the interests of that class have always been paramount.

Where government is in the hands of the whole people it is hardly likely that State action in favor of a class will be permitted. It may, therefore, be laid down that in all democracies the people will not hesitate to take whatever action may be necessary to prevent individuals acting in a way detrimental to the welfare of the general community; and, in doing this, no regard will be paid to any so-called first principles. Society is not moved to take action by any other consideration than that of self-preservation. The only "principles" it is concerned with are those of justice and common sense.

It has not been necessary until recently for the State to interfere to any great extent in the industrial sphere. I am not concerned here with the desirability of such interference where it is not absolutely necessary. The strength of the modern socialistic movement does not depend upon any superiority of collective ownership over individual *per se.* This may be a demonstrable fact, but it is to individual ownership of capital under certain conditions—which are the inevitable concomitants of modern industrialism, and which are becoming every day more and more intensified—that the bulk of the people object. No doubt a number of those who favor collectivism hold the opinion that there is a virtue in what is known as socialism that makes it preferable to individualism under all circumstances. But the majority do not share such an opinion.

The people see on every side evidences of the enormous aggregation of capital in the hands of a comparatively few individuals. They see the lands of the country in the hands of a few. They see that fair competition against such persons is out of the question, and that competition of any kind is possible only under terms which these few dictate. They see that, while extolling the virtues of competition to the skies, the great capitalists have, after ruthlessly exterminating those rivals with whom they could not come to terms, or with whom they did not desire to do so, abandoned competition and adopted co-operation. If the field in which these combines operated was small, the problem, though important, would not be vital. But over almost the whole sphere of production these new conditions have displaced, or are rapidly displacing, the old. The question is not whether free competition makes better citizens than co-operation, for competition does not exist wherever industrial methods have most highly developed. In America, where the most efficient methods of production have been adopted, at least one-third of the whole community are engaged in industries in which there is no competition amongst the employers.

The State, that is to say, the people, interfere under these circumstances for exactly the same reasons that actuated them in putting down piracy or garotting, or coining, or sweating, or in taking over the control of prisons, asylums, hospitals, and the care of the aged.

So much for the facts and general principles, and now a word or two as to the extent to which this interference should go, and its effects upon individual national character.

First, as to the extent of the interference. This will depend very largely upon the rate of development of industrial methods.

The State will consider the advisableness of taking over an industry, or group of industries, only when it has reached a stage where free competition is no longer possible, and when the carrying on of the industry by a few individuals exercising an actual or virtual monopoly is incompatible with the welfare of the employés who would have but one employer to whom they could sell their labor, and of the general public, to whom there would be but one seller of any particular commodity. I assume that, unless these conditions were present, the State would not take over the industry itself, although it might, of course, attempt to regulate it by suitable legislation. Other factors will, no doubt, be taken into consideration, but those conditions I have mentioned may be regarded as conditions precedent.

How far short of complete ownership of all capital the State will stop one can but guess. But there are good reasons for believing that several industries are not likely to be included; and there will probably be other cases where the State and the individual will work together in friendly rivalry. Agriculture may be cited as an example of this class of industry. I apprehend that not only fruit and poultry but also general farming will be carried on as at present by small cultivators, either on their own lands or on holdings leased from the State. Alluvial gold digging, opal mining, &c., illustrate other industries that would probably be left entirely to the individual. It must be distinctly understood that I am not setting limits to the sphere in which the State may operate, but only stating what I conceive will be the practical limits of the sphere in which the State will operate.

And here one point must be emphasized. As all State interference has, and can have, but one justification, the end of collectivism—whether applied to all industries or only some—must be the promotion of individual happiness. It is very necessary that this point should be made perfectly clear. The end of and justification of State interference is not, as some who confuse the means with the end imagine, the creation of the "Co-operative Commonwealth," but the happiness of the individual citizen; and he should be allowed to be happy in his own way: as to the best way—subject to the qualifications laid down—the State should leave that to his judgment. To help him to judge rightly the State should rightly educate him. If his happiness can be secured more effectively and more easily in any other way, then that other way will and ought to be preferred to collectivism.

One thing is certain: Socialism will never be adopted because of its theoretical superiority over individualism. Nations do not discard old systems for new ones from intellectual conviction. Society is an organism, and adapts itself to a changing environment as readily and completely as possible. To a violent change of environment it cannot, and will not, attempt to adapt itself.

This is not to say that intellectual conviction counts for nothing in the adjustment of society to its new surroundings. Much suffering to individuals may be avoided if misconceptions as to the cause of poverty and distress and the exact nature and effects of State interference can be dispelled. Apart from this, every step in the direction of State ownership must be justified by some improvement in the condition of the people. Collectivism has an ethical basis, but it must also rest upon practical and business methods.

And now a word upon the effects of substituting State for individual ownership of capital upon individual and national character.

During the recent elections a great deal was spoken and written upon this question. Some of this was merely undiluted nonsense, and may be passed over without comment.

References more or less erudite to Aristotle, Plato, and Sir Thomas More, to Ancient Peru and New Harmony, do not call for any special notice. Modern collectivism is not a scheme—heaven-born or otherwise—it is merely an adjustment of the organism to a rapidly changing and complex environment. As there never was anything resembling modern industrial methods in the days of Aristotle, Plato, or More, or Ancient Peru, and as Utopia, New Harmony, and all such schemes to forestall the millenium were merely efforts by small communities to live apart from society upon some plan mutually agreed upon—that is, not to adjust themselves to a changing environment, but to create a new one in which it would be possible to live according to some scheme mutually agreed upon—references to these matters are neither relevant nor interesting.

The assertions that collectivism will destroy ambition, reduce men to slavery, and prevent the elimination of the unfit deserve more consideration than I can give in this place. Shortly, however, these objections may be thus answered.

Ambition can never be destroyed in a society where grades prevail, and inequality of position and of reward for services exist. The extensions of the functions of the State as an employer will not effect any of these things, since the system now adopted in all State departments of control by independent experts will be continued.

The Commissioner for State Railways, New South Wales, gets £3,000 per annum; the newly joined porter 5s. per diem. There is surely enough scope for the most ambitious where every porter is potentially a commissioner.

And the Public Service is a hierachy where all may rise as high as they deserve. Persistent effort is not less effective in the service of the State than outside, nor less necessary if a man wishes to succeed. A great deal is said about the "Government stroke." No doubt there was much truth in this at one time, but it is not true now. The officials in the Education Department work hard, as do those in the Postal and other departments. When there were but few in the Public Service the community could afford to regard the manner in which they performed or failed to perform their duty with indifference. When a large number of the citizens are employed, the State cannot afford to tolerate anything short of a fair return for its outlay. When all or nearly all, are in the same position the Government stroke will be obviously impossible: all cannot loaf on all.

The present system certainly does not encourage honesty of labor. The ideal of "individualism" seems to lie in the direction of avoiding work. The operation of the individualist's oft-quoted law results too often in the survival of the dishonest and unscrupulous and cunning. Virtue is its own reward, and off the stage there does not appear to be much call for it.

Where mere wealth would not open all doors to positions and power, encouragement might be given to worth. Good honest work would then be regarded as the basis of the civic virtues.

Such an environment would certainly be fatal to many of those who are regarded as the "fittest" under existing conditions, but society would be a gainer from the change.

The individual would not under collectivism be less, but more independent. For one thing he would be able to have a voice in the management of the industry in which he worked. He would be paid a salary which was a fair equivalent for his work. He would not get work as a favor but as a right, as a duty. He would be expected to do his work as well as he knew how, and there would be no way of living—unless he was old or sick—except by working; and if he wished to rise to some higher position he would strive to achieve excellence in his business.

As for the law of the "survival of the fittest," in one sense civilisation itself is an interference with the operation of this principle. Every law is such an interference, as is every custom and every act which restrains the exercise of mere brute strength or cunning. Society is a protest against it. No form of government known to men tolerates it, unless it be that negation of government—anarchy.

What is understood by the majority of those who use the expression as the survival of the fittest is, however, something very different, and merely means the maintenance of such conditions as favor the existence of a certain type of individuals, which type is, by those who use the expression and belong to it, considered to be desirable.

I do not think it will be contended for a momet that the "fittest to survive" under what is known as "private enterprise" are really the best citizens. That they have certain desirable characteristics may be admitted, but, on the other hand, they have others which are most undesirable. They may act up to their code, but it is obvious that that code leaves much to be desired.

It is assumed that energy and independence of character will not be developed under State ownership. But where these qualities are valued they will always be found; and it is not true that the present system is favorable to their development.

Independence of character is certainly not developed under existing conditions. The individual is, in the majority of cases, quite helpless: he is dependent for his daily bread upon the favor of a limited number of employers. He must not, at his peril, offend these persons, or he will no longer secure employment from them. When the industry is controlled by a "combine" he has but one employer, and he is absolutely dependent upon his goodwill. There is surely no creature on earth less independent than the wage-worker under private enterprise. His individual characteristics are crushed out of him. He ceases to be a man and becomes a mere "hand." He has neither leisure, nor opportunity, nor inclination to cultivate the best that is in him.

What is true intellectually and morally is also true physically. Were it not for State interference the race would inevitably degenerate under private enterprise. The story of the effects of the factory system prior to the introduction of restrictive legislation makes sad reading. Nearly every improvement in the lot of the individual is due to the interference of the State in his behalf; and while such interference has this effect it will and ought to continue.

On the other hand, I do not think it can be shown that State control has caused any degeneracy of the individual physically, mentally, or morally; but it has prevented degeneration consequent upon the operations of private enterprise.

Here, then, we may leave the subject, with these concluding remarks. "That State enterprise in industrial matters, as in most others, ought not, and generally does not, restrict individual liberty of action, but on the contrary extends it. The happiness of the individual is best promoted by allowing him the greatest freedom of action compatible with the welfare of the community. The present system, now fast passing away, does not do this, and it is for this reason that it is being replaced by another better fitted to the requirements of civilised society."

2.—THE ORIGIN OF OUR POLITICAL IDEALS.

By Professor JETHRO BROWN, LL.D.

3.—PROPORTIONAL REPRESENTATION.

By Miss C. H. SPENCE.

[ABRIDGED.]

I must first ask you what representation is, and if each of you is represented in the Assembly, in the Legislative Council, in the House of Representatives and the Senate ? That is, are the men you voted for in these assemblies ? If they are not, you are not represented. If they are, is it the case that all your fellow-electors were represented. What is the difference between disfranchising a man and not counting his vote for anyone ? Under the proportional preferential system every voter has his vote counted to his credit.

By the Golden Rule, if a man desires an effective vote for himself he also desires it for his fellows, but the present business of politicians is to make thousands of votes ineffective. It is also their business to limit candidates. In every free country it ought to be a good thing to have many candidates with various convictions and aspirations, but by the majority system an additional candidate is looked on as a menace. How little people understand the principles of political liberty when they would fine the man who has a small following! And, although we may deplore the apathy which keeps electors from the poll, I would neither stir them up by party agents extolling one and generally misrepresenting the other side, nor would I fine or disfranchise them for their neglect. Voting should be the free act of free men and women, and all canvassing is an interference with freedom.

As the Belgian Conservative Ministry, with an enormous majority at its back, gave to Belgium the electoral reform which its wisest men had been advocating for 20 years, and greatly reduced its apparent strength, so I hope that the Labor-Liberal Ministry of South Australia may see that this is the psychological moment to give what I call effective voting by the Hare system to this State. As Thomas Hare and Stuart Mill said 50 years ago, the safeguard of democracy is more democracy. South Australia never had single electorates, and I hope never will have, for experience of long years in America and shorter trial in the United Kingdom shows that this may let the Government rest on a parliamentary majority which does not mean a majority even of the people who have votes and who exercise them. Large majorities in great centres of population, small majorities in rural districts on the other side, may give that result. And the change of a comparatively small number of votes brings such results as the Unionist-Conservative majority of 134 in 1900 and a Liberal majority of 354 over the Unionists in 1906. The real majority, according to votes polled, should have been 16 and 94.

Unfortunately, the multiple electorates in South Australia, like the important elections for six senators for the Federal Upper House, are conducted by the block vote, and we see in the metropolitan area that two-fifths of the voters are extinguished by three-fifths, and instead of the vote being seven to five all 12 are returned for the Labor-Liberal Party. Nor do I think that even by astute gerrymandering of single electorates the result would be different. The Conservatives would be defeated in detail instead of wholesale.

The remedy for this is by proportional representation—by giving each voter the power not only to notify his first preference but to tell what is to be done with his vote, in case his favorite has too few or too many votes above the quota necessary for his election. That means that he votes by means of figures quite as easy and pleasanter than by crosses. There is no complexity for the voter and very little for the returning officer, for regulations are laid down in our Bill for every contingency.

Do not think that preferential voting in single electorates will do any good. It will more effectually extinguish minorities. Do not think that proportional representation is only a fad—it is a live subject. In America, where it is needed sorely, the line of the least resistance is in municipal elections. In Canada it is advocated by a strong minister in the Dominion House of Commons for the Senate elections, and my good friend Mr. Robert Tyson is using it for elections for municipal and for trades and labor councils.

The success in Belgium induced many French deputies to go to watch the election of 1906, the fourth under the new system, and M. Charles Benoist is the leader of 250 deputies of all parties who are working for this reform. It is mainly advocated by Independent-Liberals who, under the second ballot system, find they are extinguished between the more numerous Socialists and the clerical Conservatives.

The new Finnish constitution not only gives adult suffrage, with eligibility of membership to women, but it provides for minorities by proportional representation. Holland is stirred by the examples of Belgum, and is agitating for proportional representation for the States-General. Germany, like France, is counting the votes given in the single electorates, and finds that the Social Democrats ought to have had a far larger representation. Denmark and Sweden are discussing the matter, and there has been a strong revival in England under Lord Avebury, formerly Sir John Lubbock, and Leonard, now Lord Courtney, with Mr. John Humphreys as secretary. I have worked for this great cause since 1859, and I believe that it will prevail.

4.—CLASSIFICATION OF DISEASES AND THE CAUSES OF DEATH.

By W. T. WEEDON.

5.—THE USE AND SCOPE OF STATISTICS.

By W. SIEBENHAAR, Compiler of Statistics and Sub-editor of the Year Book, Western Australia.

(WITH THREE PLATES.)

[ABSTRACT.]

In spite of the almost universal use of statistics there still appears to exist a great amount of uncertainty about its real nature. When an authority like Dr. Mayo-Smith refers to "the question whether statistics is a science like sociology, or is only a scientific method of investigation like the science of microscopy," without showing any inclination to settle the point, we may be pardoned for concluding that the conceptions as to the scope of this science or scientific method must be somewhat vague. On further investigation we find that the same uncertainty is evidenced in the definitions given of statistics, and in the material published in various quarters as statistical. For instance, the above-named authority says:—"Statistics consists in the observation of phenomena which can be counted or expressed in figures. It gives us the quantitative measurements of social phenomena which are required for the analysis of social organisation." On the other hand the definition found in Webster, no doubt also furnished by an authority, reads as follows:—"The science which has to do with the collection and classification of certain facts respecting the condition of the people in a state, especially those facts which can be stated in numbers, or in tables of numbers, or in any tabular and classified arrangement." The condition that the phenomena must be capable of being counted or expressed in figures is here, we see, not rigorously insisted on, though it is mentioned as that of the principal statistical categories. This undoubted evidence of a difference of opinion is further supported by the various kinds of information contained in statistical publications. Very few of these confine themselves strictly to phenomena that can be counted or expressed in figures. It is of frequent occurrence, in exclusively statistical compilations, that particulars are included which have no direct connection whatever with figures—ordinary information, which it is thought desirable to place on record without even considering whether it is capable of being presented in tabular or classified arrangement. The statistician whose duty it is to compile publications of this nature, either for the use of state or local government, or for some private institution, is constantly faced by the perplexing necessity of having to decide where the line should be drawn between information that may be considered as coming within his province and that which he should reject; and, as a matter of fact, he has nothing more definite to guide him than precedent and his own judgment. It is evident, therefore, that an international statistical society may do excellent work in fixing more definitely the limits of the science of statistics.

Statistical information is intended to serve two purposes, separate and different in their immediate bearing, though undoubtedly both aiming at the welfare of humanity. The one is that of scientific investigation, the other that of direct practical use.

In collecting statistics for purposes of scientific investigation it is obviously necessary to have a fairly clear conception as to what data are likely to have any scientific value. Supposing, for instance, that we wish to compare the respective degrees of fertility of women of different nationalities among the Australian population; it will then, of course, be necessary to obtain the average number of children born to married women of each nationality. Yet if this were done without differentiating between women in various age groups, the information would not only be useless, but absolutely misleading, as the proportion of women in each age group will naturally vary very much in the different nationalities, the Australian-born women being, of course, far more numerous at the younger ages, when families are consequently as yet small.

It is, therefore, indispensable before collecting statistical data to study every factor that may contribute to the result they represent, so that enough detail may be collected for purposes of adequate analysis. Only then shall we be enabled to make reliable deductions from the information obtained.

A point of the greatest importance, in drawing conclusions from the particulars available, is the length of the period to which they relate. The annual recurrence of certain phenomena for a considerable number of years warrants the assumption that a more or less permanent cause underlies their nature, and that consequently the future is likely to present similar features. The popular call for "the latest figures" is therefore somewhat vainly concerned about statistics of this nature, which, like good wine, only derive their value from the length of time for which they have been kept.

Having most carefully weighed all the circumstances, and observed a constant recurrence of the same phenomenon, the statistician cautiously predicts that in all probability the same feature will again present itself in coming years at the appointed time; and thus his prognostications may be eminently useful to the legislator, the statesman, the physician, and also to those whose personal interests are bound up with commercial or industrial enterprise. The danger, however, of drawing conclusions, and attempting to prognosticate from insufficient data, has found ample illustration in some of the striking failures on the part of celebrated statisticians to account for certain social phenomena or foreshadow events.

The practical use of statistics that naturally appeals most to the commercial and industrial classes is that which conveys information relative to the possibilities of various localities for speculation or enterprise. Here it is, more than elsewhere, of importance that the figures should be, as much as possible, up to date, since the fluctuations of trade and production have an immediate bearing on any transactions that may be in hand or contemplated. The scientific aspect is undoubtedly still present, but it is vastly overshadowed by the purely informative. Take, for instance, gold-producing states like the Transvaal or Western Australia. It would be idle to indulge in scientific statistical speculation as to the possibility of their gold yield increasing or decreasing according to some experimentally deduced law. The conditions governing its rise or fall are so largely subject to momentary and unforeseen change, that the past would afford scarcely any clue to the future, which may reveal deposits hitherto completely unknown, to be discovered either by science or by accident. This almost ephemeral character cannot, of course, be predicated of other, more stable branches of industry and commerce. But most of them are undoubtedly largely influenced by temporary causes, and it is, therefore, imperative for persons depending on them to be constantly armed with the very latest information relative to their general and local development.

The need for complete up-to-date information in such cases is obvious, and it was due to considerations of this nature that the Western Australian Statistical Department, in July, 1900, started the issue of its "Monthly Statistical Abstract," which has since been acknowledged by the united press of Australia and elsewhere to be one of the most valuable and useful statistical publications for local general information to be obtained anywhere in the world.

In addition to the speculative interest of the commercial man, there is still also the general interest of the public in subjects on which the latest obtainable information may afford a means of detecting without delay, and perhaps remedying, certain facts detrimental to the public welfare, or of making immediate use of others of a possibly beneficial tendency. Thus, for instance, it was recently noticed that the infant mortality in Western Australia was higher than elsewhere, and the more speculative physicians immediately set to work accounting for this fact, and suggesting what seemed to them the true remedy—that of preaching to the mothers the doctrine of natural feeding. Or, again, mortality statistics may show that some special locality is particularly favorable to the cure of consumption, and it consequently becomes possible for the authorities to advertise this characteristic.

The information conveyed by statistics is usually presented in arithmetical terms. The word "statistics" at once conjures up the vision of tabular statements of figures. Yet, in addition to the arithmetical method of presentation, there is also the graphical, which is, or should be, geometrical in its essence. The reason for using the latter is generally that of appealing more directly to the imagination through the perceptive sense, as it is well known that the mind requires unusual aptitude and arithmetical training to be able to fully appreciate at a glance the relative proportions in a comparative statement expressed in figures. The graphic method has, therefore, much to recommend it. At the same time it must never be lost sight of that absolute accuracy is only attained in figures—the primary and most minute form of statistical expression. Nor should the object of the graphic method be ever forgotten, viz., that of supplying the imagination with an easier means of approximately gauging differences. Any graphic method that does not achieve this object is useless.

For graphic presentation there are three primary means available, viz., linear, square, and cubic measure. Linear presentation is not only the simplest, but, in view of the object just referred to, also the most effective. There is no gauge which the eye, as well as the mind, takes in and accurately appreciates more easily than length, so long as it comes well under the direct survey of the eye. It requires very little training to approximately realise at a glance that a line 4in. long is double the length of one 2in. long; yet if the former were to represent £17,986,384 and the latter £8,993,192, only a person accustomed to dealing with figures would easily draw a similar inference from these arithmetical symbols. The method of graphic presentation by straight linear measure is often abandoned for that of circular measure. I doubt whether the natural aptitude of eye and mind can as readily appreciate proportions when thus represented, and as a test submit a very simple example for comparison. (See diagram No. 1.) Coming to square measure, the task required of our perceptive sense becomes at once far more complicated. It is true that if we wish to compare two areas, one of 600,000 acres, the other of 300,000 acres, nature's own method is to show us the difference in square measure; and this has led many writers to suppose that it is also the method that would appeal most vividly to the imagination. Nothing is, however, less true, for in reality the appeal is an extremely vague one. To put this to the test, draw two separate squares—one on the base 1in., the other on the base ·7 of an inch—and ask several untrained persons their opinion as to the respective areas of the squares, without allowing them to take measurements. Very few will conclude that the one is as nearly as possible twice the size of the other. (See diagram No. 2.) It becomes then apparent that the squares do not elucidate the proportions they represent more clearly than do the figures.

If this be the difficulty with the simplest form of square measure, it stands to reason that cubic measure adds to it very considerably. Of late years this form of graphic presentation appears to have become very popular. Modern magazines and even statistical year books teem with pictures of similar but unequal objects, purporting to convey impressions of quantitative proportions. The untrained reader simply sees, say, a gigantic soldier representing the Russian army next to a pigmy as the symbol of that of Switzerland. More than this he sees not, and cannot see. Leaving alone altogether the question of relative military efficiency, even of the numerical proportions he knows nothing more than that Russia must have several times more soldiers than Switzerland. But the trained mathematician himself is here in the dark, for first of all he does not as a rule know whether these soldiers are intended to represent the numbers by linear, square, or cubic measure; and secondly, if he does know, the complicated form only confuses his eye for measurement. I have taken the trouble to measure some of these comparative pictures, and found that they as often appear to be based on linear and square as on cubic measure, and in some cases on no correct measure of any description. The most natural supposition would seem to be that cubic measure is usually intended. Now it requires a considerable amount of training to gauge approximately the proportions of similar bodies. People will buy oranges all their lives, yet never realise that an orange with a shortest diameter of 2½in. is nearly twice the size of one of similar shape with a shortest diameter of 2in., and more nearly five than four times the size of one measuring 1½in. Or take three persons of similar build—A 5ft. high, B 4ft., and C 3ft. Only a person who has had repeated occasion to compare the weights of people will realise that A weighs approximately twice as heavy as B, and not much less than five times as heavy as C. (See diagram No. 3.)

To create, then, accurate visual impressions of proportion, impressions that approximate the actual facts as expressed in the unerring symbol of figures, linear measure is infinitely preferable to any other graphic method.

A large proportion of the statistics at present collected relates to separate nationalities, whilst in probably less numerous cases their scope is further confined to localities such as districts, provinces, or municipalities, or even to specific centres of private human activity. For many purposes these limitations are of course desirable, as they usually emphasize natural distinctions. There are, however, subjects on which it would be of still greater value if statistics of more universal scope and application were available. It is, for instance, of interest to every human being living within reach of civilisation that it be known what the world's annual production of certain commodities is, such as gold, silver, and wheat. In the collection of such statistics it would be desirable if international action could be arranged for, so that the work were not left to the unreliable chance of private enterprise, nor hampered by a multitude of varying methods of calculation and expression of results, as is now too frequently the case. For instance, it would be an advantage if all gold or wheat could be reduced to some universally recognised standard, say, the former to fine ounces, the latter to centals or bushels, or preferably some decimal measure. An office which, like the Statistical Department of Western Australia, has for some years been engaged in the endeavor to obtain reliable figures relative to the world's gold output, has thereby gained some striking experience of the difficulties to be overcome in any such effort under the conditions at present prevailing.

The scope and application of statistics are further determined by the more or less temporary or permanent interest attaching to the figures. Those, for instance, which are of the most immediate value to the financier or commercial man are at the same time often of purely ephemeral importance. Others extend their use over more or less lengthy periods, whilst to statistics of scientific value we must undoubtedly assign a permanent as well as universal importance.

The responsibility of the statistician is a particularly grave one, since it is well known that figures lend themselves almost as easily to manipulation as do legal enactments. The compilation of statistics should therefore be, perhaps more than any branch of Government activity, free from political influence or interference. Without this there may be a certain amount of temptation for those at the head of a government to make statistical truth subservient to political interests. It might, therefore, appropriately be asked whether it would not be well for government statisticians to be safeguarded by special provisions as to their position, such as are made in the case of an auditor-general or a judge, from any undue influence that may imperil the scientific accuracy of their work. Not only is it possible to present the figures collected in an entirely partial or perverse manner, but estimates are often required, and these in particular lend themselves, if the disposition should exist, to misleading presentation. An example has already been given of the possibility of wrong presentation in the case of the respective degrees of fertility of women of different nationalities among the Australian population. It would be easy to give instances where similar wrong presentation in other branches of statistical calculation might be used for most improper purposes.

Less dangerous, perhaps, than manipulation or wrong presentation is false deduction, since here, at least, the correction can be made by anyone who has access to the figures presented. It is a means only too frequently resorted to by those who are not too scrupulous about their method in gaining an object, but it also arises in a great many cases from bias or misunderstanding.

Finally, it remains to say a few words about the right use of statistics.

First of all it is necessary to use statistics correctly. In this respect it is never possible to be too scrupulous. Slovenly use soon becomes a habit. There is a dangerous euphemism called "adjustment," which, if once tolerated in its bad sense, may become a pernicious practice destructive of all accuracy and reliability. We find, for instance, in many tabular statements the convenient heading "all others," which may be very wrongly used for concealing discrepancies. It is, therefore, evidently dangerous in making statistical researches to pass over such a heading as this without a full inquiry into the nature of its detail if at all available.

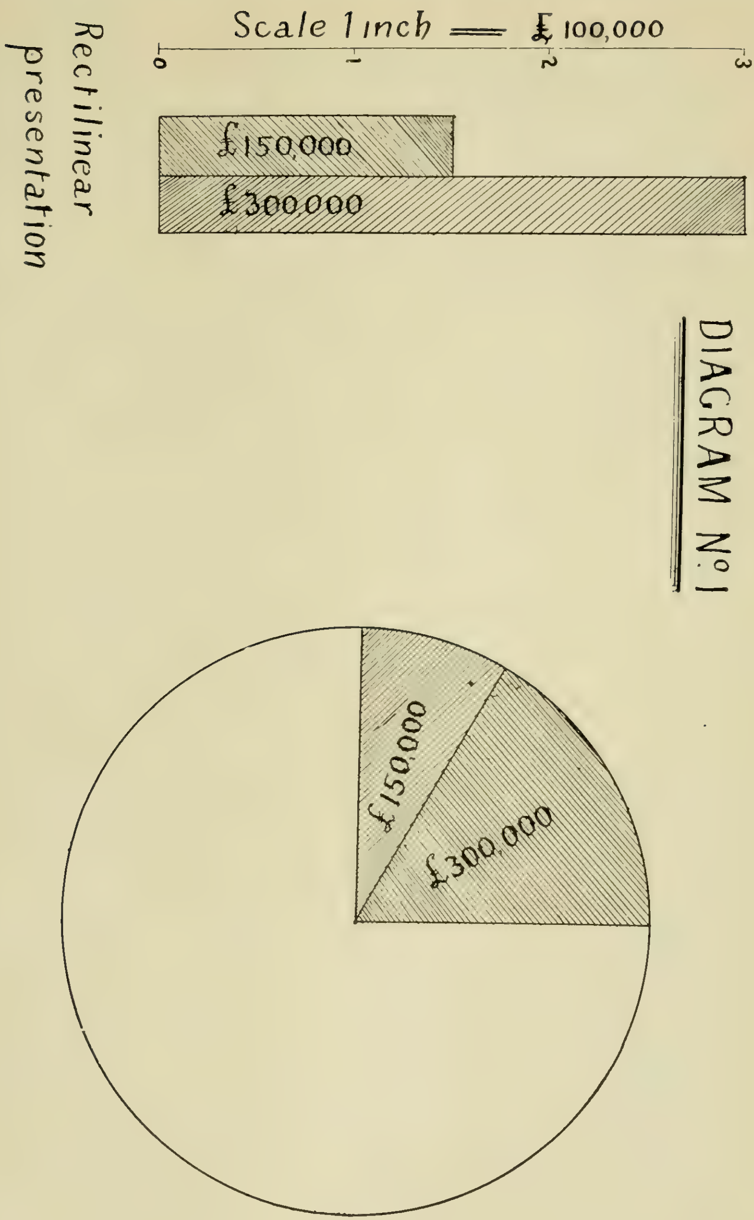
The second necessity in using statistics is that of using them impartially. It is often easy to leave out certain features of the information obtained and to give prominence to others, thereby to create certain impressions which are but half the truth. The information should be so presented as to give a correct and proportionate view of the results obtained. The fact that statistics are at present generally collected by some state or local body is a natural temptation to those working in the interests of such state or body to present its conditions in the most favorable light. This may lead to more or less reprehensible deception, resulting in disappointment to those erroneously informed, and may finally recoil disastrously on the cause it was intended to benefit. In any case it is detrimental to the cause of truth.

The third consideration of importance is the necessity of caution in drawing conclusions. Nothing is easier than to make mistaken inferences from insufficient data, a practice frequently indulged in by persons whose position in life makes it desirable for them to pose as authorities. The earnest student of statistics, knowing the many possibilities often involved, will as a rule proceed with extreme wariness and not pronounce an opinion unless the case is absolutely unequivocal. He will often confine himself to pointing out what appear to be all the possible solutions of a problem without expressing any predilection for any of them.

That, however, even statisticians do not always adopt the very best methods available to attain practical results might be proved readily enough. Take the compilation of vital statistics, where it is a practically universal custom to collect and tabulate the figures, not only for years but also for separate months, so as to obtain an indication of the fluctuations of births, deaths, and marriages in different seasons of the year. The object is, of course, an excellent one, and might be eminently useful to science. Unfortunately the method adopted for collecting the information is everywhere, as far as I have been able to ascertain, that of tabulating the information according to the date of registration, and not that on which the events really took place. As registration is not, as a rule, effected till some time after the event, and in many cases this time may amount to weeks or even months, it is obvious that the incidence of births, deaths, and marriages is almost invariably removed from the month to which it rightly belongs, and that any conclusions drawn from the fluctuation of the figures are subject to this serious objection. The reasons for preferring the date of registration to that of the actual event are, of course, well known; but whether, in view of the consequent invalidation of the results for strictly scientific investigation, they are sufficiently weighty, is a matter on which considerable doubt might be entertained.

Closely connected with the third phase of the use of statistics is the fourth, that of prognostication. Here it is obvious that the dangers of error exist in still greater abundance. For not only is it necessary now to be sure of all the conditions that determined the past, but the possibility of their modification or even complete change has to be kept carefully in view.

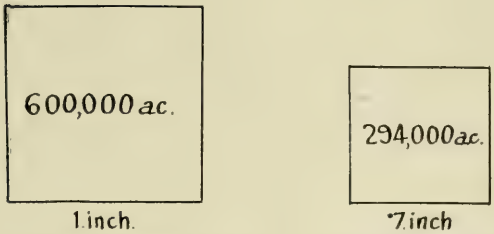
I cannot resist the temptation of rescuing from the unwritten annals of statistical history the following amusing incident. Several years ago an over-sanguine statesman in a rising country instructed the Government Actuary to write a forecast of the increase of population for the next 10 years. An interesting little pamphlet was compiled, with a carefully drawn curve representing the probable increase of the population during the ensuing decade based on recent past experience. The pamphlet was duly boomed and forgotten; but about five years afterwards the chief of the statistical office in that country



Circular presentation

(The complete circle represents £1,800,000)

DIAGRAM No. 2



Square measure presentation

DIAGRAM No. 3

A (9 Stone) B ($4\frac{1}{2}$ Stone) C (2 Stone)

Cubic measure presentation

found one of his most promising young clerks sitting with a copy of the pamphlet before him, the diagram showing the curve having evidently been improved upon by some additional drawing. Another curve was seen diverging very considerably from the original one. When the chief looked closer into the picture he read against the original curve the words "Actuarial increase," whilst against the other was written the caustic criticism "Actual increase." I am not aware whether the actuary ever heard of the incident.

After having made, however, due deduction for the many possibilities of erroneous or unwarranted use of statistics, it must be at once conceded that statistical information in many of its departments has now well nigh become indispensable to the efficient conduct of public as well as private affairs. It is often too little recognised, not only by the public but also by Governments, what modern communities owe to those who supply them with correct and complete statistics. Take, for instance, the recent rapid expansion of land settlement in Western Australia. How could this have been brought about if elaborate statistics had not proved year after year that agriculture in that State was a promising industry, and thus induced the *bona fide* farmer—who as a rule does not throw away the substance for the shadow—to leave his home elsewhere and try a country which experience had shown to be a propitious one for his calling? Yet, in the face of such facts, statistics are by many looked upon as an expensive luxury, it being surmised that because there is no immediate or direct monetary return, no practical use accrues from this class of information. The error is too palpable to require further demonstration than the facts already adduced. If it were once adequately realised how advantageous it is to obtain correct statistical records and reliable estimates of various kinds, governments would no longer hesitate to introduce the quinquennial census of population. For those who are acquainted with statistical methods know that the population basis is required for the right appreciation of almost every kind of information, and is, especially in Australia, the basis on which the principal monetary calculations or allotments for Government purposes are usually made. It will be at once realised that in Australia, with its constant and numerous inter-State migrations, a decennial census fails to afford an adequate and sufficiently accurate means for gauging the populations of various communities at intercensal periods.

In concluding my essay I wish to place on record my indebtedness to Miss Daisy Rossi, the Perth artist, for the excellently drawn illustrative figures in diagram No. 3; to the Government Statistician of Western Australia, Mr. Malcolm A. C. Fraser, for numerous valuable suggestions; and to Mr. W. Morrison, of the Western Australian Statistical Office, for the accurate drawing of the diagrams.

6.—THE FINANCIAL RELATIONS OF THE AUSTRALIAN COMMONWEALTH STATES

By Hon. D. MACKINNON.

Section G (II.)—AGRICULTURE.

1.—DRAINAGE IN CONNECTION WITH IRRIGATION.

By A. S. KENYON, C.E.

[Published in the *Journal of the Department of Agriculture of Victoria*, April, 1907.]

2.—MILLING CHARACTERISTICS OF AUSTRALIAN WHEATS.

By F. B. GUTHRIE and G. W. NORRIS.

[Published in the *Journal of Agriculture of South Australia*, February, 1907, and reprinted as Bulletin No. 18 of the Department of Agriculture and Intelligence of South Australia.]

3.—AVAILABLE PLANT-FOOD IN SOIL.

By W. A. HARGREAVES, M.A., F.I.C.

[Published in the *Journal of Agriculture of South Australia*, February, 1907, and reprinted as Bulletin No. 20 of the Department of Agriculture and Intelligence of South Australia.]

4.—SOIL SURVEYS.

By F. B. GUTHRIE.

[Published in the *Journal of Agriculture of South Australia*, February, 1907, and reprinted as Bulletin No. 21 of the Department of Agriculture and Intelligence of South Australia.]

5.—THE VALUE AND AIMS OF PLANT PATHOLOGY.

By D. McALPINE.

[Published as Bulletin No. 22 of the Department of Agriculture and Intelligence of South Australia.]

6.—NOTE ON THE FREE ACID IN SUPERPHOSPHATES.

By F. B. GUTHRIE and A. A. RAMSAY.

7.—ON METHODS OF SOIL ANALYSIS.

By W. A. HARGREAVES, M.A., F.I.C.

8.—COMMERCIAL POULTRY-BREEDING.

By D. F. LAURIE.

Section H.

ENGINEERING AND ARCHITECTURE.

1.—WATERWORKS CONNECTIONS FOR EXTINCTION OF FIRES.

By THOMAS WALKER FOWLER, M. Inst. C.E.M., Am., Soc. C.E., M.I. Mech. E., &c.

Town water supplies are provided primarily for domestic or domestic and manufacturing purposes, but when established they are available for other uses also, prominent amongst which come fire-extinction, street-watering, and flushing of gutters, &c. Whilst the actual quantities of water required for these purposes are comparatively small, to obtain effective results, more especially for fire purposes, the pipes must be capable of delivering large volumes of water in short periods of time. As the requirements for fire-extinction are in excess of those for street-watering and gutter-flushing it is intended to deal with the former only in this paper.

When a jet of water is discharged on a fierce fire it necessarily passes through an intensely heated atmosphere prior to reaching the actual flames, and unless the volume of the jet be considerable the whole, or at least the major portion, of the water may be converted into steam before reaching the fire. Hence a given discharge of water is necessarily more effective when concentrated in a small number of large fire streams than when divided up amongst a greater number of smaller streams. In many cases, however, Australian reticulations are arranged with utterly insufficient provision for this important service; and hence our fire services are hampered by a lamentable want of water. Mr. Wm. Thwaites, M. Inst., C.E., Engineer-in-Chief to the Melbourne and Metropolitan Board of Works, in a recent report states that for good fire service in Melbourne a fire stream should deliver 125galls. (that is 20 cubic feet) per minute, with a nozzle pressure of 70lbs., and he considers that in the city provision should be made for the simultaneous use of 20 such fire streams, the number being reduced in the suburbs. Turneaure and Russell give as American practice that in cities fire streams should discharge 250 U.S. gallons per minute, and in residential suburbs 175 U.S. gallons per minute, quantities which correspond to 208 and 146 imperial gallons respectively. General Rockwell states that American horse-drawn fire engines throw up to 600galls. per minute, and mentions self-propelled engines delivering up to 1,036galls. per minute; whilst in Boston arrangements have been made for jets of 1,500galls. per minute. In all cases these quantities are presumably U.S. gallons.

Turneaure and Russell state that the sizes of mains and cross mains in a reticulation will depend largely upon the number of fire streams required at any point. "In small cities and outlying districts of large cities 6in. cross mains, with 8in., 10in., or 12in. pipes at intervals of four to six blocks, is a common arrangement. Four-inch pipe should rarely be used to supply hydrants. For compactly built districts many of the cross pipes require to be 8in., and a more frequent use made of 12in. and 16in. pipes. A good arrangement for a comparatively large demand is to lay 6in. pipes lengthwise of the blocks and 8in. pipes crosswise." This quotation is sufficient to indicate the nature of American practice in the matter of street-reticulation and provision for fire-extinction. Whilst with Australian prices its cost would usually be prohibitive the general trend is undoubtedly on sound lines.

Mr. Thwaites states that to force one fire stream of 125galls. per minute through a 3in. main a head of 29ft. per five chains length would be required, whilst for two he puts the corresponding head at 116ft. These heads are somewhat in excess of those generally allowed for clean pipes, and evidently include an allowance to cover any resistance due to corrosion. And yet in Victorian urban water supplies 2in. and 1½in. galvanized iron mains have been freely used, and in some cases even smaller sizes have been adopted, and this notwithstanding that in many cases the supplies come from wrought-iron or steel tanks placed at comparatively low elevations. In many cases articles destroyed by fire cannot possibly be replaced at any cost, and insurance cannot compensate for losses sustained through the disarrangement of business. Hence effective fire-protection pays in more ways than in the reduction of insurance premiums; but such protection is not secured unless the reticulation pipes are of diameters sufficient to allow of effective fire streams being supplied.

Whilst it is most desirable that the reticulation should be capable of delivering good fire streams at satisfactory pressures direct, in many cases the local conditions will not permit of this; and in such case the most satisfactory arrangement is to discharge from the hydrants through short lengths of hose into canvas tanks, from which the water is delivered on the fire by steam or hand fire engines. By this means the reticulation is relieved of the back pressure from hose and nozzle resistance, and hence can deliver the water at a more rapid rate.

The usual diameter of fire hose adopted is 2½in., and to discharge a fire stream of 125galls. per minute through such a hose the velocity must be 576ft. per minute, or 9½ft. per second. In a pipe line the resistance under such conditions would be so enormous that no engineer would attempt to convey such a stream at such a rate. According to Freeman's classical experiments the resistance with the best rubber hose under such conditions would be about 7lbs. per 100ft., and with ordinary canvas hose over 16lbs. per 100ft. Hence it is desirable that the lengths of hose required should be reduced as much as possible by having fireplugs spaced fairly close together, and that the hose diameter should be increased so as to reduce the frictional resistance per unit length. A fireplug spacing of five chains or a little farther is usual, and Mr. Thwaites suggests intervals of 100yds. in closely built localities, and 150yds. in more sparsely built ones. Even the shorter of these distances would render necessary the use of a considerable length of hose and consequent loss of pressure, and I would urge that a spacing of not more than three chains would be much more effective. By using 3in. hose in lieu of 2½in. the velocity of the water would be reduced below 7ft. per second, and the hose resistance practically halved, whilst the connections (which necessarily pass inside the hose) could also be enlarged from 2¼in. to 2¾in., and thus even greater reduction of resistance could be effected.

The fireplugs next demand attention. These should have the following qualities :—

(*a*) They should be prominently marked so that they may easily be found when wanted even in dark nights.

(*b*) They should be arranged so that the hydrants and hose may be quickly and conveniently connected to same.

(*c*) They should be of such construction that under no circumstances can the water supply be polluted through street drainage getting access to it through the plugs, more especially when the pressure drops or the water is turned off.

(*d*) They should be of such construction as to provide an ample waterway for discharge of the water, and hence have small resistance.

(*e*) They should be arranged so that the hydrant seat and lugs shall not be liable to be obstructed by debris, mud, or rubbish after rain, &c.

(*f*) The cost of the plugs fixed complete in position should not be excessive.

In cold climates another consideration comes in, namely, the plug and its attachments should not be liable to be blocked or choked with ice. In such cases it is necessary that the water mains and fireplugs be kept below the frost-line, and that provision be made for draining away all waste water which may have collected in the plug chamber, unless the plug be kept warmed artificially during cold weather. Hence fireplugs suitable for use in Australia are not necessarily suitable for Canada or the northern portions of the United States.

Taking Australian practice, the fireplugs in common use may be divided into two groups, one being that in which the closing is effected by downward pressure, which may be termed the screw-down group, and the other those in which the closing is effected by the upward pressure of the valve—usually a ball—against its seat. Each of these groups may be divided into two sub-groups, namely, those in which the plugs are placed below the level of the footpath or roadway, and are covered by a suitable cover—usually of cast iron—with a movable lid, and the other in which they are placed above the level of the roadway or footpath and usually on the line of kerb, so as to form a dwarf post or pillar. The former may be termed roadway fireplugs, and the latter pillar fireplugs.

All roadway fireplugs are necessarily open to the objections that being placed below the street surface they are necessarily more difficult to find than pillar fireplugs, and that the fireplugs are liable to be more or less buried in clay, grit, debris, &c., which works in through the cover, and has to be removed before the hydrant can be properly attached. This latter is a special disadvantage where the plugs are fitted in unmetalled streets, and the fire brigade superintendent of an important town states that, in addition to having the fireplugs inspected and the boxes cleaned out every quarter, he has frequently to have this work re-done after heavy rains. Pillar fireplugs being placed above the street level are necessarily free from these objections, but are more expensive than the roadway type, which can be placed directly over the main, whereas special branches have to be provided leading to the pillars on the kerb line.

The screw-down fireplugs are similar in principle to the ordinary screw-down high-pressure taps, and whilst they are not used in Victoria they appear to have been adopted extensively in some of the other States. With them the hydrant connection is preferably of the ordinary bayonet-joint type, and as the opening and closing of the plug is effected by a separate key (which has, of course, to be carried by the firemen) the hydrant waterway is not obstructed by any disk or rod. It is claimed that with these plugs there is no liability of the water mains being polluted with street drainage, as they are not automatically opened when the pressure is removed or the mains emptied. On the other hand, they do not act as air valves, and as the opening gear is independent of the hydrant the water cannot be as quickly and conveniently turned on. They are more expensive than fireplugs of the upward pressure type, and they require large covers, which, in addition to being more expensive, are objectionable as being greater breaks of an objectionable character in the street surface.

Whilst the writer has no personal experience with these plugs, he notes that necessarily dirt and filth will accumulate under the covers and in the portion of the fireplug between the hydrant seat and the valve. In the event of the plug being accidentally opened at a time when the pressure is off, such filth will necessarily drain back into the mains. Further, it is well known that high-pressure taps at times become leaky, and it reasonable to assume that fireplugs on a similar principle may do the same. With a leaky fireplug of this type and an empty water main there is a liability for street drainage and liquid filth to get access to the water mains, whereas pillar fireplugs, in which the hydrant seats (or hose connections) are above street and drainage level, are necessarily free from any such liability to pollute the water supply.

The Bateman and Moore is the original of the upwards pressure fireplugs, and is in extensive use in Victoria. In it the closing valve is a ball of specific gravity less than that of water, and is placed in a valve chamber on top of which is bolted a casting forming valve seat and hydrant seat, and having lugs for holding the hydrant in place. A rubber ring is usually provided between the two castings, and facilitates the formation of water-tight joint. The water pressure forces the ball against the rubber ring and valve seat automatically closing the plug, which can be opened when required by depressing the ball. This is done with a small disk attached to a rod passing through the centre of the hydrant tube. When the mains are empty the plugs open automatically, and hence act as air valves. Whilst this is an advantage in the case of roadway fireplugs, it is accompanied by the great disadvantage that under such conditions any street drainage or filth which may have accumulated round the plug and under the cover obtains direct access to the water mains.

Various types of ball have been used, the principal ones being indiarubber, gutta-percha, ebonite, and wood. Wooden balls covered with about three-sixteenths of rubber are very satisfactory, and cost about 3s. each for 3in. balls. Gutta-percha balls are liable to soften and deform with heat, and under special circumstances have been blown through the valve seats. Ebonite is satisfactory in cases (as with pillar plugs) where grit cannot accumulate. Experiments are being tried with wooden plugs which are very promising, and if successful will result in considerable economy, as they cost about 6d. each, whereas some of the others cost 4s. 6d. each.

With fireplugs of the Bateman and Moore type the pressure between valve and valve seat is limited by the water pressure, whereas with the screw-down type the act of closing necessarily places considerable stresses upon the valve, valve spindle, and connections between these parts and the valve seat; and with leaky or imperfectly fitting valves the intensity of such stresses will be limited only by the strength of the valve key and of the man working the same. As the force applied by such man acts at a considerable leverage, evidently such stresses will be large, and unless the parts are made of ample strength breakages may be expected.

The ordinary Bateman and Moore fireplug has a rather small chamber, and the waterway at the bottom of the same is considerably restricted by stops provided to prevent the ball dropping into the main. The writer has designed a new type of valve chamber giving ample waterway round the ball, which is kept centred by four vertical fins. This chamber is also made of ample depth, so that the ball cannot be forced down on the stops, as is frequently done with the Bateman and Moore plug, where the hydrant rod is of excessive length. The discharging capacities of the Bateman and Moore plugs in such cases are reduced, and very frequently the balls are damaged and have to be renewed. When tested at Geelong the writer's fireplug was found to pass 25 per cent. more water than a Bateman and Moore plug under similar conditions, the plugs being on a 3in. branch one chain in length and connected to a 7in. main having 82lbs. pressure.

Pillar fireplugs of the screw-down type are extensively used in Adelaide. In this type the valve gear is placed on top of a hollow pillar, up which the water passes, and connections are provided for attaching the hose to the pillar, no intermediate portable hydrant being required. Samples of the Adelaide pillars were supplied to the Melbourne authorities, who adopted a modified design, preserving the upward pressure system of the Bateman and Moore. The design includes an opening spindle and connections for hose above the valve seat, so that the Melbourne pillar hydrant may be described as a Bateman and Moore fireplug placed on top of a pillar, and having permanently fixed over same a dwarf hydrant.

Both Adelaide and Melbourne types of pillar hydrants or fireplugs may be considered excellent pieces of apparatus, and each can be arranged to give ample waterways up to the hose connections, whereas all roadway fireplugs have necessarily to be made to fit the standard portable hydrants, so that increased waterways could only be obtained with them by scrapping all existing hydrants and commencing *de novo*, The following objection has been urged against the screw-down system in pillar hydrants. As the valve spindle is necessarily made of brass and the body of the plug (for economy) of cast iron, the pressure with which the valve presses on its seat will vary with he temperature, increasing with heat and decreasing with cold; and hence that plugs closed during the heat of a hot day may be expected to leak during any succeeding cooler weather, whilst those closed during cold weather will be subject to excessive strains during following hot spells. This is understood to have been one reason for the Melbourne engineers modifying the type, and it would be interesting to learn whether any trouble has been experienced from this cause in Adelaide.

The Adelaide and Melbourne pillar hydrants may be considered satisfactory but costly, and hence an effective and economical substitute for them becomes desirable. To provide this the writer has designed an arrangement by which a fireplug (preferably wi'h large valve chamber as already described) is placed on the kerb-line, the hydrant seat being about 5in. above the footpath level, or at least 1ft. above gutter-level. In this position the plug would form a dangerous obstruction unless suitably protected; but this is done by covering it with a movable dwarf pillar standing about 3ft. above the kerb-level. Alternate types are in use, one being a detachable pillar provided with internal arms to engage the fireplug lugs and a locking pawl worked by a suitable key, by means of which the cover is locked in position. The other is a hinged cover which is normally locked in place by a weighted catch, but which can when required be thrown back, leaving the fireplug available for use. The latter is undoubtedly the more convenient arrangement, but is slightly more expensive. These fireplugs are effective in stopping pollution. They can be readily found and are easy to connect to, whilst they are much lower in first cost than either Adelaide or Melbourne pillar hydrants. It is further to be noted that during hot weather the water temperature in the Adelaide and Melbourne pillar hydrants will be much higher than in the case of the Fowler pillar fireplugs, the water chambers being much more exposed; and hence in them bacterial growth will necessarily be more rapid.

Tests as to times required to couple up a hydrant and 50ft. of hose to Bateman and Moore fireplugs and Fowler pillar fireplugs with detachable covers, and to couple up 50ft. of hose to the Melbourne pillar hydrants were made on October 4th, 1905, at the Melbourne Fire

Brigade Head Station, under direction of Superintendent Stein, and the results may be of interest. At the time the hinged cover plugs were not available.

Type of Plug.	Bateman and Moore.	Melbourne Pillar.	Fowler Pillar.
First test...........	12 sec.	9 sec.	12 sec.
Second test	$7\frac{1}{2}$ sec.	8 sec.	11 sec.

At first test the Bateman and Moore plug, though in good order, had to be cleaned of some grit. Of course this had not to be done on the second occasion. The men were stationed at the plugs, and hence no time was lost in searching for same. Whilst in service no time would be lost in searching for the pillar plugs, as already pointed out, a considerable amount of time might be so lost with a Bateman and Moore or any "roadway" plug.

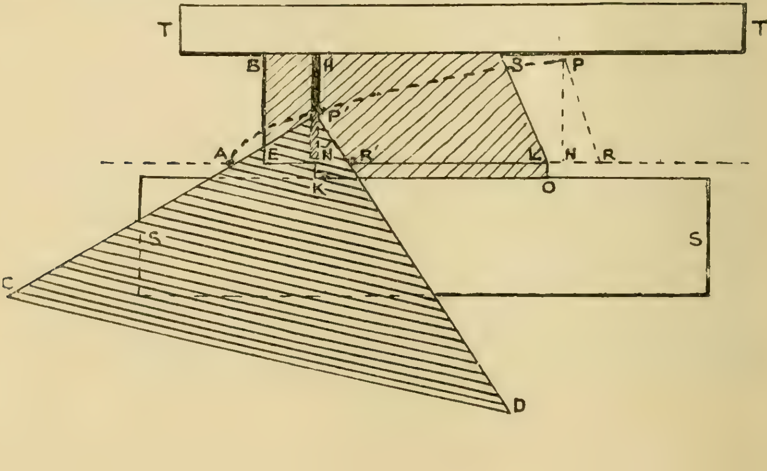
2.—THE DESIGN OF COUNTRY WATERWORKS.

By J. W. H. HULLETT.

3.—PARABOLAGRAPH: AN INSTRUMENT FOR DRAWING PARABOLIC CURVES.

By S. SMEATON, B.A.

Axis A N + *point* P *given.*—Put pin in at A. With tin square find R, A P R being a right angle. Put pin on line in slotted board at R′, centre of slot to R′ = N R; press corner at N′ against pin A, making end of line at L come on axis. Weight straight-edges in contact with board. Pass pencil through loop in square at P′ and into slot. Now trace curve. Turn board upside down, and re-insert pin at some distance from slot; re-adjust, and trace other half of curve. Proof—$y^2 = mx$; y is a mean propl. between x and $4m$. P′ N′ $= y$, A N′ $= x$, N′ R′ $= 4m$. P′ N′ is a mean propl. in the right-angled triangle A P′ R′.



4.—THE MAKING AND MAINTENANCE OF MACADAMISED ROADS WITH A VIEW TO THE PREVENTION OF DUST.

By J. VICARS, M.C.E., City Engineer of Adelaide, South Australia.

It is customary, though not strictly correct, to refer to all broken stone road pavements as macadam, of which the various systems introduced by others are considered as varieties. This classification, though not as scientific as could be desired, is nevertheless convenient, and will be adopted in this paper.

The historical aspect of broken-stone roads is, perhaps, more, interesting than serviceable, unless, indeed, its chronicle supplies a beacon warning against the Scylla and Charybdis of road-making—rocks where they are not wanted. As there are so many lengthy accounts of the early efforts in this direction, only a brief summary of the salient epochs will here be attempted.

It has been wittily stated that the first roads known to man were of the nature of in-roads. It is, however, safe to say that primitive man knew no roads, in the sense under consideration, and therefore no pavements. Before his existence in communities his house was a tree or a cave, and his home and occupation the forest and the chase. As time wore on the tribal tracks became paths; and after the lapse of many centuries the interchange of commerce, at the dawn of civilisation, developed trade routes.

Perhaps the first attempt at a paved surface emanated from tribes which had ceased to be nomadic, and where the frequent use of a track made the employment of gravel or burnt clay essential to its existence.

Some authorities contend that the transport of armies first induced the construction of paved surfaces; but from our knowledge of semi-barbarous peoples, it would almost seem certain that roads of a kind—even the approach or the clearing of a track through a wood to some drinking place—came into existence when tribes still fought in bands and made their onslaught secretly, without the lengthy warning necessitated by the making or paving of tracks for that purpose.

Then it may reasonably be conjectured that with the evolution of our race from one age to another—from the Stone age to the Bronze age, at latest—man, with increased intelligence and means at hand, broke down stones to form the first real pavement.

By pavement is meant a surface of material artificially prepared, as opposed to one formed of materials as found in nature, such as a layer of gravel. Owing to the absence of the material necessary for the preservation of such records, and the non-existence of written language, the pages in this past history of mankind and his works are unfortunately a blank, and we now can only conjecture and reason deductively from the evidence of other less perishable remains which have from time to time been brought to light by the archeologist and traveller. In these matters it is established beyond doubt that negative evidence is no proof of the previous non-existence of such works.

Perhaps the first pavement, of the existence of which there is strong presumptive evidence—although here even some yet consider a trace of doubt attaches thereto—is that of remains discovered in the vicinity of the Great Pyramid in Egypt. Along this supposed road leading across a sandy waste Pharoah, of the fourth dynasty, is thought to have conveyed material for the construction of that monument 4,000 years B.C. Subsequently we read of the broad paved road which led from the city of Memphis to the Great Pyramids, and which was about six miles long. Judged from the modern standpoint, these roads must have been of the crudest description.

Not until somewhere about B.C. 600 do we approach the period of authentic record. The Carthagenians were probably the first to systematically construct and maintain their roads. With the destruction of Carthage by the Romans in B.C. 146 the latter began to make history—and roads—after the art of the Carthagenians.

These two great powers of their day waged many bloody wars against each other; and the history of the Punic wars reveals a master mind in the person of the great Hannibal, the Phœnician general, whose military achievements compare with those of the great Napoleon. By his genius immense armies were taken thousands of miles; and where no roads existed they were made, or may be only formed, to facilitate his ends. In one case it is stated (but not by an eye witness) that he kindled huge fires on impassable rocks, then poured vinegar on them till they crumbled away and permitted a road to be made. Where the immense quantity of vinegar came from not even the historian Livy offers any information.

About B.C. 300 the Appian and Flaminian ways were commenced by the Romans. They were said to have been built with stone and cement mortar, which in places attained a depth of several feet and lasted probably a thousand years. The Romans constructed roads concurrently with conquest, and in Great Britain alone they made 2,500 miles of roads, also many miles in Palestine.

In the new world excellent foot roads were constructed by the Peruvians and Mexicans centuries ago.

After a long interval the mantle of the Romans seems to have been assumed by the French, and they are deservedly reputed for the excellence of their roads and systematic maintenance of same. The first paved roads in Paris date back to the reign of Phillip Augustus, about 1184, the population then being about 200,000. A new era in road-making was marked when in the sixteenth century Henry IV. established the office of "Great Way Warden," whose duty it was to control and keep in order the public roads in France.

In Spain, Cordova is credited with paved roads dating back to 850 A.D., but the first constructed subsequent to the Roman era were made in 1749 by Fernando VI., from Santander to Reinoso. In 1749 a special bureau was constituted in charge of all road work. The first actually systematic arrangement was not, however, attained until after the establishment of a school of engineering in 1834.

In 1555 the first Highway Act was enacted in England, while the first pavement in London was the Strand, constructed in the fourteenth century.

Up to nearly the end of the eighteenth century the Roman system of broken-stone pavements was adopted for the best work; but subsequently several modifications were introduced, culminating in the universal adoption more or less in its entirety of the method instituted by Macadam.

In concluding this historical introduction it will, therefore, be proper to advert to the times of Trésaguet, the great French road engineer, and Macadam and Telford, the illustrious English engineers, to whose genius the early conceptions and inauguration of our present system is due. Macadam pavements, on account of their low first cost, are everywhere the most general form of road-construction now in vogue.

The systems practised by the Romans may have produced an equally good road surface, at any rate for their purposes, yet they were extremely costly; and it remained for John Loudon Macadam to devise a systematic and rational method of constructing broken stone pavements in a thoroughly scientific manner, so as to entail a minimum of expenditure.

In 1775 M. Trésaguet adopted a system of road-making very similar to that devised by Telford 25 years later. Prior to 1775 the broken stone pavements of France had been made after the Roman fashion, according to which the ground was excavated level to a depth of about 2ft., then largish stones were laid on flat in three layers to form a foundation; on these small stones were laid and beaten down, and on top of these a course of smaller stones was laid and beaten down firmly. Trésaguet altered this by excavating the ground to a depth of about 1ft., with the bottom curved the same as the finished surface, then stone pitchers were laid edgewise by hand and beaten to an even surface and finished off as before.

In 1784 Macadam was appointed a road trustee and manager of a district in Ayrshire, where he practised the method of road-making which still retains his name. His system consisted of spreading 2in. stones wherever possible on—not below, as in the case of Trésaguet and all others—the properly levelled and drained road surface to a depth of 10in., and the convexity given was only sufficient to properly shed the rainwater readily to the side drains. In 1815 he was appointed surveyor of roads in Bristol, where he metamorphosed some 178 miles of roadway. By his system local finances, previously embarrassed, were placed on a sound basis. So marvellous were the results obtained that other authorities consulted him with equal success. The road trustees of the Carse of Gowrie turnpike road in Perthshire became almost insolvent owing to the cost of maintenance. They secured the advice of Macadam and remade their roads accordingly, and their funds were soon restored to a financial position. In 1850 Macadam's system was adopted throughout France, perhaps the greatest compliment he could have had.

In 1802 Thomas Telford undertook his first great piece of work in the Highlands of Scotland, involving the expenditure of £450,000 and embracing 920 miles of road. According to his system the formation was levelled as in the case of Macadam, or excavated as in the case of Trésaguet, but still with flat bottom, then pitchers were hand-packed across the surface with base down and standing 7in. high in the centre reduced to about one-half at the sides; over this foundation was spread a coat of $2\frac{1}{2}$in. metal to a depth of 7in. in the centre and somewhat less at the sides. The bottom course was carefully levelled, graded, and compacted with small stones by hand to keep earth from working up through road metal and ruining road, as might readily happen on soft ground; the top coat was covered with 1in. of gravel.

Telford's *magnum opus* was, however, the construction of the Shrewsbury and Holyhead Road, one of the finest pieces of road engineering carried out up to that time. The surface traversed consisted of rocks, bogs, ravines, and precipices. In those days road pavements were consolidated by the traffic, with all the attendant inconvenience, losses, and delays.

Since the advent of the steam road-roller the making of macadam roads has entered a new phase. The formation is made parallel to the finished surface, and instead of pitchers hand-packed, 4in. metal is now laid for a bottom or foundation course where one is required, and a top course of 2in. or $2\frac{1}{2}$in. metal lightly blinded and well rolled by a steam roller weighing from 10 tons to 20 tons. Under the old system it took months to consolidate a road, but nowadays they are made to-day and are in use to-morrow. They may now be made any time of the year, though the autumn is the best season, instead of only in the winter as formerly, and they withstand heavier traffic. This is in brief the recognised standard system on which the best macadam roads are now made.

The rationale of the different pavements alluded to is as follows:—The Roman pavement was made as solid as possible, partly owing to difficulty of draining foundation, and partly to insure durability and minimum of maintenance. With large flat stone foundation the top course of metal must be thick or the flat stones must be in several layers.

A thick coat of metal distributes pressure and prevents a load being concentrated on one particular part of flat stone. With a thin top course and one layer of flat stones there is a local concentration of load, and the flat stones will surely cockle and rock sooner or later, letting rain into foundation and ultimately ruining the road. The Romans therefore adopted two or three courses of flat stones, sometimes cemented together.

Where a road is formed below the natural surface, or where the surface is bad, a strong foundation is advisable; but before the advent of the steam roller the only possible way to attain this end was by laying hand-packed stones on flat with points upwards, wedged and jammed with small stone shivers tightly driven in. This prevented the soft earth working up and destroying the surface, and enabled the great thickness of the Roman road to be halved and the expense reduced; but drainage had to be carefully provided for. This was the system of Trésaguet and Telford.

Wherever the natural formation is good a 10in. coat of metal broken to a 2in. gauge is sufficient to distribute the weight of a vehicle with moderate load without injury to earth foundation; and as, without a heavy roller, all dirt, &c., that is put on to such road while the metal is loose must stay there, it is preferable to use grit. Where the metal is consolidated by wheel traffic, sufficient grit will be abraded from metal without the addition of anything else, provided the surface is properly tended. This is the system of Macadam.

Under modern conditions and requirements roads carrying heavy traffic would have to be made with a Telford base if a heavy roller were not available. With a heavy roller a foundation 8in. thick of 4in. metal can be consolidated so as to stand heavier loads than the standard Telford foundation; but for country roads the true macadam road is quite satisfactory. The distinguishing feature of a macadam road as now known strictly speaking lies in the use of metal broken to a gauge whether 4in. or 2in., no matter whether consolidated in one layer or two, or three, so long as there is no set foundation.

The average cost of making a macadam road in Adelaide is as follows:—Per chain of 22ft. 6in. between watertables:

	£	s.	d.
First-class Road—			
Excavation—55 cub. yds. at 1s. 6d.	4	2	6
Grading and rolling formation—165 sq. yds. at 1d.	0	13	9
Bottoming (12in., loose)—55 cub. yds. at 4s. 8d. supply + 4d. spreading + 2d. rolling = 5s. 2d.	14	4	2
Blinding (chippings)—11 cub. yds. at 2s. 6d.	1	7	6
Intermediate coat (4½in., loose)—21 cub. yds. at 4s. 9d. + 4d. + 9d. = 5s. 10d.	6	2	6
Blinding—2 cub. yds. at 3s.	0	6	0
Top coat—21 cub. yds. at 4s. 9d. + 4d. + 1s. = 6s. 1d.	6	7	9
Blinding—2 cub. yds. at 3s.	0	6	0
Total cost per chain	£33	10	2
Second-class Road—			
Excavation—37 cub. yds. at 1s. 6d.	2	15	6
Grading and rolling formation—165 sq. yds. at 1d	0	13	9
Bottoming (8in., loose)—37 cub. yds. at 5s. 2d.	9	11	1
Blinding—7 cub. yds. chippings at 2s. 6d.	0	17	6
Top course (4½in., loose)—21 cub. yds. at 6s. 1d.	6	7	9
Blinding—2 cub. yds. at 3s.	0	6	0
Total cost per chain	£20	11	7
Third-class Road—			
Excavation—20 cub. yds. at 1s. 6d.	1	10	0
Grading and rolling—165 sq. yds. at 1d.	0	13	9
Metal (6in., loose)—28 cub. yds. at 6s. 1d.	8	10	4
Blinding—3 cub. yds at 3s.	0	9	0
Total cost per chain	£11	3	1

The cost of re-sheeting any one of these roads would be that of renewing the top coat of the first or second class road, viz., £6 13s. 9d. per chain. Now the streets in which the dust nuisance is to be combated it is evident will not be those which are watered regularly. They will be comparatively light traffic roads, and subject to re-sheeting once in about five years. The average cost of this sheet per annum would therefore be not less than £1 6s. 9d. per chain, or 2d. per square yard per annum.

The ordinary macadam road is a great dust-producer, and to overcome this evil many minds have been at work. Almost all have started out to so treat the macadam surface that any dust formed or grit worn off would be made self-binding and reinforce the surface like a mat or cushion. In this way the life of the road might be greatly increased and the comfort of the people equally improved by lessening the vibration, noise, and dust. Others, again, have attacked the problem from another direction, and have sought to combine with the macadam some substance which will virtually produce a new kind of pavement, or substitute a new and different pavement altogether, having the desired qualities in a high degree.

Following up the latter scheme first, it will be seen that such pavements include mineral asphalte, wood blocks, and others which are too costly for the majority of the streets. Tar pavements of various kinds have been tried with more or less success for a time, but they are difficult to repair and are extremely hot—in fact the hottest pavement known. When double-distilled tar is used and the traffic is not heavy they give good results, though more costly than tar-dressed roads, and their use is chiefly indicated when the traffic is too heavy for the latter. All pavements which are of the nature of a substitution have this great drawback, that they can only be adopted as existing pavements become worn out, and relatively they are costly, and, with the exception of Val de Travers asphalte, require frequent dressings of tar and sand, estimated at 2d. to 4d. per square yard per annum according to traffic. Regarding this class of pavement the Board of Commissioners appointed to investigate the question of pavements for Washington, United States of America, reported that "while some of the latter and better class of coal tar pavements show good service, and give a fair promise of reasonable durability, yet the general condition of this class of pavements in the city is such as to lead to their condemnation as faulty in principle and deficient in vitality."

Referring now to those inventions or methods which aim at treating the existing macadam so as to confer on it the desirable qualities of dust-prevention, coolness, pleasant travel, and absence of glare, they are naturally divided into two distinct classes. One class of itself is dry and inert, and requires a very humid atmosphere or frequent sprinkling from a watervan. Some of these processes are relatively cheap to apply, but are costly if watered. Perhaps the best of this class is calcium chloride, which, without the presence of water or moisture, itself becomes a powder and rises in dust under traffic, and in winter it tends to produce mud. The chief use of such substances is to reduce the cost in connection with streets which are regularly watered. Where water is free for city purposes, as in Adelaide, their employment would be rarely justifiable on that score alone; but the less water the less wear and rutting of surface. Where they do not increase the cost of watering their use may be justified. Where streets are swept with horse broom every day they would have to be applied daily and would generally prove too costly.

Soluble silicate of soda and numerous other substances, which become dry and powdery when absorbed into road surface, are equally unsatisfactory.

Tar is also applied to roads, being broomed over the surface, which is sprinkled with sand or gravel before it dries. There can be no doubt that where the traffic is light this dressing produces a very satisfactory and cheap treatment, and is entirely successful in reducing dust and noise and in pleasantness of travel; but it is extremely hot, and if double-distilled tar is used noise is not reduced very much, and the clatter of horses' hoofs becomes very marked in narrow streets. The cost varies greatly with the price of tar. In Adelaide tar costs 6d. per gallon at the site, and one dressing costs from 1¾d. to 3d. per square yard, according to the amount of repairs to be effected, and it is rarely less than 2d. On roads with a fairly heavy amount of traffic this coating in winter frequently works up into a black mud, which is very objectionable. Although it is serviceable on many roads, the limited supply of tar and increasing demand point in the direction of much higher prices. Yet, where the cost does not exceed the average annual cost of repairs to macadam roads, its use is preferable to other substances which do not provide a wearing surface in themselves.

There has recently been placed on the market quite a number of patent lines having an oil base, and these, or some of them, seem to offer great promise of success under almost all circumstances of traffic and weather.

It should, however, be remembered that air-borne dust is not amenable to any local treatment, no matter how effectually it may preserve the surface to which it is applied.

The following list has been selected as illustrating the importance attached to this subject in England, and in fact Europe and America generally, and are from experiments made in England :—

Westrumite, a solution of petroleum and water, costs in England £8 10s. per ton, and when used in 10 per cent. solution costs ½d. per square yard per application. In Australia the price quoted is double, representing over 1d. per square yard per application.

Dustroyd, a patent liquid preparation manufactured from tar, has pleasing odor, is not soluble in water and binds road surface. It costs in England £4 per ton, but, having to be used full strength, does not go so far as westrumite, and would probably be as costly.

Akonia is another patent preparation, and so far seems to occupy a similar position to dustroyd.

In 1902-3 and 4 Mr. John A. Brodie, M. Inst., C.E., City Engineer of Liverpool, conducted extensive experiments with oil mixtures, and the following brief summary of the results will be of interest :—Experiments were made with creosote oil, hot and cold, also mixed with pitch, resin, and tallow; coal tar hot; cheap waste petroleum; westrumite; crystallised creosote; pyneoline; and calcium chloride.

The cost varied from ¼d. to ½d. per square yard per coat, the lowest being that of cheap crude oil. Chief objections were raised to the smell of creosote oil, but it banished flies. The surface having the cleanest and whitest appearance was that coated with creosote oil mixed with resin, while that covered with the same oil mixed with tallow had the least odor. The crude Texas petroleum gave the most lasting results, and portions of the road which were heavily coated showed a somewhat glazed surface formed of oil and dust. The experiments show us that the dust has been satisfactorily laid, and the experience gained will probably enable future trials to be carried out more economically. From the point of view of wear and tear of the road surface, the oiling has on the whole been advantageous; the wear appears to be less; the surface of the road dries more quickly after rain; the number of loose stones picked up has been reduced; the combination of earth and dust on the surface also appeared to make it a somewhat quieter surface. Westrumite was found too costly, and its effects passed off under a fortnight. In the moist climate of England it was found that calcium chloride, costing $\frac{1}{8}$d. per square yard per application, promised to give good results.

In France calcium chloride has been used for over 30 years, and gives good results where the streets are periodically watered.

In Adelaide the City Council have made several experiments with phenolic, which is a preparation of crude petroleum, and is soluble in water to a considerable degree. The oil is not saponified, as is the case with other soluble oil preparations, but when mixed in the proportion of one of oil and four of water becomes denser, and is apparently of thicker consistency. It is spread on the roads from a centrifugal watervan with perfect ease, and covers splendidly with 1gall. of mixture to five square yards of surface, and costing $\frac{1}{4}$d. per square yard. One application lasts a month under ordinary circumstances and three weeks under heavy traffic. Apart from its dust-laying qualities, it can be applied at any season of the year, and the surface treated does not produce mud in winter, and the life of the road is materially extended. It has been found sufficient for light trafficked roads to give six applications per annum, monthly during January, February, March, April, November, and December; and 10 three-weekly applications on heavy trafficked roads. The behaviour of phenolic on the Adelaide roads seems to bear out Mr. Brodie's conclusions from the results of his experiments in Liverpool. Another good feature is that its use in streets that are watered greatly reduces the tendency of the surface to form ruts and become corduroyed or wavy. These experiments have been in progress during the past three years, and it seems that the so-called dust fiend can be practically abolished—not simply abated—by its use. Two sections of road are now under treatment here. One portion being 7,000 square yards at the east end of South Terrace, a favorite route for motorists; the other of 16,000 square yards in Grote Street west. The former had the last coat a week ago, while Grote Street has not been touched for six weeks, to enable any members of this Congress to witness the next application of the preparation.

In concluding, it is right to point out that this immunity from local—not air-borne—dust can now be assured, but not for nothing; and it seems warranted to remark that if the boon is not worth 1$\frac{1}{2}$d to 2d. per square yard per annum for tar-paving, tar-dressing, or treatment with an oil preparation, then dust will continue; for it is quite certain that it will never be possible to lay dust at a less cost.

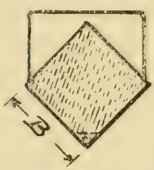
5.—THE RELATIVE STRENGTH OF CERTAIN BEAM SECTIONS.

By EDWARD VINCENT CLARK, B.Sc., Assoc. M. Inst. C.E.

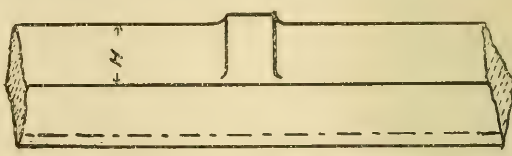
In the course of a paper on "The Theory of Cast-Iron Beams" (Min. Proc. Inst. C.E., vol. CXLIX.) the author pointed out that the calculated modulus of resistance of a beam of square section set with a diagonal vertical, if of cast iron or any other material considerably stronger in compression than in tension, is increased by the removal of metal from the corner under tensile stress up to a certain point; and that under the assumption of a perfectly elastic material the maximum modulus of resistance is reached when about one-eighth of the total depth of the beam has been removed, being 11·34 per cent. greater than the modulus for the full section. In the case of cast iron, whose elasticity is by no means perfect, the precise amount of material to be removed to procure maximum modulus will be slightly different; but by taking the stress-strain curves of cast iron to be parabolic and of the form there determined (*loc. cit.*), and by making certain other assumptions, it was deduced that the maximum modulus of resistance would be reached when about one-tenth of the total depth had been removed, and that it would exceed the modulus of resistance of the full section, calculated upon the same assumptions, by 6·19 per cent.

Ordinarily (*cæteris paribus*) we assume that the strengths of two beams are in the same ratio as their moduli: but that is quite unjustified here. The modulus of a beam's section, under the customary assumption of the independence of the different longitudinal layers of the beam, enables us from the bending moment to determine the (apparent) stress in the outermost layer of the beam's section, all material nearer the neutral axis having less stress. Immediately prior to fracture taking place it is (under the common theory) only the outer layer of material that is strained to breaking point; and not until this outer layer is ruptured and the full load cast upon the remaining section, which being smaller has in general a lower modulus, does the second layer become strained to its limit. Thus fracture of cast iron by bending may be regarded as a process of tearing (though instantaneous to the eye) accompanied by a steady shift of the neutral axis from its initial position to very near the compression side of the beam, as is shown by the fact that the broken face exhibits throughout the clear fracture of tension, with only at the very extreme edge any sign of crushing. But in this particular case of a beam of square section with diagonal vertical, the diminution of section as fracture begins does not lower the modulus, but, on the contrary, raises it; and hence that load which strains the extreme corner to its limit will not strain the next layer so severely after the first is broken, so that an increase of load should be required to complete the fracture of the beam. In other words, on the usual assumption of the independence of the different longitudinal layers of the beam, one may expect that the same load will be required to break the beam of full section as of truncated section; that the former is stronger than its calculated modulus would imply; and that distinctly before it receives its full breaking load it will have its tensile corner cracked down some 10 per cent. of its total depth. If, however, as many consider, the ordinary beam theory is little more than an approximation to the truth in the case of a beam upon the point of fracture, when, owing to mutual lateral support, there is produced to a large extent an equalisation of stress over a great part of the section independent of distance from the neutral axis, then one would certainly expect a greater strength from the beam of full section than from that with part of the section removed. It was therefore considered of interest to make experiments upon such cast-iron beams of full square section and of the truncated section, *i.e.*, with metal removed from the tension corner, in order to ascertain their comparative resisting strengths.

Six specimen bars, 22in. long, were obtained, all cast from the same ladle to ensure as great similarity of constitution as possible. Each was machined all over to approximately $\frac{7}{8}$in. side, about $\frac{1}{8}$in. metal being removed from each face to eliminate errors due to the skin. On each specimen were cast three bearing lugs, about $\frac{1}{2}$in. wide, carefully faced at 45° to the sides of the beam, to take the bearing edges of the testing machine. Then from each of three of the bars the tension corner was machined off to a depth of $\frac{1}{8}$in., being approximately one-tenth of the total depth of the section.



Full section as figure.



Truncated section machined off along dotted line.

The specimens were finally broken in a hydraulic testing machine, with the results shown by the following table :—

TABLE I.—FULL-LENGTH BARS (19·9IN. SPAN).

Type of Section.	Bar No.	Side B.	Semi-depth H.	Breaking Load.	Remarks.
		Inch.	Inch.	lbs.	
Full section	1	·882	·624	1,120	Greatest variation from mean (corrected for size), 2½ per cent.
	2	·879	·622	1,075	
	3	·876	·620	1,055	
	mean	·879	·622	1,083	
Truncated section ..	4	·880	·623	1,095	Greatest variation from mean (corrected for size), 3 per cent.
	5	·879	·622	1,105	
	6	·878	·621	1,140	
	mean	·879	·622	1,113	

Mean strength of full sectioned bar, 1,083lbs. Of truncated section, 1,113lbs., *i.e.*, 2·8 per cent. higher than the full section.

This table gives a slightly greater strength for the bar of truncated section than for that of full section—2·8 per cent. higher. But the variations of the individual beams of the same type, from their mean being of about the same magnitude as this, one naturally has doubts as to the value of this result. To get further evidence upon the matter, the broken halves of these beams were again fractured in the testing machine. In this case small vee blocks were placed between the jaws of the testing machine and the test bars to obtain a good distribution of pressure and prevent crushing of the corners. One month elapsed between the first and second sets of tests, so that on the second occasion the bars should have recovered from any temporary state of strain set up in the first tests. Tables II. and III. give the figures of the experiments upon the shorter bars tested on 10in. and 8½in. span.

TABLE II.—HALF-LENGTH BARS (10IN. SPAN).

Type of Section.	Bar No.	Side B.*	Semi-depth H.*	Breaking Load.	Remarks.
		Inch.	Inch.	lbs.	
Full section	1	·880	·623	2,200	Greatest variation from mean (corrected for size), 1 per cent.
	2	·877	·620	2,160	
	3	·877	·620	2,140	
	mean	·878	·621	2,167	
Truncated Section ..	4	·879	·622	2,340	Greatest variation from mean, 5½ per cent.
	5	·879	·622	2,105	
	6	·880	·623	2,205	
	mean	·879	·622	2,217	

* Each bar was measured at the point of fracture, and hence the dimensions B and H differ slightly for the same bar in different tests.

Mean strength of full sectioned bar, 2,167lbs. Of truncated section, 2,217lbs. actual, or 2,205lbs. corrected for size of bar, *i.e.*, 1·8 per cent. higher than the full section.

TABLE III.—HALF-LENGTH BARS (8½IN. SPAN).

Type of Section.	Bar No.	Side B.	Semi-depth H.	Breaking Load.	Remarks
		Inch.	Inch.	lbs.	
Full section	1	·879	·622	2,560	Greatest variation from mean (corrected for size), 2½ per cent.
	2	·877	·620	2,580	
	3	·880	·623	2,490	
	mean	·879	·622	2,543	
Truncated section ..	4	·879	·622	2,635	Greatest variation from mean, 4 per cent.
	5	·879	·622	2,675	
	6	·879	·622	2,815	
	mean	·879	·622	2,708	

Mean strength of full sectioned bar, 2,543lbs. Of truncated section, 2,708lbs., *i.e.*, 6·5 per cent. higher.

In each set of experiments, then, we find that the truncated section is on the average rather stronger than the full section, the increase being 2·8 per cent., 1·8 per cent., and 6·5 per cent. in the three cases, or 3·7 per cent. as the average of all experiments ; and hence we may take it that the removal of a little metal from the tension corner of a beam of square section set with a diagonal vertical will actually increase the strength of the beam by a small percentage.

Although this disagrees with the abstract argument of the earlier part of this paper, yet further consideration shows that it is only to be expected if one brings into account the fact that the material of the beam is not absolutely homogeneous in texture, while still regarding each layer as acting independently of those adjacent to it. For it is to be noticed that while the strength of a beam depends upon its modulus of section, yet its deflection depends upon the product of the modulus and the distance "h" from the neutral axis to the outer edge of the section, *i.e.*, upon the moment of inertia of the section ; and although the modulus in this type of beam increases on truncating the section, yet the moment of inertia is diminished, so that the truncated beam will deflect more than that of full section. Hence, on testing a beam of full se tion to destruction, as soon as the outer layers break the deflection must be increased, even though the load is not enough to complete fracture. Were the material perfectly homogeneous, so that every particle had an identical breaking point, then, as the load approached the critical point, the material would break in such infinitesimally thin layers that the increase of deflection would be perfectly gradual, the load coming on to the remaining section without shock ; but the metal not being quite homogeneous is bound to break across a layer of appreciable thickness, causing a sudden increase of deflection, and thereby transferring the load to the remaining section with a jerk, which may overcome its modulus of resistance, although a static load of the same amount could have been carried in safety. And, further, when the outer layer becomes stressed beyond its limit and fails, it will break at one point only in the form of a minute crack, causing a spot of local concentration of stress, and thereby reducing the strength of the sound section underneath ; just as from this cause a beam has its strength more affected by a narrow saw cut being made on its surface than by having the whole of its surface removed to an equal depth.

The above experiments were carried out at University College, London, by the courtesy of Professor J. D. Cormack, to whom the author's best thanks are due for permission to make use of the testing apparatus in the Engineering laboratory of that institution.

6.—BENDING STRESSES IN WIRE ROPES.

By R. W. CHAPMAN, M.A., B.C.E.

7.—ARTESIAN WATER SUPPLY IN SOUTH AUSTRALIA.

By S. SMEATON, B.A.

Section I.

SANITARY SCIENCE AND HYGIENE.

1.—SOME NOTES ON THE BIOLOGICAL TREATMENT OF SEWAGE, WITH SPECIAL REFERENCE TO THE WORKING OF SEVERAL INSTALLATIONS AT NORTH SYDNEY.

By EDWARD S. STOKES, M.B., Ch.M., D.P.H., Medical Officer and Bacteriologist to the Metropolitan Board of Water Supply and Sewerage, Sydney, New South Wales.

[WITH PLATE.]

The treatment of sewage has now become an ever-present problem with us in this continent, and in the future it will with certainty call for determination with increasing emphasis. Obviously the reasons for this are intimately connected with the growth of our towns and cities, with the concomitant advance of ideas embraced in the progressive civilisation of the age, and with the more widely spread recognition of the truth of the hygienic principle that accumulation of refuse and waste-products in and around our dwellings make for disease and disaster.

That the solution of the problem is beset with difficulties must be evident to everyone who dwells seriously upon it ; but in this connection it is interesting to note that it is not uncommon to encounter individuals who, although they should know better, will readily settle the point by advising everyone requiring information to go and build a septic tank and the microbes will do the rest.

The history of sewage treatment is full of interest, as exemplifying the peculiar complexity of the subject. Whilst it would be beyond the scope of this communication to traverse the past, I might be permitted to state that during the past 50 years in England commissions dealing directly and indirectly with inquiries into the treatment of sewage have been sitting for more than 25 of such years, and that at the present time the latest Commission, appointed in 1898, is still in existence—full of vigor, and with no indication of the advance of old age. The significance of these facts is apparent.

Although the last word on the subject is still far ahead of us, yet we may consider we have reached a point at which we can venture, without being dogmatic, to present certain soundly established principles underlying the biological treatment of sewage.

The first and essential tenet of the belief to which we subscribe is that sewage contains elements capable of effecting its reduction to innocuous matter.

The other articles are subsidiary to and included in the above, and outline the stages in the purifying process. It has been shown that during the first stage there is a breaking up of complex organic molecules with solution of solid matter, and that during the second there is more or less oxidation of the nitrogen, carbon, and hydrogen previously existing in organic combination. The two stages are distinct, and the second cannot be accomplished without the completion of the first.

I propose to consider the practical application of these principles as illustrated by the results of the experience we have gathered from the working of several installations in Sydney, in which the sewage is treated on purely biological lines. Before, however, discussing any details I wish most emphatically to draw attention to one point that I hold can and should never be forgotten, namely, that while the above principles hold good under a wide variety of circumstances, the methods of their application must be varied to suit the peculiar requirements of the different sewages calling for treatment. These requisites are incapable of definition, and, further, cannot be decided by any at present known test or series of tests. They can only be determined by experience gained at outfall works, so that in fact each installation must be regarded to some extent as an experiment, in which various forces are manipulated and directed from time to time as the demand arises.

As part of the metropolitan system of sewerage in Sydney there have been constructed three biological installations, each serving a separate but neighboring locality, and each dealing with ordinary domestic sewage. Since November, 1905, regular monthly analyses of samples collected under strict conditions have been carried out. The results contain some points of interest. and appear to me worthy of record.

NORTH SYDNEY OUTFALL WORKS.

The works are situated at the head of Willoughby Bay, near Folly Point in Middle Harbor. They were constructed by the Department of Public Works and handed over to the Board in 1898. Originally they were designed for treating sewage by lime-precipitation, and were fully equipped with the necessary machinery for sludge-pressing. In 1901 the Board decided to alter the system by converting the precipitation tanks into open septic tanks. In 1905 the tanks were provided with substantial covers. No change was made in the use of the filter beds below described.

The installation consists of (1) two silt pits through which sewage is run alternately to facilitate the operations incidental to removing the deposited matter; (2) a series of eight covered tanks, each 119ft. long by 23ft. wide, of an average depth of 5ft. 6in. (inlet end 6ft. 10in. in centre, 5ft. at sides; outlet end, 5ft. 4in. in centre and 3ft. 10in. at sides), and of an approximate capacity of 94,000galls.; and (3) an area of about eight acres of sand, 5ft. to 6ft. deep, subdivided by low dykes into eight filter beds. The beds are structurally continuous (*i.e.*, there are no partition walls between them) and are emptied by a series of effluent drains.

The population served is nearly 30,000, and the daily average flow is about 750,000galls. in dry weather.

Stormwater is dealt with as follows:—Until the flow becomes about three times the maximum normal daily flow, it is all run through the tanks. Then, when quantities above this amount come down, an overflow from the main carrier operates automatically, and the dilute sewage is conducted on to one of the filter beds, which is kept almost entirely for use as a stormwater filter. In the event of these arrangements proving insufficient the excess runs over the end of the carrier into a large concrete stormwater channel provided to carry off the stormwater from Willoughby Falls Creek. Exact figures are not available, but it is obvious that the sewage must be enormously diluted when on rare occasions it reaches the harbor untreated.

Provision is made for screening the sewage by means of grids at the inlet chamber. The grids are constructed with iron bars 1in. apart. These are not used in ordinary dry weather flows, but are placed in position so as to arrest floating matter brought down by any rise in the flow, and thus assist in preventing buoyant solids from reaching the harbor in times of heavy rain.

If the whole of the tanks were in operation at one time there would be sufficient tank space available to permit of the dry weather flow remaining therein for 24 hours, but if a deduction be made for an approximate average of 2ft. of scum over all tanks, this time would be reduced to 15 or 16 hours. As a matter of fact, however, for the last four months only three tanks have been in operation, so that the actual time the sewage is in the tank is less than six hours.

The scum formation in these tanks is, and has been, of particular interest. Before the tanks were covered the scum was of such thickness and strength in parts that persons could walk on it. The surface became dry and hard, and supported a luxuriant growth of self-sown grasses and vegetables, and undoubtedly caused such obstruction in the tanks as to interfere seriously with their working. It was thought that by covering the tanks the scum would be prevented from drying and that liquefaction would be favored. The scum was, as it is now, by far the thickest at the inlet ends of the tanks.

The table given below, kindly compiled by Mr. Cook from his notes, shows the changes that have taken place in the thickness of the scum at both the inlet and outlet ends of individual tanks during the 12 months under consideration. In addition, the tanks that were in use during the several months are indicated by an asterisk placed below the figures for the month. The thickness was estimated by thrusting a graduated pole into the scum to such a depth that on withdrawal the liquid beneath was seen or heard rising through the resultant hole. As a supplementary guide the disappearance of resistance to the passage of the pole was of some service. For several reasons the measurements given can only be considered as approximately representing the thickness of the scum. In the first place, there is no very hard and sharp line of demarcation between the scum and the liquid contents of the tanks. Although the upper layer of the scum is firm—but not dry,

TABLE I.—*North Sydney Outfall Works—Table showing*

Number of Tank.	November, 1905.		December, 1905.		January, 1906.		February, 1906.		March, 1906.	
	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.
	' "	"	' "	"	' "	"	' "	"	' "	"
1	6 0	3	3 9	6	5 0	1	3 10	1	3 1 *	0½ *
2	4 3 *	3 *	7 6	6	5 3	1	5 3	1	3 10	1
3	4 3 *	F *	7 6	6	5 5	1	5 3	0½	3 10	0½
4	2 0 *	F *	2 11 *	0½ *	3 3 *	1 *	3 0 *	2 *	3 9 *	2 *
5	3 0 *	F *	4 10 *	4½ *	4 7 *	2 *	4 3 *	4 *	3 7 *	5 *
6	2 3 *	F *	4 4 *	0½ *	4 8 *	2½ *	5 4 *	3 *	3 11 *	3 *
7	1 4 *	F *	3 8 *	2½ *	3 11 *	4½ *	4 6	3	2 11	1
8	2 3 *	2 *	4 0 *	5½ *	4 9 *	9 *	4 2	10	3 9	11

NOTE.—At the end of June all eight tanks

F=Small particle of flocculent matter—no continuous scum.

as was the case when the tanks were open—the lower parts are very soft and sludgy, so that on withdrawing the measuring pole the opening closes below by collapse of its sides, and no liquid is observed arising therein. In the second place the scum does not present an even upper surface. Bulgings and upheavals occur with corresponding valleys and depressions. Consequently it may happen that varying readings are secured from the one point at different periods, without any material alteration in the average thickness of the scum. Despite these disabilities I think the figures given below may be taken as a comparable series, and as fairly representing what they claim. The observations were made by Mr. Cook personally (and checked on the spot by Mr. T. Griffiths, Superintendent Engineer for Sewerage), with a full appreciation of the above-mentioned possible sources of error.

Thickness of Scum in the several Tanks for Each Month.

April, 1906.		May, 1906.		June, 1906.		July, 1906.		August, 1906.		September 1906.		October, 1906.		Remarks.
At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet.	At Inlet.	At Outlet	
' "	"	' "	"	' "	"	' "	"	' "	' "	' "	' "	' "	' "	Filled.
3 2*	2*	4 6*	5*	2 9*	5*	3 6*	9*	2 8*	1 3*	3 2*	1 5*	3 6*	1 10*	10-5-05
3 7*	1*	3 6*	1½*	2 7*	4*	3 8*	4*	4 0*	0 8*	4 0*	1 2*	3 0*	1 3*	16-5-05
3 2*	0½*	3 10*	2½*	2 8*	3*	4 4*	3*	3 8*	0 5*	3 3*	0 8*	3 9*	1 0*	24-5-05
3 [illegible]*	1*	3 10*	3*	2 6*	3*	3 4	3	3 4	0 3	3 1	0 1	2 3	0 1	3-6-05
3 2	6	3 0	3	2 8	1	4 3	1	2 9	0 1	2 10	0 1	2 3	0 0½	17-6-05
4 0	4	3 1	1	3 4	F	4 6	0½	4 3	F	3 9	0 0¼	3 9	0 0¼	6 7-05
2 9	0½	3 4	0½	2 10	F	4 6	0½	2 10	F	3 4	0 0½	3 7	0 0½	26-7-05
3 5	8	3 2	7½	3 0	4	4 5	4	4 0	0 3	3 5	0 2	2 6	0 4	2-8-05

were run for five days during heavy rain.

* Denotes that the tank was in use during the month.

It will be seen that the tanks were used in combination as follows :—

TABLE II.

Tank—	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	Total.
1905.									
November	0	1	1	1	1	1	1	1	7
December	0	0	0	1	1	1	1	1	5
1906.									
January	0	0	0	1	1	1	1	1	5
February	0	0	0	1	1	1	0	0	3
March	1	0	0	1	1	1	0	0	4
April	1	1	1	1	0	0	0	0	4
May	1	1	1	1	0	0	0	0	4
June	1	1	1	1	0	0	0	0	4
July	1	1	1	0	0	0	0	0	3
August	1	1	1	0	0	0	0	0	3
September	1	1	1	0	0	0	0	0	3
October	1	1	1	0	0	0	0	0	3

1 = Tank in operation. 0 = Tank idle.

Tank No. 1—which was idle from November until March—presented 6ft. of scum at the inlet in the first-named month, and a few inches at the outlet, which means that the tank space was almost occluded at the inlet. This amount gradually lessened, until in March it stood at about 3ft. After being used for five months in combination with three or four other tanks, the scum was but a few inches thick distributed in practically the same ratio. For the last four months it was worked with only two other tanks (Nos. 2 and 3), and while the scum at the inlet remained about the same that at the outlet more than doubled.

Tanks Nos. 2 and 3 were thrown out in December, when there was 7ft. 6in. of scum at the inlet—practically solidified to the bottom—and remained so until April, when about half the solids had liquefied. For the next three months they were worked in combination with two other tanks, and at the end of the time they showed a diminished thickness. Since then they were used with No. 1, as already mentioned, and present an increase most marked, as in the case with No. 1, at the outlet.

These three tanks have this in common, that at their respective inlets the scum at one time accumulated to a much greater extent than in any of the others. This is probably due to their situation with regard to the main carrier. Being the first tanks to which the sewage has access, it appears reasonable to assume that they receive a larger proportion of the suspended matter than the others.

After working for the first eight months and resting for the remaining four, No. 4 tank contained about the same thickness of scum as it did at first.

Tanks Nos. 5 and 6 were idle for seven months, and Nos. 7 and 8 for nine months respectively. There is a marked tendency towards a thinning down of the scum except in No. 7, where an increase is recorded. This, however, may be due to one of the possible errors of observation mentioned above. A gradual reduction occurred up to June, but the next month the rise referred to below took place. Since then solvent action has again progressed.

A curious phenomenon is revealed by the records of July, where an all-round increase is observed. At the end of June for five days during heavy rain all the tanks were used, and undoubtedly the increment must be due to this: it could not be an accidental coincidence.

The conclusions that present themselves from a consideration of the above history are these:—

1. That with a slow flow through the tanks there is a tendency to heavy scum formation at the inlet end and very little at the outlet.

2. That in resting a tank containing scum the scum shows a gradual but irregular disposition to become thinner.

3. That with the most rapid flow so far employed (less than six hours through the tanks) the scum not only shows no tendency to excessive accumulation at the inlet, but, on the other hand, is more evenly distributed over the whole surface of the tank contents.

These conclusions, it is hardly necessary to state, cannot be held to be established from the above experiences as applicable to all sewages in all biological installations. They may be so, but, as far as we can say here, they are only true for the conditions under which they were observed.

I shall show later in what way purification of the sewage was effected by the changes made in working the tanks.

The tanks have been twice cleaned out to make alterations. On neither occasion was there any accumulation of silt of importance.

In the filter beds the second stage of purification is effected by a process which is in reality one of the classical varieties of land-treatment, viz., "intermittent downward filtration." The beds are worked, if not to their utmost, at all events constantly, and cultivation is not attempted.

Seven out of the eight filter beds are in constant use, the eighth being kept in reserve—as already mentioned—for stormwater and other emergencies. Each bed is used in rotation, and receives a day's flow once a week. The tank effluent is run over the surface from the main carrier until the whole is submerged several inches. The length of time that elapses before the liquid disappears varies from a few hours to several days, according to the looseness or otherwise of the surface soil and to existing meteorological conditions. From time to time the beds are subsoil ploughed, and this operation permits the effluent to sink from sight in a few hours. As the beds become consolidated and clogged from use, the time extends to as much as two and a half days. In times of rain, of course, percolation and evaporation are much retarded. As soon as a bed is dry enough to permit it, harrowing operations are commenced and the upper few inches turned over.

TABLE III.—*North Sydney Outfall Works.*

	Raw Sewage.								Tank Effluent.								Final Effluent.								Remarks.
	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.	Tanks in operation.
1905. November	81·2	10·8	5·76	1·23	·00	·00	1·26	3·94	52·2	11·6	5·86	1·12	·00	·00	1·47	3·98	43·8	11·6	2·83	·122	*	1·20	·13	·51	7
December	65·0	10·4	5·60	1·68	·00	·00	1·50	5·00	55·0	10·0	4·84	·83	·00	·00	1·20	3·20	51·0	9·6	3·15	·193	*	·50	·21	·73	5
1906. January	47·6	9·6	4·14	1·36	·00	·00	3·16	4·34	59·4	10·4	5·10	1·17	·00	·00	1·.2	3·63	57·0	10·0	2·90	·225	*	2·40	·31	1·33	5
February..............	54·6	10·0	4·83	1·63	·00	·00	1·33	4·36	58·0	10·0	5·66	·94	·00	·00	1·27	3·76	52·8	9·4	2·36	·192	*	·76	·19	·71	3
March	51·4	9·6	4·95	1·43	·00	·00	1·27	4·21	56·8	10·2	6·04	1·15	·00	·00	1·15	3·55	57·6	10·0	2·58	·180	*	·97	·13	·38	4
April..........	69·8	9·8	4·78	1·40	·00	·00	1·36	4·07	53·4	9·6	5·66	1·01	·00	·00	1·10	2·74	59·2	10·2	2·68	·120	·16	·37	·14	·56	4
May	88·4	11·0	5·27	2·20	·00	·00	1·52	4·89	55·4	10·6	7·40	1·13	·00	·00	1·04	2·33	61·0	10·6	2·29	·102	·01	·18	·11	·42	4
June	56·4	10·2	4·35	1·08	·00	·00	·83	2·32	57·6	11·0	5·50	·98	·00	·00	·77	1·82	60·0	10·0	2·16	·092	·02	·84	·09	·45	†4
July	60·2	11·0	5·61	1·78	·00	·00	1·17	3·39	61·6	11·6	6·29	1·47	·00	·00	1·05	2·29	58·8	11·0	2·91	·155	·03	·21	·10	·60	3
August...	59·2	11·0	5·82	1·96	·06	·00	1·46	4·41	61·8	12·4	6·66	1·41	·00	·00	1·23	3·62	63·4	11·2	3·25	·222	·02	·81	·17	·59	3
September	46·2	10·8	4·13	1·18	·00	·00	1·03	3·06	53·0	11·0	4·68	1·06	·00	·00	·91	2·61	62·6	10·4	2·74	·077	·01	·99	·13	·57	3
October	57·0	11·0	4·61	1·19	·00	·00	·98	2·84	51·8	11·6	4·73	·90	·00	·00	·88	2·60	46·8	10·4	2·23	·067	·01	1·72	·12	·49	3
Average	61·4	10·4	4·99	1·51	·00	·00	1·41	3·90	56·3	10·8	5·70	1·10	·00	·00	1·10	3·01	56·2	10·4	2·67	·150	·04	·91	·15	·63	

NOTE.—Parts by weight per 100,000. * Small quantities not estimated. † Heavy rain during sampling.

Once a month samples of the raw sewage, tank and final effluents, are collected and submitted for analysis. The samples are gathered over a period of 48 hours in order to ensure fair average specimens of the daily flow. In the table on the preceding page I have set out the results of these analyses.

The figures show a marked uniformity from month to month, which indicates that the system of sampling adopted can be depended upon to give, if not absolute, at all events comparable results. It will be observed that after the sewage has passed through the tanks there is a slight increase in the free ammonia and a decrease of about one-quarter in the figures for organic matter. Oxidized nitrogen is entirely absent. After treatment in the filter beds nearly nine-tenths of the organic matter disappears, free ammonia diminishes by one-half, and a fair amount of oxidized nitrogen is found. The final effluents were, as a rule, clear (rarely slightly turbid), bright, and free from any smell, and withstood the incubator test (see post.).

It will be seen from the table that in January the final effluent contained organic matter much above the average. Up to this time five or more tanks were being worked. This number was then reduced to four, and coincidently the organic matter showed a steady decline from month to month until June, when one tank was cut out. An immediate rise was observed lasting for the next two months, and followed by a fall to a point below any reached previously during the series. Now, for the last four months three tanks only were employed, and the final effluents obtained of a high grade. We may conclude from this that, in dealing with this sewage, as high-class effluents can be secured after a short passage through the tanks as after a more prolonged sojourn.

In order to present the matter in a manner that does not involve columns of decimals, I have constructed the following table, which gives the percentage reduction of the figures for albuminoid ammonia and oxygen absorbed from permanganate in four hours in both the tank and final effluents, and also the sum of these which is the total purification effected by the installation. I have further given in a separate column the percentage reduction of total organic matter. This I have calculated by expressing the difference between the sum of the albuminoid ammonia and oxygen absorbed figures in the final effluent, and the sum of the same constituents in the raw sewage as a percentage of the latter. This is, of course, empirical, but it has a practical application.

On an average roughly about one-third of the total reduction occurs in the tanks and the remainder in the filters. In the tank the loss of organic nitrogen is slightly in excess of that observed for organic carbon. It may further be observed in this connection that even though the loss of organic matter in the tank, as indicated by the chemical tests applied, be small (cf. records for November, June September, and October *supra*), still the tank effluent shows that it is in a condition suitable for the second stage of purification by its response to treatment by the filters.

TABLE IV.—*Table showing Percentage Reduction in Organic Matter Effected in Tanks and Filters, Separately and Combined.*

NORTH SYDNEY OUTFALL.

	Tank Effluent.		Final Effluent.		Total.		Total Reduction of Organic Matter.
	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	
1905.							
November .	9	0	81	87	90	87	88
December . .	51	36	38	49	89	85	86
1906.							
January . . .	14	27	70	43	84	70	75
February . .	43	16	45	68	88	84	85
March	20	23	67	63	87	86	87
April	28	33	63	53	91	86	88
May	49	52	46	40	95	92	93
June	9	20	82	61	91	81	84
July	27	33	64	56	91	89	86
August	28	18	61	69	89	87	87
September .	7	15	86	67	93	82	85
October . . .	2	7	92	76	94	83	86
Averages	27	23	63	61	90	84	86

CHATSWOOD OUTFALL WORKS.

The scheme was taken over by the Board in February, 1902, after the Department of Public Works had conducted the same for about six months. Up to that time tanks Nos. 1 and 2 had only been used for sewage, but No. 3 had been filled with city water, and a few water hyacinths were growing feebly in one corner of it. In May, 1902, some of this water was run out and sewage turned in to fill the tank. Hyacinths began to thrive at once, and in two months had completely covered the surface of the tank. In September, 1902, as the scum was not forming on tanks Nos. 1 and 2, it was decided to place some hyacinths in them, and in a month the tanks were covered with the growth.

The installation consists of three open tanks and four contact filters; in addition a small silt bed is in existence, but up to the present it has not been found necessary to use it, because the sewage is found to carry but little detritus. By means of a flume the sewage is conducted across this pit into the main carrier which feeds the three tanks. The tanks are provided with submerged inlets and outlets, so arranged that the entrance and discharge is 4ft. below the surface. Each tank is 41ft. 9in. wide by 70ft. long by 6ft. 8in. deep, and contains approximately 120,000galls. A collecting channel at outlet end of tanks receives the tank effluent, which is conveyed from this point by means of an iron flume to the automatic gear regulating the distribution on to the filter beds. Each filter bed is 64ft. long, 39ft. 3in. wide, and 4ft.

2in. deep, and is composed from below upwards of 10in. of broken stone, 24in. of coke breeze, and 6in. of bluestone shivers. The effluent drains are of open-jointed brickwork. The automatic gear abovementioned is of special design, constructed by the Public Works Department, and is actuated by filling and emptying of floating buckets. The arrangement has proved very efficient. The final effluent passes into Sugarloaf Bay, an arm of Middle Harbor. The tank effluent is discharged on to each filter bed in rotation by means of a system of open surface drains. The main drain conducts the effluent into a number of branch box drains or open channels formed in the surface of the bed. In the case of the box drains the effluent flows over the sides and sinks through the material of the beds. With the open channels, however, it filters directly through the bottom and sides of the same.

The number of persons served with this installation is at present 4,230, and the daily flow is estimated at about 100,000galls.

On an average only one tank was in use at one time during the year, and it is calculated from this that the sewage occupied about 30 hours in passing through the same. The general method of working the tanks will be gathered from the table given below.

TABLE V.—*Table showing which Tank was in Operation at the Time of Taking the Monthly Sample, and also the Number of Days each Tank was in Operation.*

CHATSWOOD OUTFALL.

	No. of Tank in Operation at Time of Sampling.	Number of Days each Tank Worked during Periods between Sampling.		
		Tank No. 1.	Tank No. 2.	Tank No. 3.
1905.				
November	2	7 days	17 days	7 days
December	3	15 "	14 "	7 "
1906.				
January	2 & 3	7 "	14 "	12 "
February	1	10 "	19 "	17 "
March	3	17 "	6 "	11 "
April	3	12 "	4 "	5 "
May	1	5 "	14 "	9 "
June	2	9 "	7 "	14 "
July	1	10 "	16 "	0 "
August	2	9 "	3 "	23 "
September	1	16 "	18 "	2 "
October	2	7 "	7 "	14 "
Total	....	124 days	139 days	121 days

NOTE.—The total number of days worked by tanks is slightly in excess of the actual number of days in the period covered by this report. This is due to the fact that occasionally two tanks were used in combination for a few days at a time.

The filters pass through the stages of filling, standing full, emptying, and standing empty, the time for each stage depending upon the rate of flow. The periods, of course, do not coincide in the different beds. Mr. Cook has represented the working of the filters diagrammatically, and has kindly permitted me to make use of a copy of his drawing, which is attached. The diagram is very clear, and conveys more than could be told in columns of writing.

The scheme was designed to treat sewage on the separate system, and as far as possible stormwater is prevented from entering the reticulation; but despite precautions it is found that during heavy rain a considerable volume of excess water reaches the outflow, and that after rain the flow is still maintained above the average for some time owing to the entrance of subsoil water into the sewers. On account of the large tank space at present available, several times the normal flow can be run through the tanks; but in very excessive storms the flume leading to the main carrier overflows, and the many-times-diluted sewage flows past the tanks and filters into the watercourse, where a further dilution occurs by the water which naturally collects in this part. No screening of any kind is carried out. About one-fifth of the area of each tank is covered with floating scum of an average depth of from 7in. to 8in., the remaining four-fifths being covered with a close mass of water hyacinths.

In February, 1896, that is about four years after the works were first placed in operation, it was found that silt had accumulated in the bottom of the tanks to an average depth of 10in., and up to this time no attempt had been made to remove it. In addition to the silt the tanks contained a considerable amount of fine suspended matter, which might be considered as the accumulated residue of organic matter incapable of undergoing further resolution in the tanks. This matter was carried by the natural flow into the filter beds and appeared in the final effluents, giving rise to slight turbidity. For this reason it was considered advisable to attempt to remove this residue, and the work was carried out during heavy rains by permitting the flow to scour through the tanks and carry out as much as possible. The operation was repeated several times during the winter rains, with the result that in October, 1906, the average depth of the deposit had been reduced to about 6in., and a diminished amount of suspended matter was observed in the tank effluent.

In the following table the results of the analysis for 12 months are set out. It will be seen that, speaking generally, the sewage is of the same character as that seen at the North Sydney outfall, the slightly lower figures for organic matter in the average being probably due to the effect of heavy rain on the three occasions of sampling. It will be noted that a far greater loss of organic nitrogen occurs in the tanks than in North Sydney; but it will be further observed that the total percentage purification is not so great as at the latter place. The effect of dilution of the sewage by subsoil water is well shown in the analyses of June, September, and October, where it will be seen that the sewage contained a very appreciable amount of oxidised nitrogen. The comparatively high figures for albuminoid ammonia in the final effluents may possibly be due to the washing through of the suspended matter from the tanks mentioned above.

TABLE VI.—*Chatswood Outfall Works.*

Raw Sewage.

	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.
1905. November	48·4	12·3	3·27	1·42	·00	·00	·92	3·22
December	51·2	13·6	3·43	1·16	·00	·00	·83	2·83
1906. January	66·6	13·6	3·14	1·49	·00	·00	1·17	3·84
February.........	50·2	10·8	3·28	1·34	·00	·00	1·09	2·79
March †	58·4	17·2	3·65	1·19	·00	·00	1·00	3·01
April †	60·4	13·6	4·72	1·85	·00	·00	1·24	3·41
May	51·4	11·4	4·52	1·40	·00	·00	1·00	2·23
June ‡	36·0	11·2	·93	·52	·03	·78	·30	·71
July	81·6	13·6	3·87	1·99	·00	·00	·97	2·90
August............	69·8	12·6	4·71	1·31	·00	·00	·96	2·54
September § ...	39·8	11·6	1·65	·54	·13	·04	·29	·82
October §	46·2	11·6	1·26	·61	·03	·14	·44	1·52
Average ...	55·0	12·8	3·22	1·23	—	—	·85	2·48

Tank Effluent.

	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.
1905. November	46·2	13·0	7·25	·53	·00	·00	·66	2·15
December	46·4	13·0	4·67	·55	·00	·00	·62	1·90
1906. January	44·8	13·2	4·11	·51	·00	·00	·61	1·75
February.........	35·2	12·2	4·79	·67	·00	·00	1·24	4·10
March †	44·2	10·0	3·91	·55	·00	·00	·65	2·10
April †	41·6	9·0	4·12	·60	·00	·00	·67	2·13
May	37·2	12·0	5·56	·55	·00	·00	·69	1·77
June ‡	40·0	11·6	1·24	·18	·01	·76	·13	·40
July	58·0	15·4	5·31	·88	·00	·00	·59	1·80
August............	42·8	11·3	4·58	·62	·00	·00	·62	1·11
September § ...	38·4	11·8	1·39	·47	·04	·44	21	1·01
October §	54·2	11·0	·80	·38	·03	·14	·59	2·06
Average ...	44·1	12·0	3·98	·54	—	—	·61	1·86

Final Effluent.

	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.
1905. November	41·2	13·0	3·81	195	*	·80	·21	1·45
December	37·8	12·8	2·25	·127	*	·82	·25	·59
1906. January	38·0	12·4	1·92	·190	*	1·16	·15	·52
February.........	38·8	12·2	1·83	·285	*	·45	·28	1·03
March †	33·6	10·0	1·86	·247	*	1·32	·19	1·53
April †	36·8	9·6	2·37	·210	·02	·49	·26	·83
May	39·4	12·4	3·06	·250	·04	·33	·34	·91
June ‡	36·4	11·8	·82	·255	·03	·38	·13	·48
July	38·0	14·2	2·05	·255	·01	·32	·16	·59
August............	36·2	11·3	2·92	·212	·01	·60	·15	·29
September § ...	38·6	11·4	·80	·107	·01	1·07	·08	·35
October §	39·6	11·3	·51	·080	·02	1·32	·06	·38
Average ...	37·0	11·9	2·02	·201	·02	·74	·19	·75

NOTE.—Parts by weight per 100,000. * Small quantities not estimated. † Heavy rain fell between sampling of raw sewage and effluents.
‡ Heavy rain during sampling. § Heavy rain before sampling.

In Table VII. below, the reduction of organic matter in the tanks and filters respectively is shown. The higher reduction of organic nitrogen effected in the tanks as compared with similar figures for North Sydney is worthy of notice.

TABLE VII.—*Table showing Percentage Reduction in Organic Matter Effected in Tanks and Filters, Separately and Combined.*

CHATSWOOD OUTFALL WORKS.

	Tank Effluent.		Final Effluent.		Total.		Total Reduction of Organic Matter.
	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	
1905.							
November.	63	33	23	22	86	55	63
December.	53	33	36	46	89	79	82
1906.							
January ..	66	55	21	32	87	87	87
February..	50	—	29	64	79	64	68
March	54	30	25	20	79	50	58
April	68	38	21	38	89	76	80
May	61	20	21	39	82	59	68
June......	—	—	—	—	50	33	40
July	56	38	31	42	87	80	83
August....	53	56	31	33	84	89	87
September.	13	—	67	58	80	58	66
October...	38	—	49	75	87	75	79
Averages	56	25	28	45	84	70	75

In December, 1906, an opportunity occurred for examining some of the coke from No. 4 filter bed. Two samples were secured, one (No. 1) from the neighborhood of the distributing gear, and the other (No. 2) from a point as remote as possible from this. The samples were washed, and a certain amount of fine floating matter—termed the residue in the table below—separated off. The larger pieces were picked out by hand and forceps. Originally the coke was, I am informed, supposed to have been carefully graded to $\frac{3}{4}$in. gauge. The term " large coke " is applied to masses from about three millimetres in diameter upward. Probably it would average about two centimetres. The " fine coke dust " was from three millimetres downwards, and would average less than one. The " residue " consisted of a brown peaty pulverent matter which contained a small amount of organic nitrogen and some very minute particles of coke dust. After separation the different portions were dried down at 100° C., and the moisture estimated by difference. The total amount taken in each case was 100 grammes.

TABLE VIII.

	Sample 1.	Sample 2.
	Grammes.	Grammes.
Large coke	50.85	55.70
Fine coke dust	10.7	4.40
Residue	6.0*	3.30
Water	32.45	36.60
	100.00	100.00

* Including ·027 grammes of organic nitrogen.

Expressing the quantities as percentages of the total dried matter we have :—

TABLE IX.

	Sample 1.	Sample 2.
Large coke	74.90	87.85
Fine coke dust	16.08	6.94
Residue	9.02	5.21
	100.00	100.00

The difference between the two samples is probably due to the position from where they were taken. Where No. 1 was situated the bed would be walked on and raked over more than at the other point. On the whole, however, it will be seen that considerable degradation of the coke had occurred.

BALMORAL OUTFALL WORKS.

These works are the most recent of the three under consideration. They were constructed by the Public Works Department and handed over to the board in July, 1904. Previous to this the department had conducted the working of the installation for a few months, but during this time there was practically no sewage coming in.

The outfall is situated on the north-west shore of Middle Head, and discharges into Middle Harbor. The installation comprises a small silt bed, four covered tanks, each 28ft. 6in. wide, 68ft. 6in. long, and 6ft. 2in. deep, and containing 75,000galls. The filters are eight in number, each 32ft. wide, 68ft. long, and 4ft. deep, and are constructed of destructor breeze about 3ft. 2in. deep covered with 10in.

of bluestone shivers, and provided with suitable under-drains. The filling and emptying of filters is automatically controlled by means of the Cameron-Martin alternating gear of the latest type. The number of persons served by these works is about 1,500, and the average daily flow is approximately 35,000galls. to 40,000galls. The system is designed to receive domestic sewage only; but, as at Chatswood, it is found that the flow is affected by rains. At the silt pit there is an overflow, by which any quantity may be diverted from the tanks, the amount being regulated by the height of a stopboard placed across the outlet. No screening of any kind is attempted.

Up to date two tanks only have been used, and these are used one at a time only. The scum on the one at present in use is 19in. thick at the inlet, thinning off gradually to 2in. at the outlet. On the tank now resting the scum has gradually disappeared until a film of about ½in. only remains.

The results of analyses for the last 12 months are given in Table X., and it will again be observed that the sewage is of essentially the same character as is found in the parts already mentioned. On observing the changes effected by the discharge of sewage through the installation, it will be seen that there is practically no diminution, and in fact during some months an actual increase, in the oxygen absorbed in four hours in the tank effluent as compared with the raw sewage. The explanation of this phenomenon in all probability lies in the fact that the sewage takes approximately 48 hours to pass through the tank, and doubtless during that time the process of disintegration is carried on to a point where the organic carbon exists in combinations more sensitive to the oxidising effect of the acid permanganate. It certainly cannot be considered that there is any accession of organic carbon compounds to the sewage during its discharge through the tanks. The test indicates in reality molecular changes. There is also a loss of organic nitrogen to the same extent as observed at Chatswood in the final effluent. Whilst on the one hand the organic nitrogen figures are somewhat higher than at Chatswood, on the other hand those for oxidised nitrogen are higher also; and in this connection it is interesting to observe the effect of heavy rain upon the nitrifying processes in the filters, as exemplified in the analyses for June and subsequent months. Up to June the nitrates were abundant in the final effluent. During that month heavy rain fell and nitrates correspondingly diminished. Further, during this heavy rain, the stormwater overflow mentioned above was not put into operation, so that the whole of the flow passed through the tanks and filters. The result of this was a complete cessation of nitrification in July. In the next month, namely August, the nitrifying organisms must have recovered, at all events partially, as evidenced by the very high figures for nitrites. During the next two months the nitrifying process appears to be slowly reaching its normal level. The percentage of reduction in organic matter is set out in Table XI., which can, with advantage, be compared to similar tables for North Sydney and Chatswood.

TABLE X.—*Balmoral Outfall Works.*

	Raw Sewage.							
	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.
1905. November	113·2	14·4	5·38	2·60	·00	·00	1·73	5·87
December	—	—	—	—	—	—	—	—
1906. January	65·0	15·0	5·63	1·55	·00	·00	1·30	3·03
February.........	55·4	15·6	5·24	1·49	·00	·00	1·50	4·40
March	49·6	11·8	4·38	·74	·00	·00	·95	2·58
April	50·4	12·2	6·38	1·31	·00	·00	1·20	3·04
May	51·2	13·4	5·03	1·36	·00	·00	1·23	3·39
June †	41·4	8·2	·38	·41	·05	·72	·34	1·30
July	55·4	12·4	6·40	1·47	·00	·00	1·29	3·69
August............	63·6	12·6	7·37	1·96	·00	·00	1·48	3·26
September	57·4	12·0	5·49	1·13	·00	·00	·98	2·84
October	65·4	14·0	5·35	1·27	·00	·00	1·09	3·00
Average ...	60·7	12·9	5·19	1·39	—	—	1·19	3·31

	Tank Effluent.							
	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.
1905. November	61·6	14·2	7·28	·64	·00	·00	1·50	4·42
December	—	—	—	—	—	—	—	—
1906. January	53·6	15·6	5·69	·46	·00	·00	1·08	3·55
February.........	65·8	15·6	7·28	·73	·00	·00	1·21	4·11
March	51·0	10·0	4·93	·61	·00	·00	·98	3·07
April	62·2	13·2	7·68	·68	·00	·00	1·13	3·32
May	58·2	13·6	7·17	·63	·00	·00	·98	4·08
June †	39·4	9·4	1·00	·27	·11	·41	·31	1·19
July	58·4	15·2	6·61	·86	·00	·00	1·39	3·32
August............	60·2	13·8	7·87	·86	·00	·00	1·33	3·80
September	50·4	12·0	5·88	·59	·00	·00	·88	2·33
October	47·4	13·0	6·57	·76	·00	·00	1·15	2·87
Average ...	55·3	13·2	6·17	·64	—	—	1·09	3·28

	Final Effluent.							
	Total Solids.	Chlorine.	Free Ammonia.	Albuminoid Ammonia.	N. as Nitrites.	N. as Nitrates.	O. Absorbed in 3 min.	O. Absorbed in 4 hrs.
1905. November	52·2	13·8	3·01	·205	*	2·60	·34	·94
December	—	—	—	—	—	—	—	—
1906. January	59·4	14·4	2·12	·145	*	2·50	·16	·68
February.........	51·6	14·6	3·25	·292	*	1·64	·25	·79
March	50·8	10·2	1·23	·170	*	2·58	·16	·69
April	58·0	13·4	2·80	·282	·02	2·58	·17	·47
May	53·4	11·8	2·39	·197	·01	2·00	·14	·56
June †	39·2	9·4	·24	·080	·01	1·12	·12	·59
July	51·4	15·2	3·48	·410	·00	·00	·42	1·03
August............	51·6	14·0	3·55	·507	1·73	·90	·35	1·12
September	40·8	12·0	2·51	·242	·03	·61	·26	·74
October	41·8	11·9	1·92	·367	·03	1·52	·21	·75
Average ...	50·0	12·8	2·41	·265	·26	1·64	·23	·76

NOTE.—Parts by weight per 100,000. * Small quantities not estimated. † Heavy rain during sampling.

TABLE XI.—*Table showing Percentage Reduction in Organic Matter Effected in Tanks and Filters, Separately and Combined.*

BALMORAL OUTFALL.

	Tank Effluent.		Final Effluent.		Total.		Total Reduction of Organic Matter.
	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	
1905.							
November .	76	25	16	59	92	84	87
December . .	—	—	—	—	—	—	—
1906.							
January . . .	70	—	21	78	91	78	82
February . .	50	7	30	75	80	82	82
March	18	—	59	73	77	73	74
April	48	—	31	85	79	85	84
May	54	—	32	83	86	83	84
June	34	10	47	45	81	55	61
July	41	10	31	62	72	72	72
August	56	—	19	66	75	66	69
September .	48	18	31	56	79	74	76
October . . .	40	4	31	71	71	75	74
Average .	54	1	27	76	81	77	78

INCUBATOR TEST.

All the above final effluents were examined by the incubator test carried out thus. The oxygen absorbed in three minutes from acid permanganate, at room temperature, was estimated in the fresh samples. A bottlefull of the same was then placed in an incubator at 37° centigrade, and kept there for one week. At the end of the period the bottle was removed, allowed to cool, and the oxygen absorbed in three minutes again estimated. Further, any decomposition as indicated by smell was observed, and also the general appearance of the effluent, whether turbid or otherwise.

In general it may be said that none of the effluents showed any physical signs of decomposition; but on estimating the oxygen absorbed it was found that the North Sydney effluents invariably showed an increase, sometimes considerable. As in view of the physical condition of the effluent after incubation it appeared highly improbable that this increase was due to the presence of easily oxidised products of decomposition, an estimate was made of the amount of nitrites after incubation. It was then found that coincidentally with an increase in the oxygen absorbed there was an increase of nitrites.

In the report of the present English Royal Commission on Sewage Disposal, McGowan recommends that allowance should be made for the nitrites found in the effluent after incubation. This does not appear to me to be altogether practicable, because, at room temperature, at all events, the nitrites are not fully oxidised at the end of three minutes. Fowler recommends the destruction of nitrites by the addition of urea after the sulphuric acid. This I have not tried.

In view of the irregularities caused by the presence of nitrites, and, further, in view of probable confusion from the test made in this way, it seems to me that full value can be secured by the observance of the physical conditions after incubation, and that chemical examination, as indicated above, is superfluous. The test of itself is undoubtedly of value, but the results are capable of more accurate interpretation by the simpler methods of direct observation than by the more complicated chemical tests recommended. By its application in the way I suggest it becomes available for more extended use by persons not skilled in chemical procedure.

The full results of the incubator tests, together with the changes in the nitrites, are given in the following table :—

TABLE XII.—*Showing Results of Incubator Test.*

	North Sydney Outfall.				Chatswood Outfall.				Balmoral Outfall.			
	Oxygen Absorbed in 3 minutes.		Nitrogen as Nitrites.		Oxygen Absorbed in 3 minutes.		Nitrogen as Nitrites.		Oxygen Absorbed in 3 minutes.		Nitrogen as Nitrites.	
	Before Incubation.	After Incubation.	Before Incubation.	After Incubation.	Before Incubation.	After Incubation.	Before Incubation.	After Incubation.	Before Incubation.	After Incubation.	Before Incubation.	After Incubation.
1905.												
November	·13	·60	*	†	·21	·07	*	†	·34	·23	*	†
December	·21	·66	*	†	·25	·16	*	†	—	—	—	—
1906.												
January	·31	·46	*	†	·15	·16	*	†	·16	·17	*	†
February.........	·19	·24	*	†	·28	·25	*	†	·25	·39	*	†
March	·13	·52	*	†	·19	·16	*	†	·16	·60	*	*
April	·14	·51	·16	·42	·26	·19	·02	·13	·17	·13	·02	·02
May	·11	·16	·01	·18	·34	·25	·04	·02	·14	·23	·01	·03
June	·09	·37	·02	·30	·13	·11	·03	·01	·12	·07	·01	·03
July	·10	·35	·03	·64	·16	·11	·01	·00	·42	·21	·00	·00
August............	·17	·19	·02	·25	·15	·14	·01	·08	·35	·24	1·73	·02
September	·13	·28	·01	·50	·08	·21	·01	·34	·26	·16	·03	·15
October	·12	·16	·01	·22	·06	·06	·02	·02	·21	·18	·03	·02
Average ...	·15	·37	·04	·36	·19	·16	·02	·09	·23	·22	·26	·04

NOTE.—Parts by weight per 100,000. * Small amounts not estimated.
† No test made.

As to the source of nitrites after incubation, I have reason to believe that they are due to the reduction of nitrates. In several instances where the amount of nitrates was estimated it was found that there had been a proportional diminution. The reduction was probably, to a large extent, effected by bacteria, for it is well known that in the absence of free oxygen many bacteria possess a faculty of deriving their oxygen from nitrates, reducing them in some cases to nitrites, and others to ammonia.

In a recent paper by Johnson and others (*Journal of Infectious Diseases*, Chicago, February, 1906) on "Putrescibility in Sewage Effluents," the authors deal exhaustively with the factors involved, both in causing and arresting decomposition. They point out that better indications can be secured by incubation at 37° for from 24 to 48 hours than for longer periods. They further show how probably putrescibility of a sample can be computed from chemical data. They recommend that the oxygen consumed, the nitrogen as nitrate and nitrite, and the dissolved oxygen be estimated. They arrive at their oxygen consumed figures by treating the sample with acid permanganate at boiling point for five minutes, and by dividing the results by five. The final figure obtained closely approximates the oxygen consumed figure for three minutes' treatment in the cold, but has in the authors' opinion the advantage that it is not so readily influenced by the presence of easily oxidised compounds, such as nitrites, ferrous salts, &c. With these data they interpret the putrescibility of an effluent in the following manner :—First, when the consumed oxygen value is equal to or in excess of the amount of dissolved oxygen in the effluent, and no nitrates or nitrites are contained therein, the sample will putrify. Secondly, when the consumed oxygen value is equal to or slightly less than the amount of oxygen contained in the effluent in the form of nitrates, nitrites, and dissolved oxygen, the sample may or may not putrify; and thirdly, when the consumed oxygen value is less than the oxygen contained in the effluent in the form of nitrates and nitrites, under ordinary circumstances the sample will not putrify.

The truth of their third conclusions is borne out by our experience with the effluents at the North Sydney outfalls.

It will be seen that when the oxygen in the nitrates and nitrites is calculated (to do this multiply the nitrite figure by 1·71 and the nitrate by 2·86) the amounts are, in practically every case, considerably in excess of the oxygen absorbed in three minutes.

SUMMARY AND CONCLUSIONS.

On comparing the structural features of the method of working and the results secured at the three outfalls (the essential items in this connection are set out in Table XIII. below) it will be seen that at North Sydney, with a very rapid flow through covered tanks and subsequent prolonged treatment by intermittent downward filtration, very excellent final effluents are obtained; and at the same time at Balmoral, with more extended treatment in the tanks and comparatively short time in contact filters, the final effluents are satisfactory, and contain a good proportion of oxidised nitrogen. Chatswood, with open tanks and contact filters, occupies an intermediate position as regards the period of treatment, and also gives a good type of final effluent. Other points of comparison present themselves, but scarcely call for comment.

TABLE XIII.—*Outfall Works.*

	Estimated Average Age of Sewage on Reaching Outfall.	Type of Tanks.	Length of Tanks.	Estimated Average Time of Treatment in Tanks.	Rate of Flow through Tanks per Minute.	Percentage Purification Effected in Tanks.		Filter-beds—Material of	Type of Filtration.	Estimated Average Time of Treatment in Filter-beds.	Percentage Purification Effected in Filter-beds.		Percentage Purification Effected in Installation.		Total Reduction of Organic Matter.
						Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.				Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	Albuminoid Ammonia.	Oxygen Absorbed in 4 hours.	
	Hours.		Feet.	Hours.	Feet.										
North Sydney	$2\frac{1}{3}$	Covered	119	8	·250	27	23	Sand	Intermittent, downward	Some days	63	61	90	84	86
Chatswood	$1\frac{1}{2}$	Open	70	30	·041	56	25	Coke	Contact	Some hours	28	45	84	70	75
Balmoral	$1\frac{1}{2}$	Covered	$68\frac{1}{2}$	48	·024	54	1	Destructor breeze	Contact	Some hours	27	76	81	77	78

Conclusions in matters concerning the biological purification of sewage must, like the principles enunciated above, be of a broad and comprehensive character if submitted as available for general application. The only conclusions of a positive nature that I feel justified in drawing from the experience gathered during the present investigation is that the natural processes at work can carry on under a fairly wide range of circumstances, and that, if asked an opinion, one would more probably fall into error in venturing to prophesy a failure than in submitting a favorable view, provided the suggested conditions were not altogether beyond a reasonable limitation. In addition, it must be evident that 24 hours—as generally laid down—is not inflexible minimum for treatment in a septic tank, and that double this time does not always give rise to the train of symptoms described as resulting from "over-septicisation," but, on the contrary, appears favorable to active nitrification.

But, although I regret I cannot bring forward a series of final opinions on the many vexed points that are associated with sewage treatment, still there were certain incidents of such interest as to warrant special notice, and from which one may draw certain provisional conclusions. Reference has been made to them above, but a short enumeration may not be amiss. They are as follows :—

NORTH SYDNEY OUTFALL.

1. The scum formation and changes therein.
2. The rapid rate of flow through the tanks.
3. The method of filtration.
4. The high degree of purification secured.

CHATSWOOD OUTFALL.

1. The absence of heavy scum formation.
2. The growth of water hyacinths in the tanks.
3. The small amount of silt in the tanks after four years' working.
4. The degradation of the coke in filter beds.

BALMORAL OUTFALL.

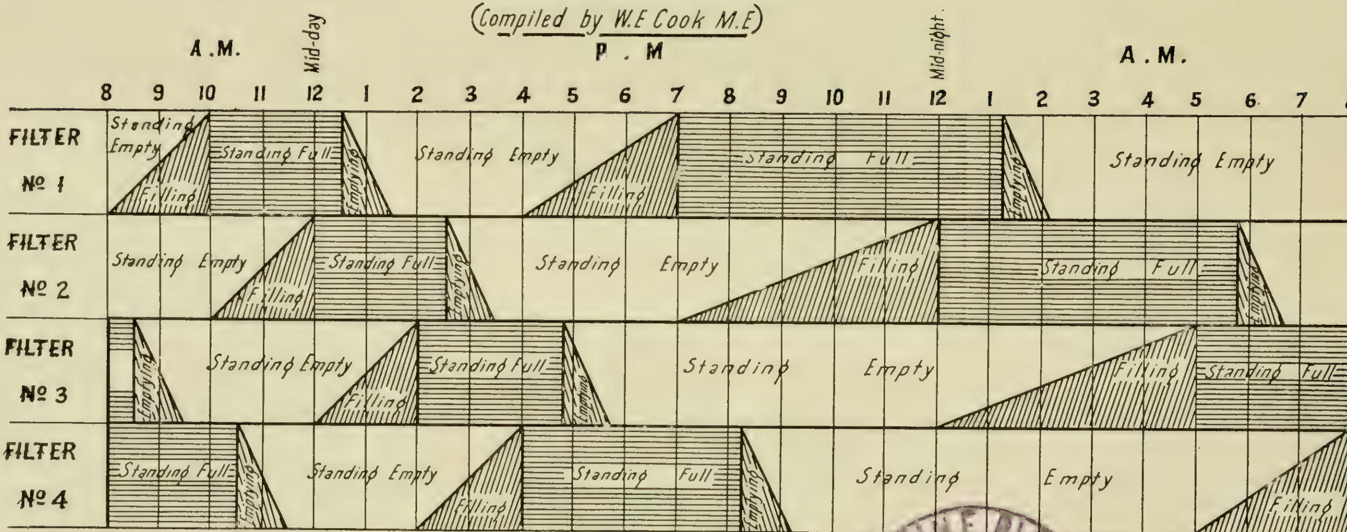
1. The effects of lengthy treatment in the tanks on the "oxygen absorbed" figures.
2. The high nitrification in the filters.
3. The cessation of nitrification after the contents of the tanks had been suddenly washed through the beds.
4. The slow recovery of the nitrifying agencies in the filters.

Finally, I take this opportunity of expressing my indebtedness to Mr. W. E. Cook, District Engineer for the Metropolitan Board of Water Supply and Sewerage, who has direct supervision over the outfall works at North Sydney, for his ready kindness in supplying me with the engineering details and other like information necessary for completion of this communication.

CHATSWOOD SEPTIC TANKS

CYCLES OF FILTERS

(Compiled by W.E Cook M.E)



2.—THE DISEASES OF ANIMALS AND MEAT INSPECTION IN WESTERN AUSTRALIA.

By J. B. CLELAND, M.D., Ch.M., Government Bacteriologist and Pathologist, Perth, Western Australia.

The importance from a public health point of view attached to the proper supervision of meat supplies is increasing year by year. In this connection the Chicago scandals of 1906 have marked an epoch, and the public are now no longer apathetic but justly insistent upon their right to be served with meat foods about which there can be no question.

Western Australia, for its thickly populated districts, possesses a highly efficient staff for the inspection of meat. This consists of five inspectors, all specially trained in their work, three of whom deal with the abattoirs at Fremantle, one with the smaller ones in the neighborhood of Perth, and one at Kalgoorlie.

To aid them in understanding exactly the nature and modes of spread of the diseases with which they deal, they have further spent a considerable amount of time in doing elementary bacteriology and pathology in the laboratory of the Central Board of Health. To the laboratory are also forwarded all interesting or ambiguous diseased organs for further examination, so that the exact nature of every pathological state can be ascertained. Each inspector is also furnished with a number of printed cards, one of which is filled in for each animal showing any sign of disease, particulars enumerated being the disease, its position, the age and sex of the animals, the abattoir where slaughtered, and the locality whence the animal came. It is hoped that in this way very valuable data will be obtained, indicating not only the nature of the diseases met with, but also their relative proportions and the localities in which they occur.

INFECTIOUS DISEASES COMMUNICABLE TO MAN.

(1) Tuberculosis.

A reference to the tabulated result of three months' classification of the pathological lesions in slaughtered animals will show you that tuberculosis is a common disease amongst the north-west cattle of Western Australia, and amongst the pigs of the more southern portion.

Of the total cattle killed at the Fremantle abattoirs 8·8 per cent. had tuberculosis. Of 383 of these 357 were from the north-west. At this season of the year, however, nearly all the cattle are from that region, only a small minority being from the more southern portions of Western Australia, or from eastern States. The above percentage, then, will represent fairly accurately the extent of this disease in the north-west, though it is probably slightly under-estimated. The percentage in the eastern States is probably distinctly higher than this, the pastures being older.

This percentage of 8·8 compares favorably with the figures given by Legge and Session for various Continental towns, thus :—

Leipzig, 1897, number of cattle slaughtered	27,191	
Percentage tubercular........................		36·4
Carlsruhe, 1895, number of cattle slaughtered.........	9,496	
Percentage tubercular........................		10·4
Stettin, 1895, number of cattle slaughtered	8,818	
Percentage tubercular........................		22·7

Amongst sheep tubercular lesions of the liver have been twice met with.

I will not discuss in this paper the possibility of danger to human beings from the products of tubercular cattle. These dangers may be divided into two groups, according to the nature of the foodstuffs, viz. :—(1) The meat of tubercular animals, and (2) the milk of such. The latter is outside the province of this article. Authorities differ upon the first group, though the majority consider there is a decided danger in eating partially cooked meat containing "bovine tubercle bacilli," and all agree as to the advisability of removing all the diseased parts.

But what I particularly desire to ascertain and to ask a remedy for is the means of preventing the spread of the disease. Year by year hundreds of cattle over vast areas are affected ; they spread the disease further and further afield, and the monetary loss to cattle-owners, not to speak of the danger to human beings, must be great and ever-increasing. Can nothing be done to check this scourge ? Can no means be taken to prevent its extension ? The first question to be decided is what is the means of spread (*a*) in cattle, (*b*) in pigs. This having been decided, we then come to the second question : What means can be recommended to limit its extent ?

Indications of the Means of Spread in Cattle.

On consulting the tabulated results it will be seen that in 76·4 per cent. of the cases the lungs were affected, in 34 per cent. these alone.

The retropharyngeal glands were tubercular in 55·5 per cent., and these alone in 33·3 per cent. In only four instances (·83 per cent.) were the lesions generalised. In 13 cases the glands draining the scrotal pouch were affected, evidently indicating an infection of the wound of castration. Cases not included in the above groups in which other organs were diseased form a small minority of 30 (·83 per cent.), all connected with the alimentary canal.

The small percentage of these in which the parts connected with the alimentary canal were affected alone negatives, I think, the likelihood of food infection. This is supported by the fact that cattle rarely browse over the same tract as one of their fellows, and this would lessen the risk of such infection by contaminated pastures.

We see, instead, that the chief burden falls on the lungs and glands in the throat, and next to them are the retropharyngeal glands. This suggests at once inhalation of the tubercle bacilli, which would draw them either directly into the lungs or else would allow of their arrest in the upper air passages, such as the pharynx, whence they would easily reach the various lymphatic glands of the neck. Cattle, we know, rest together at night time, and frequently lick each other, and either of these processes would give ample opportunities to diseased cattle to distribute tubercle bacilli amongst their fellows.

In pigs the glands of the neck bear by far the chief incidence of the disease. In them, I think, it is probably due to the feeding on improperly cooked tubercular milk or meat, the bacilli gaining entrance through the numerous membranes. The remedy is obvious.

The Prevention of Extension of Tuberculosis in Cattle.

I am afraid I can suggest but little of practical import here. It is imperative, however, that something should be done, and I should like strongly to urge that the Federal Government should appoint a commission to investigate the matter, and devise remedies. Otherwise, it will be again the cry, "Too late! too late!" Stockowners might be induced to destroy all obviously diseased animals and burn their carcasses, and to segregate the calves from the rest of the herd, while infected districts might be sharply marked off and quarantined from non-infected.

(2) ACTINOMYCOSIS.

Actinomycosis, caused by the ray-fungus, and most typically known in the condition called "lumpy jaw," is not very rare in north-western cattle. Twenty-seven cases in cattle have been met with in various parts of the body in three and a half months. The fungus is probably introduced attached to grass seeds. It is rarely, if ever, conveyed directly from animals to man.

(3) OTHER INFECTIOUS DISEASES.

Anthrax may possibly exist in the State, but has not yet been reported as such.

Foot and mouth disease, trichinosis and measles (*cystidercus cellulozæ*) in pigs, and measles in cattle (*C. bovis*), are so far not known.

DISEASES INDIRECTLY COMMUNICABLE TO MAN.

Hydatids.—This disease, conveyed to man, cattle, sheep, and pigs through the intermediation of the dog, is of fairly common occurrence throughout the State. To prevent its spread the viscera of all animals slaughtered and containing hydatid cysts should be rendered sterile before giving the offal to dogs. Dogs are forbidden within the precincts of our abattoirs.

Inspection.—As to this, there is no direct danger to man. When the cysts in the liver are few or small, the affected portions are removed and destroyed and the rest passed. If the invasion is extensive, the part is condemned.

EPIDEMIC DISEASES NOT COMMUNICABLE TO MAN.

Pleuro-Pneumonia of Cattle.

During the nine months under my notice very few cases of this disease were met with. Cattle from Wyndham, where pleuro-pneumonia was very prevalent last year, frequently showed a fibrotic condition of the lungs, with pleuritic adhesions.

As this disease is not communicable to man, the instructions to meat inspectors are that only when the animal is slaughtered at the height of the disease, and the carcass is "fevered," or when there is evidence of much absorption from septic foci in the lungs, should the carcass be condemned.

Tick Fever.

Tick fever is endemic amongst the cattle of certain parts of our north-west. When cattle from "clean" country pass through these infected areas on their way to the coast, they are very liable to contract tick fever. Consequently, it is no uncommon event for animals to reach the abattoir while at the height of the disease, or during recovery. If the carcass is fevered (*i.e.*, indicates that the animal at the time of slaughter had severe pyrexia), it is condemned; on the other hand, even if considerably jaundiced, if there are no sighs of pyrexia, the carcass is passed. This is founded on the fact that jaundice may persist for some while after the height of the disease is over, and that tick fever is a disease which cannot be communicated to man.

Swine Fever.

A mild epidemic of this disease occurred amongst some herds early in the year with considerable mortality. Though the *post-mortem* lesions closely resemble those of typhoid in man, the disease cannot be transmitted to man, and the carcasses are dealt with as those of pleuro-pneumonia and tick fever in cattle.

Swine Fever and Swine Erysipelas.

No authenticated instances of the occurrence of epidemics of either of these diseases in Western Australia has come to my knowledge.

DISEASES DUE TO PROTOZOA.

Tick Fever of Cattle.

This has already been dealt with. It is due to a parasite of the red blood corpuscles (*Piroplasm bigeminum*), transmitted by the tick *Rhipicephalus undulatus*.

Tick Fever of Fowls (Spirillesis).

This disease, due to a spirillum in the blood, transmitted by the tick *Argas*, occurs extensively in Perth, and is very fatal.

Spirochætes in Castration Wounds of Pigs.

Pigs frequently exhibit large tumors at the seat of castration. These possess a thick fibrous wall, with a central cavity containing a little thick purulent material. In this pus, amongst other bacteria, were, in every instance examined, numerous delicate spirochætes.

DISEASES DUE TO WORMS.

Cystic Stage of Cestodes.

Hydatid Cysts.—The cystic stage of *Tænia echinococcus* of the dog occurs in cattle, sheep, and pigs. Already dealt with.

Cysticercus tenuicollis.—The cystic stage of *Tænia marginata* of the dog.

During the three months under review the liver and lungs of more than half the sheep and lambs (in 1,120 out of 20,634) have been invaded by this cysticercus, the organs being absolutely riddled by them. They have been, also, not infrequent in the pig. At this time of the year the ova seem to be ingested by their host, and are found making their way *via* the liver or lungs into the serous cavities. Their tracks in the liver and lungs—occupied by necrotic debris—are often very noticeable. Apparently the great majority perish during their progress, as it is rare to find, later on in the year, more than a few adult cysticerci.

Adult Cestodes.

Tænia ovilla is found frequently in lambs. How is it this worm disappears in the adult ?

Tænia denticulata (?) of cattle.

Trematodes.

Distoma hepaticum (fluke) is found not infrequently in the livers of cattle and sheep from the eastern States. It has not so far been recorded, I believe, for Western Australia.

Amphistoma corricum is fairly common in the rumen of eastern cattle. Inspector Clutterbuck has called my attention to the fact that so far it has always been associated with fluke in the liver.

Nematodes.

Ascaris Snilla is common in the pig.

Strangyli are met with not infrequently in the lungs of cattle, sheep, and pigs.

Spiroptera.—Nodules are common in cattle, embedded in the muscles.

Larval Nematodes in Nodules in Intestine of Bullock.—In one instance the intestines of a bullock were found studded with scattered round, firm, nodules, in which were found larval nematodes.

OTHER PATHOLOGICAL CONDITIONS.

During nine months the following interesting conditions have been met with :—

Malignant (Cancerous) Growths.

Cancer in the Breast in a Cow (aged).—The udder was affected with a scirrhous mass. The sublumbar and other glands were secondarily affected.

Cancer of the Breast in a Lioness (10 *years*).—Malignant growth in udder and sublumbar glands, &c. Numerous secondary deposits in lungs, liver, and spleen. Also growths on pleural surface of one rib, in omentum, and probably in kidney.

Malignant Growth of Suprarenal Gland in Sheep.—The suprarenal was much enlarged, and the growth extended below into the right kidney and above into the liver. The liver and lungs were occupied by numerous large secondary deposits.

Malignant Tumor of Mediastinum in Bullock, forming a Cap to the Heart.—This very large growth was formed of masses of large cells in alocote.

Single Tumors.

Chordroma of Rib in Sheep.—A large cartilaginous tumor the size of the fist.

Melanotic fibromata.—These were found sometimes in cattle in various subcutaneous parts.

MELANOTIC PIGMENTATIONS.

A very interesting series of melanotic pigmentations has been met with both in cattle and sheep. Macroscopically and microscopically the pigment looks like melanin, and it answers to the rough chemical tests for this substance. Its origin is shrouded in obscurity. One case suggests the cortex of the suprarenal as being the producer, while others are generally attributed to the nature of the food.

Melanotic Livers of Sheep (*Saltbush Liver*).—These are of frequent occurrence in the livers of eastern sheep. The organ is a deep bluish-black, and in sections the lobules are mapped out. The portal glands are similarly pigmented. Microscopically there is a deposit of melanin granules in the liver cells and in the lymphoid tissue. The organs are called "saltbush livers," from the idea that feeding on this shrub causes the pigmentation.

Melanotic Deposit in Kidney of Sheep.—A dark black pigmentation is seen in the cortex. Microscopically the basement membrane of some of the tubules is occupied by a black pigmented material.

Intense Melanotic Pigmentation of Suprarenal and Connective Tissues of Bullock.—This case is very interesting. The cortex of the suprarenal is somewhat enlarged, and jet-black. There is a dense accumulation of melanin granules between the cells. The medulla seems free. In addition to this, there are several large wedge-shaped areas of melanotic pigmentation with granules in the lungs, extensive blue-black pigmentation of the connective tissues round the aorta, and a similar coloration of the dura and pia-mater of the spinal cord, and part of the brain. Another similar, but less marked case, has also been met with.

Melanotic Pigmentation of Lung of Bullock.—In another animal similar wedge-shaped black areas were found in the lungs.

FAT NECROSIS IN BOVINES.

Animals are frequently slaughtered in which the omental, perirenal, and other abdominal fat is extensively converted into a whitish, more friable, and firmer substance, which, microscopically, is found to consist of needle-shaped crystals in rosettes in the fat cells. This is evidently of the nature of fat necrosis. Is its origin possibly microbic, due to the fat-splitting power of some bacterium ? Inspector Buckley informs me that it is found almost invariably in cows. If so, has it any relation to pregnancy ?

Occasionally in the brisket of bullocks a putty-like deposit is found, but this has no relation to the above.

CATTLE SLAUGHTERED AT FREMANTLE ABATTOIRS.

(*For three months, from part of August to part of November*, 1906.)

Number slaughtered	4,067, and calves 37
" " with pathological lesions	665 = 16·4%
Tubercular cattle	360 = 8·8%
Of tubercular cattle, 275 lesions in lungs = 76·4%	
" " 200 " retropharyngeal glands, &c., 55·5%	
Antinomycosis	26 = 6%
Hydatids	84 = 2%
Fluke	26 = 6%

SHEEP AND LAMBS SLAUGHTERED AT FREMANTLE ABATTOIRS.

(*For three months, from part of August to part of November*, 1906.)

Number slaughtered		20,634
Number with pathological lesions		1,497
Tuberculosis—Liver	3	
Lung	1	
	—	4
Pseudo-tuberculosis		4
Hydatid cysts		254
Strangylus filaria		24
Fluke		6

PIGS SLAUGHTERED AT FREMANTLE ABATTOIRS.

(*For three weeks, from part of August to part of November*, 1906.)

Number slaughtered		1,801
Number with pathological lesions	149	
" " tuberculosis	61	
" " Hydatids	12	
" " Swine fever	13	

(Owing to the scattered nature of the abattoirs where these animals were killed, complete supervision by the inspectors could not be maintained. Hence these figures must be considered as much lower than the actual ones.)

3.—THE SANATORIUM TREATMENT OF CONSUMPTION FROM A PUBLIC HEALTH POINT OF VIEW.

By A. H. GAULT, M.D.

There may be differences of opinion as to the exact value of the sanatorium treatment of consumption, but there can be no question as to its being the most successful form of treatment yet adopted.

The subject should be of special interest to this Section, for this form of treatment may be looked on as the apotheosis of the hygienic life. The method of treatment is simply the adoption of the most healthy life possible in the most healthy locality available, and its results form one of the grandest triumphs of sanitary science. It would weary you were I to describe in detail the requirements of a sanatorium, for I must remind you that though they may be summed up in three words—air, food, rest—yet in practice they are difficult of attainment, and to ensure success the principles must be carried out with scrupulous exactitude.

I wish to point out that a sanatorium simply aims at a perfectly healthy life, and it should be the endeavor of everyone who wishes to ensure good health to approximate to it.

Of first importance is—

Fresh Air.—But the words have acquired a new meaning. To constitute proper ventilation it is not sufficient that each individual should have 3,000 cubic feet of air per hour, but it means that the air indoors should be of exactly the same quality as that outside. It is not sufficient that windows be open freely, for on a still day the air in a room soon becomes contaminated unless it is in constant motion. That draughts are a source of danger is a firmly rooted conviction in the mind of the majority of people, and it will take a generation to get rid of it. Sanatorium treatment has proved without a doubt that draughts are not only harmless, but beneficial, so long as the body is sufficiently clothed. It would be impossible under modern social conditions for us always to breathe fresh air, but it must be our continual aim to do so.

The second item is—

Good Food.—There is a disposition to accept Professor Crittenden's conclusions, that the majority of persons eat a great deal too much, and that the health of the community would be much benefited by a considerable diminution in the amount of food taken. How far this is true I am not prepared to say, but there is no doubt consumption is a disease which leads to a great increase in expenditure, and to maintain the balance it is necessary to pay attention to the income. There is an idea that at a sanatorium patients are forced to eat much more than they desire ; this is not true. They are encouraged to eat as much as possible. The healthy life promotes good appetite and digestion, and the amount of food consumed by erstwhile dyspeptics, and the weekly increase of weight are surprising.

Patients have three good meals a day, following on an hour's complete rest. The diet is generous but simple, and the cooking must be above criticism. No stimulants are given. Patients, unless their condition is absolutely hopeless, steadily gain in weight, till their previous maximum is surpassed.

The third essential is—

Rest.—For healthy life a due apportionment of rest and exercise is essential; in a sanatorium it is of the utmost importance. When the disease is active the movements of the lungs must be restrained as much as possible, absolute rest in the recumbent position may be required for a time, and we have to be guided much by the pulse and temperature. Incalculable harm is often done by the idea that deep-breathing exercises are beneficial for the lungs. Such ill-timed movements break down adhesions, and frequently make a quiescent disease active. For perfect health, good digestion, and good circulation, exercise is necessary; and one of the most difficult problems of a sanatorium, and the one requiring the nicest discrimination and most persistent care, is the adjustment of proper rest and exercise. Home treatment must always fail in this respect. Walking is the best exercise, on the flat and up gentle slopes. By watching the results of each day, reducing the distance if there is any evidence of its being too much, increasing it if all goes well, the patient becomes able to take longer walks than in previous good health without the slightest feeling of fatigue.

I have no hesitation in saying that the whole success of the treatment depends on the apportionment of rest and exercise.

Many other things help to make the treatment successful. The surroundings must be bright and cheerful, the life in every way pleasant and agreeable, for a hopeful mental condition is a *sine qua non* of success. The simple routine, the increased sense of well-being, the returning health and strength, the freedom from anxiety, *all* go to assist in making this form of treatment not only the most successful, but also the most agreeable.

The sanatorium is the high-water mark of the perfect hygienic life, and it must be the aspiration of the sanitary reformer to lift the life of every member of the community to the same level. When this is accomplished the death rate will be reduced to a minimum, and the millennium be at hand, for with the improvement in physical health will come an accompanying improvement in social and moral life.

The sanatorium is a standing object lesson of what preventative medicine can do by simply following the laws of perfect sanitation.

In conclusion, I would like to draw your attention to the important part the sanatorium plays in diminishing the tubercular death rate by segregation and education. One of the most important conclusions arrived at by the Tuberculosis Congress, held at Paris in 1905, was the value of segregation in preventing consumption.

The diminution of the death rate in England has been steady during the last half-century, and has been brought about by many contributory causes, chief of which is general improvement in sanitation; but in Germany, during the last decade, the death rate has diminished by 25 per cent. without any marked improvement in sanitation, but during that period £10,000,000 have been spent by insurance societies on the erection of sanatoria, to say nothing of large sums spent privately in the same way; and it is admitted that the diminished death rate has been brought about in great measure as a result of the sanatorium treatment. In France during the same period, where few sanatoria have been erected, the death rate has remained practically stationary. During the same period in the Australian States, which have been slow to adopt the sanatorium treatment, there has only been a slight decrease; whereas in South Africa the mortality from consumption seems to be on the increase.

The conclusion is that the greater the number of patients who can be cared for in sanatoria and special hospitals, the sooner will this disease be stamped out. But it must be remembered that the patients in these institutions are not quarantined; we cannot restrain their movement, nor do I think we are called upon to do so. The importance of these special institutions is that they educate the patients in those principles which prevent the spread of the disease. It is high time that we thoroughly understood the nature of the infectiousness of consumption. It was an immense advance when we recognised that it was really an infectious disease, and due to a specific organism, but a great deal of unnecessary hardship is entailed upon the sufferers from the popular misjudgment of the nature of its infection. You must remember that the tubercle bacillus is one of the most difficult of all pathogenic germs to cultivate, and that it does not maintain life very long outside the human body. It is very easily destroyed by fresh air and sunlight. It is admitted that in not more than 20 per cent. to 30 per cent. of cases can we trace any definite source of infection, and the contraction of the disease seems to depend much more on susceptibility, either inherited or acquired, than on exposure to infection.

The precautions adopted in a sanatorium are ample, and if these are carried out with scrupulous cleanliness we are convinced that a consumptive need not be banished from society. I could point out that old standing chronic cases are the greatest menace to the safety of the public. Such patients grow weary of taking precautions, or are too weak to pay attention to the demands of cleanliness. For such, the provision of such hospitals as we have on North Terrace is the only satisfactory safeguard.

4.—SCHOOL HYGIENE IN TASMANIA.

By J. S. C. ELKINGTON, M.D., D.Ph., Chief Health Officer and Permanent Head of the Department of Public Health of Tasmania.

[The substance of this paper has been included in an article under the same title published by the author in the "Journal of the Royal Sanitary Institute," London, vol. XXIX. (1908), pp. 285-290.]

5.—CONSUMPTION: A NATIONAL DISEASE AND ITS REMEDY.

By C. REISSMANN, M.A., M.D. (Camb.), B.Sc., M.R.C.P. (Lond.), Physician in charge of Kalyra Sanatorium, and Assistant Physician to the Adelaide Hospital in charge of the Consumptive Department.

[WITH THREE PLATES.]

HISTORICAL.

In a certain book of medicine the statement occurs that "the greatest and most dangerous of all diseases, and the one that proves fatal to the greatest number, is consumption." There is nothing very astonishing in this statement except that the book in which it occurs was written more than 2,000 years ago, by that astute observer Hippocrates. What was true 2,000 years ago has been true ever since, and year by year through all the centuries consumption has continued to claim its victims. It has sought them chiefly among the young and the beautiful, it has taken the promising and the best. To-day a trustworthy writer assures us that consumption accounts for one-seventh of all deaths, and that one-sixth of all mankind is tuberculous. Everyone who realises what this means will wish to know something about this disease, what it is, how it is contracted, how it is avoided, how it is cured.

So much has been spoken and written about consumption during the last few years that I suppose everybody now knows that it it a contagious disease, and that the immediate cause of the disease is a tiny microscopic plant known as the tubercle bacillus, which was discovered by Koch in 1882.

Long before Koch discovered the tubercle bacillus, nay, centuries before Pasteur created the science of bacteriology, the contagious nature of consumption was suspected, known, and acted upon.

Many scientific truths and laws of nature which were discovered during the last century—the age of scientific renaissance—may be found dimly outlined in the ancient writings of men like Heraclitus and Lucretius, and so it is with the contagious nature of consumption.

Isocrates, more than 2,000 years ago, knew and taught that consumption is a contagious disease, and Galen, in the second century after Christ, wrote "*periculosum preterea est consuescere cum his qui tabe tenentur*" (it is moreover a dangerous thing to live with those who are consumptive). *

Avicenna, 100 years after Christ, and Montano, 1,400 years later, proclaimed the contagious nature of consumption. Monanto, indeed, believed that it was possible to contract consumption by walking bare-footed over the expectoration of a tuberculous patient.

Once or more during every few centuries some great physician appears to have discovered that consumption is a contagious disease, but the warning has not often been heeded.

* For this and other historical facts mentioned I am indebted to Knopf's Alvaregna Prize Essay.

Morgagni, who lived about 200 years ago, and was the founder of the science of pathological anatomy, was well aware of the contagious nature of consumption. A keen observer, a man who was consulted by his seniors, "*adeo erat in observando attentus, in praedicendo cautus in curando felix*," the author of a great work on the cause of disease, based upon exact anatomical observations, Morgagni was so convinced that consumption could be contracted by contact with something tubercular that he absolutely refused to make a *post-mortem* examination upon persons who had died from that disease. ("Encyclopædia Brit.")

The compulsory notification of consumption, and the compulsory disinfection of the dwellings of consumptives after their decease are usually regarded as institutions of quite modern days. But in some old records of the city of Nancy, some time in the eighteenth century, one may read the story of a woman who contracted consumption, and who had frequently shared the same bed with another woman who died of consumption; and it is stated that the municipal authorities of the city, recognising that this woman had caught the disease from her bedfellow, ordered the furniture and bedding of the latter to be burned.

It will surprise most of you to know that in 1782 a royal decree was issued at Naples, ordering the isolation of consumptives, and the disinfection of their apartments and their personal property. If anyone disobeyed this order he was liable to be punished with three years in the galleys, or with a fine of 300 ducats, together with imprisonment in a fortress.

To-day, a physician in this State who fails to notify a case of consumption is liable to a fine of £10, but in Naples, in the eighteenth century, failure to notify involved the physician in a fine of 300 ducats for the first offence, and for the second offence banishment from the country for a period of 10 years.

In Spain and Portugal at the end of the eighteenth century the parents of a consumptive were obliged to notify the authorities when the disease had reached the final stage, so that proper disinfection might be carried out.

Now, I have said enough to show that the infectious nature of consumption has been asserted for ages. But the frequent repetition of a principle does not prove that principle to be true. After all, no one had brought forward incontrovertible evidence that consumption was an infectious disease, and in the nineteenth century it was not suspected that the only way in which consumption could be contracted was by contact with something tuberculous.

"Tuberculosis," said Pidoux, an antagonist to Pasteur, in a speech that was greatly applauded at the time, "Tuberculosis is the common result of a quantity of divers external and internal causes, and is not the product of a specific agent ever the same."

When Villemin, a disciple of Pasteur, proved that tuberculosis is a disease which reproduces itself, and cannot be reproduced but by itself, he was treated almost as a disturber of medical order. ("Life of Pasteur.")

So far had the teaching of the earlier physicians been forgotten that Professor Koch opened his Nobel lecture in December, 1905, with the following words :—" Only 20 years ago tuberculosis, even in its most dangerous form—pulmonary phthisis—was not considered infectious."

Koch's discovery of the tubercle bacillus settled the matter finally. It is now universally acknowledged that the tubercle bacillus is the sole cause of consumption; without the bacillus there can be no consumption.

THE SOIL.

Lest I should overstate the danger of contracting consumption in which we all stand, let me say at once that the tubercle bacillus will not easily grow unless planted in suitable soil. The human subject, debilitated by illness or overwork, by cares and disappointments, or by a faulty mode of living, is the soil on which it best grows. Dark, ill-ventilated, and small dwellings in a crowded neighborhood are the nurseries in which it flourishes. If a man leads a healthy life he will not easily be a prey to consumption.

HOW THE DISEASE IS SPREAD.

I would like to give you a clear idea of the way in which consumption is spread. I think I cannot do so better than by placing before you a magnified image of a tiny speck of expectoration taken from a tuberculous patient (Plate I., fig. 1).

You see there are a number of little rod-shaped bodies, stained a red color. These are the tubercle bacilli, and there are a great many of them.

The actual volume of this little portion of expectoration which you see here, greatly magnified, is a little more than three one-hundredths part of a cubic millimetre, and if you count the number of bacilli in the picture before you you will find that there are 144 of them. If we assume that the amount of expectoration coughed up by this patient in 12 hours was a half litre (which is not an unusual amount), then in a whole day (of 24 hours) this patient will have thrown out more than four and a half billion tubercle germs. Further, since 1,000 tubercle germs measure about four millimetres, if we imagine all the germs coughed up by this patient in a day to be arranged end to end, to make one continuous filament, they would form a thread $11\frac{1}{4}$ miles in length.

Think of it, more than 11 miles of living tubercle bacilli in a day. Now the man who was producing these miles of germs travelled to Adelaide from his home, which is about 200 miles away in the country. When I saw him at his lodging he spat indiscriminately upon the floor of the room. He did not stay long in the same house, and he distributed germs wherever he went. This man was a public danger, and I had no power to detain him. When we know that consumption is an infectious disease, which can only be contracted by contact with tubercle germs, and when we consider that consumption is the immediate cause of more deaths than any other disease, does it not seem extraordinary that we should, nevertheless, allow such a man as this to travel hundreds of miles over the country disseminating the seeds of disease wherever he goes.

The law of right social relationship is that every man shall have freedom to do all that he wills, provided he infringes not on the equal freedom of any other man. By scattering the tubercle bacillus, which is the cause of disease, this man is breaking the law of right social relationship, and I think that the municipal authorities should have the power to detain such an individual, and to keep him under supervision until they are satisfied not only that he knows the proper way of disposing of his expectoration, but that he can also be trusted to carry out the instructions it should be their duty to convey to him.

EMPLOYMENT OF CONSUMPTIVES.

I think also that it should be made an offence at law for any person to employ a consumptive in the manufacture or distribution of any article intended for human food.

I have known a man suffering from active and advanced consumption to be employed at a dairy, a girl who was employed in handling and packing sweetmeats, another who was employed by a retail butcher, and so on. It is quite as important to stop such practices as it is to find money for the erection of sanatoria.

HARMLESS CONSUMPTIVES.

Before I proceed further I will show you the magnified image of the expectoration of another consumptive patient (Plate I., fig. 2). I wish to lay particular stress upon the fact, which is at once obvious, that there are no tubercle bacilli to be seen in this specimen. The expectoration has been examined many times recently, but on no occasion have we found the tubercle bacillus, although the patient is very ill. The question will naturally occur to you, how do I know that this man is actually suffering from consumption, and not from some other illness.

Well, apart from an examination of the expectoration, and apart from the signs revealed by a physical examination of the chest, we have at our disposal another test by which consumption may be detected. This is known as the tuberculin test.

If a minute dose of a fluid called the old tuberculin of Koch be injected under the skin of a healthy person he feels perfectly well, and nothing appears to happen to him as the result of the injection. But if the same quantity of tuberculin be injected under the skin of an individual who is suffering from consumption, then, within 24 hours, a certain reaction occurs, which becomes evident chiefly by a rise of temperature. I will show you the temperature chart of a man who was injected with tuberculin on two occasions, but who did not suffer from consumption (Plate I., fig. 3). You will see that the temperature did not rise after the injection. I will show you the temperature chart of the patient, an image of whose expectoration you have just seen (Plate II., figs. 4, 5, 6, 7). I show this patient's temperature record for five months, and you will observe that during the whole of this time the temperature never rose above 99° until tuberculin was used. The dose of tuberculin was the same as in the previous case, and you see that after an injection of 0·001cc. of tuberculin the temperature rose to 104°, and then rapidly fell again to normal. This man, therefore, gave a positive reaction to tuberculin—as we express it—and that proves that he was suffering from consumption. As a matter of fact, he has it in a very advanced stage, and is hopelessly incurable. Here, then, is a man in the last stage of consumption, whose expectoration, nevertheless, does not contain any tubercle germs. Since a man can only convey consumption to other people when his expectoration or excreta contain the tubercle germs, this patient is perfectly harmless; he cannot convey the disease to others, even though he should try to do so. Yet, it so happens that this very man is isolated at the Government institution for incurable consumptives, while that other man who expectorated miles of living germs every day has been travelling about the country. The poor fellow was ignorant of the evil he was committing, and we will not think unkindly of him; he has since crossed the bar.

CLASSIFICATION OF CONSUMPTIVES.

The matter I have just discussed is obviously of great importance, and I cannot remember that it has ever been clearly brought before the public. All consumptives can be arranged into two classes (see diagram): those whose expectoration contains tubercle germs, and who are, therefore, capable of conveying the disease to others, and those whose expectoration is free from these germs, or who have no expectoration at all—that is, the harmless consumptives.

Consumptives in the first class, whose expectoration carries the tubercle germs, may be further divided into those who have been trained in the proper method of preventing infection and those who have received no such training.

In the interests of public health I consider this to be the most rational and useful way to classify consumptives. This classification should form the basis of those laws and regulations which must be framed to prevent the spread of consumption.

The compulsory isolation of every consumptive in tent colonies, which at the present time is contemplated by the authorities at Buda Pesth, is a measure far too drastic ever to be adopted by British people, and perhaps it is unnecessarily severe.

Nevertheless consumption, which is called a preventable disease, is not in fact being prevented. It causes the death of thousands who never would have contracted the disease if efficient laws had existed for the proper control of consumptive people.

If you will remember that almost every person who contracts consumption owes his misfortune to the careless action, unconsciously committed it may have been, of some individual who is suffering from the disease, you will at once perceive that the action of consumptive people should be under the control of some constituted authority, such as the Board of Health.

REMEDIES PROPOSED.

The measures which I would propose are reasonable, and I think not more severe than the nature of the case demands. I will ask your careful consideration of the propositions I have to make.

In this State at the present time it is the duty of a physician directly he is consulted by a person suffering from consumption to notify the fact to the Board of Health. I consider that simple notification is not sufficient, but that the physician should state in his certificate whether his patient is or is not in the infectious stage of the disease. If the case is not in the infectious stage no action need be taken by the Board of Health, but the patient must supply a certificate, not less than once every month, to the effect that he is still not in the infectious stage, and he must continue to send these certificates until his disease has undergone arrest. So long as he provides certificates that he is not infectious the board will not interfere with him.

If, on the other hand, the physician notifies the case to be in the infectious stage, then the case must be isolated either at home or at a hospital until the board is satisfied not only that he has learned, but that he can be safely trusted to carry out the prescribed rules of personal cleanliness and disinfection. The patient must further remain under the supervision of the Board of Health until the disease has undergone arrest, or until he has died.

IMPORTED CONSUMPTIVES.

It is undeniable that in Australia we have suffered greatly from the importation of consumptives from the old country. If to some consumptives who come here from abroad our climate affords the means of regaining their health, let them be heartily welcome, let them benefit by all we can do and give them, but let us make sure, if we can, that none of them will spread the disease to others here. Every consumptive who enters this State should be compelled to report himself on arrival to the Board of Health, and should he be in the infectious stage the board must require his immediate isolation until they are assured either that he is free from infection, or that he is both trustworthy and competent to carry out the prescribed rules of personal cleanliness and disinfection.

PERSECUTION OF CONSUMPTIVES.

The measures which I have proposed should not only be a safeguard to the general public, they should prove a boon to the consumptives themselves. Many of these unfortunate sufferers are to-day fully alive to the fact that they may convey the disease to others, and they therefore strictly and conscientiously carry out the rules of personal cleanliness and disinfection to which I have referred. They are in consequence very little danger to others. Nevertheless they are shunned by all who know them, they are very unjustly persecuted. But after all this is quite natural; it arises from the fact that the general public has at present no means of distinguishing between a dangerous consumptive and one who is harmless. If the Board of Health would issue certificates to those who are not dangerous, according to the method that I have proposed, the cause of the present persecution would be removed, and persecution would in consequence be less.

BOVINE TUBERCULOSIS.

The proposals I have made are far from perfect, but if they were properly put into operation they would undoubtedly lessen the spread of tuberculosis from man to man. But steps must also be taken to prevent the spread of consumption to man from infected animals. The question whether man can contract consumption from tuberculous cattle has been widely discussed. You will remember at the British Congress on Tuberculosis, held in London in 1901, Professor Koch stated his conviction, which rested on the safe foundation of carefully-planned experiments, that there was a difference between human tuberculosis and the tuberculosis of cattle, and that human tuberculosis could not be conveyed to cattle. Touching the converse question, which is of supreme importance, namely, whether man is susceptible to the tuberculosis of cattle, Koch said—"If such a susceptibility really exists, the infection of human beings is but a rare occurrence. I should estimate the extent of infection by the milk and flesh of tuberculous cattle, and the butter made of their milk, as hardly greater than that of hereditary transmission; and I therefore do not deem it advisable to take any measures against it."

Koch's opinion has not been accepted by the greater part of the medical profession. It has, however, received some support from the observations of Kitasato, a very eminent Japanese bacteriologist. Kitasato has pointed out that ever since the history of Japan has been chronicled tuberculosis has been known to exist in Japan, but that nevertheless the cattle of the present day are not infected with tuberculosis. In Japan the use of cows' milk as a food for infants is unknown, and the Japanese altogether consume very little milk. Intestinal tuberculosis, therefore, which is as frequent in Japan as elsewhere, cannot, in the opinion of Kitasato, be attributed to the ingestion of infected cows' milk.

The argument of Koch and of Kitasato may be right or it may be wrong, but I am quite sure that it will not affect the present attitude of the public in the matter, for who is there among us that would allow his child to take the milk of a cow that was known to be suffering from tuberculosis of the udders.

The opinion of most physicians to-day is in agreement with that of Professor Kössel, whose views were summarised at the Congress on Tuberculosis held in Paris in 1905. There are two distinct types of tubercle bacilli: they can be distinguished by their morphological character, and by the soil on which they are most easily grown. They are called the bacillus *Typus humanus* and the bacillus *Typus bovinus.*

Cattle are susceptible only to the bacillus *Typus bovinus.* Swine are susceptible to both varieties of the bacillus, but more especially to the *Typus bovinus.*

Man suffers chiefly from the bacillus *Typus humanus*, but he is also susceptible to the bacillus *Typus bovinus*, which he may ingest in meat from tuberculous animals, or in milk from cows suffering from tuberculosis of the udders.

The risk of infection from boivne tuberculosis is very small in man compared with the risk of infection from a consumptive human being.

This opinion has been materially strengthened by some interesting experiments that have recently been made upon anthropoid apes. From the nature of the experiment the susceptibility of man to bovine tuberculosis cannot be determined by direct inoculation, but it occurred to Professor Dungern and Dr. Henry Smidt to experiment on anthropoid apes as being the nearest relatives to man in the animal scale.

The experiments were carried out in Sumatra upon two varieties of the Gibbon (*Hylobates syndactylus* and *Hylobates agilis*). Three animals were inoculated under the skin with cultures of tubercle of human type, and three with cultures isolated from cattle (10mg.). The animals proved to be equally susceptible to the bacilli of both types; they all contracted tuberculosis. Next, three Gibbons were fed with cultures of human type, and three were fed with cultures of the *Typus bovinus.* In each case two out of three animals became affected with generalised tuberculosis. From these experiments it was concluded that as the Gibbon was equally susceptible to both types of tuberculosis man was probably also susceptible to both human and bovine tuberculosis. (B.M.J., 1906, II., 721).

In the present state of our knowledge, then, we must act in the belief that man, especially in infancy, is liable to contract consumption from tubercular cattle. After the hopes that were raised by Professor Koch's announcement, this is a disappointing conclusion, but perhaps in the end it may prove to be to our advantage. Some physicians who have carefully studied the matter affirm that mild boivne tuberculosis contracted by man in childhood confers a certain immunity against pulmonary consumption in the adult, just in the same way that vaccination protects against smallpox. Indeed Calmette is so convinced that bovine tuberculosis protects man against ordinary consumption that he has even suggested that infants of a few weeks old should be dosed with small quantities of sterilised cultures of tubercle of human and bovine origin, and he prophesies that in this way the child will escape future consumption. Perhaps the day will come when preventive inoculation against consumption will be generally adopted, but we shall require certain proof of its safety and of its efficacy before we shall be willing to consent to any such treatment. (B.M.J., 1904, II., 907).

THE CURE OF CONSUMPTIVES.

Now that I have tried to impress you with the prevalence of consumption, and I have shown you how many in the present state of things are the opportunities and facilities for those people who are susceptible to contract the disease, I want to deal with the question that is so often asked —*Can a person suffering from consumption be cured?* The answer to this question is yes and no. A man's chances of recovery from consumption depend upon several factors, such as his natural power of resistance, the length of time he has suffered from the disease, and the particular strain of bacillus with which he has become infected. The last fact is not sufficiently recognised. There appear to be certain strains of tubercle bacilli which are mild, almost harmless, and others that are extremely virulent.

If one man contracts consumption from another who is suffering from a chronic mild type of the disease, then the person last infected will usually also suffer from a mild form of consumption. But if, on the other hand, a man contracts consumption from one who is suffering from rapid or galloping consumption, then the last infected is likely also to suffer from rapid consumption. I regard a man suffering from rapid consumption (acute caseating tuberculosis) as far more dangerous than a person suffering from the more common forms of consumption, and I think that persons suffering from rapid consumption should accordingly be strictly isolated, and the doctor who notifies the case should definitely state on his certificate that the patient is suffering from the more dangerous form of the disease.

To come back to the point of my discussion. A man's chances of recovery depend in part upon the virulence of the strain of bacillus which has invaded him. It also depends upon the extent of the damage that has already been wrought by the disease.

If a portion of a man's lung has been destroyed by the action of the tubercle bacillus it is never replaced by new lung. The part destroyed, if not too great, may be replaced by scar tissue; but sometimes one or more whole lobes of the lung may be completely destroyed, and when that has happened there can be no question of cure in the ordinary sense of the word.

I show you a photograph of the right lung from a patient who had consumption, and you will see that it is a mere space—there is no spongy lung tissue at all. In a case like this there can be no question of cure (Plate III., fig. 8).

I mention this fact particularly because in the daily papers you can always see the advertisements of certain unscrupulous men who assert that their quack remedies will cure consumption in any stage of the disease.

The matter is wholly different in the earlier stages. I affirm most emphatically that the great majority of cases of consumption can be completely and permanently cured if the appropriate treatment is adopted in the very early stages of the disease.

BREHMER'S MOTTO.

Brehmer, the founder of the modern sanatorium treatment in Germany, wrote a thesis for his degree under the title "*Tuberculosis, in stadiis primis semper curabilis*." In the early stages consumption is always a curable disease. This motto might well be inscribed upon the gates of a modern sanatorium.

It is a fact which everyone should know. Because people do not know it the majority of consumptives come for treatment when it is too late. It is no discovery of modern days, for even Hippocrates, 2,000 years ago, knew that early consumption could be cured, and he wrote: "If the patient be treated from the beginning he will get well." Hippocrates taught that fresh air, rest, and regulated exercise would cure these early cases.

A plentiful supply of milk, rest, and carefully planned exercise, and sometimes a sea voyage, were prescribed for consumptives by Aretæus 250 years before Christ.

Sunlight and the pleasant air of pine forests were advised by Pliny the elder 23 years before Christ.

A residence in the pure air at high altitudes was Galen's prescription about 200 years after Christ.

The famous Arabic physician, Avicenna, at the beginning of the eleventh century A.D., also sent his patients into the mountains.

Willis, in the seventh century, sent his patients to the Riviera.

Lænnec (1781–1826), a physician of great experience in chest diseases and the inventor of the stethoscope, had the misfortune to inoculate himself accidently when performing an autopsy on a tubercular subject. He died from consumption. Before his death he caused sea air to be artificially produced in his bedroom.

SANATORIA.

It was in England, in the year 1839, that the first sanatorium for the systematic and scientific treatment of consumptives was founded by Dr. George Bodington, of Sutton Coldfield. Dr. Bodington did not receive the proper acknowledgment which his excellent work merited, and when Brehmer founded his famous sanatorium in Gobersdorf Bodington was forgotten. To-day there are in the world no less than 560 sanatoria for the treatment of consumption.

From my own personal experience I am convinced that the best chances of recovery from consumption are afforded by sanatorium treatment, and that no other form of treatment, at home or elsewhere, can be compared with it. *At a well-managed sanatorium* 75 *out of every* 100 *cases who have entered while they are in the earliest stage of consumption leave without any vestige of disease, and are in every sense sound and well.*

Every year some thousands of people are being discharged from sanatoria who have been cured of consumption. Sanatoria deserve all the support they get, and many of them would be able to do much more good if they were more liberally supported by the public. A system of treatment which aims at curing a disease by increasing the natural resisting power of the patient by rational and hygienic measures, as sunlight, fresh air, a liberal diet and regulated exercise, can never be superseded by any other. But it is possible that in the future some form of treatment will be discovered which, if used in conjunction with the sanatorium treatment, will make the latter more successful than it has been in the past.

OPSONIC TREATMENT.

Something is already being done in this direction. By a series of ingenious experiments Wright has shown that a substance exists in the blood which acts upon the tubercle bacillus (or other germs) and renders it vulnerable to the white blood corpuscle. If one mixes together equal volumes of white blood corpuscles, an emulsion of tubercle bacilli, and normal saline solution, and incubates the mixture at body temperature for 15 minutes, the leucocytes will not attack the tubercle bacilli.

We can examine the mixture with the microscope after incubation, and we shall find the bacilli and the leucocytes lying free in the field and no bacilli in the bodies of the white corpuscles. I will throw upon the screen an exact representation of an actual experiment that was made for me by Dr. Helen Mayo (Plate III., fig. 9). You will observe that the tubercle germs are all outside the white blood corpuscle.

The result would have been different if in the above experiment we had used human blood serum instead of normal salt solution. In other words, if one mixes equal volumes of white blood corpuscles, an emulsion of tubercle germs, and blood serum, and incubates the mixture for 15 minutes, then the white corpuscles will attack and ingest the germs. I will throw upon the screen the result of this second experiment (Plate III., fig. 10.) You will observe that many tubercle germs are in the substance of the white blood corpuscles. It follows from this experiment that the blood serum contains a substance which has the power of acting upon the tubercle bacillus, and injuring them so that they become attacked and eaten by the white blood corpuscle. This substance Wright has called an opsonin.

Opsonins, therefore, are substances which exist in the blood of every individual, and protect him against the invasion of certain germs. The blood of every healty person appears to contain nearly the same quantity of opsonin, but if he contracts consumption then it is usually found—at all events in the early stages of the disease—that the amount of opsonin in the blood is diminished.

Professor Wright's treatment aims at increasing the opsonin in the blood. This is done by injecting under the skin at stated intervals minute quantities of a sterilised preparation known as tuberculin. The result of each injection is carefully determined by a somewhat elaborate examination of the blood. The opsonic treatment is now being employed in several sanatoria. I have used it myself upon a number of patients at the Kalyra Sanatorium, and in this work I have received very considerable assistance from Dr. Helen Mayo.

The results so far tend to show that in early cases the opsonic treatment is very valuable, in intermediate cases it is sometimes also useful, but in advanced cases it is of no use. We have, however, devised a method by which we hope to make the treatment useful also to some advanced cases.

CONCLUSIONS.

Let me now summarise the substance of this paper in the following conclusions :—

1. Consumption is a contagious disease, and every case that arises has been contracted directly or indirectly from a human being or—more rarely—from a bovine animal that is suffering from the disease.

2. All persons suffering from consumption are not capable of conveying the disease to others in an equal degree. Those who practice strict rules of personal cleanliness and disinfection rarely distribute the disease to others, while those whose sputum is free from bacilli are incapable of conveying it.

3. Persons suffering from active consumption are not equally dangerous ; but those who have galloping consumption (acute caseating pneumonia) are extremely dangerous.

4. Every case of consumption should be notified to the Board of Health, and if in the infectious stage he should be isolated until the officer appointed by the board is satisfied that the patient has been properly instructed in the precautions that must be taken to prevent contagion, and until he is satisfied that the patient can be trusted to carry out these precautions. Certificates should be granted to those who are free from infection.

5. Consumption in the early stages is a curable disease, and the cure consists in sanatorium treatment, assisted, perhaps, by injections of tuberculin after the method of Sir A. E. Wright.

EXPLANATION OF THE PLATES.

Plate I.

Fig. 1.—Sputum of an advanced consumptive. It contains many germs, and the patient is therefore a source of danger.

Fig. 2.—Sputum of another advanced consumptive. It is free from germs, and the patient is therefore harmless.

Fig. 3.—The tuberculin test. The temperature chart of a patient free from tubercular disease, showing no rise of temperature after an injection of tuberculin.

Plate II.

Figs. 4, 5, 6, 7.—The positive tuberculin test. Showing no rise of temperature for several months, and a considerable rise following immediately upon an injection of tuberculin. The temperature rapidly falls to normal again.

FIG. 1.

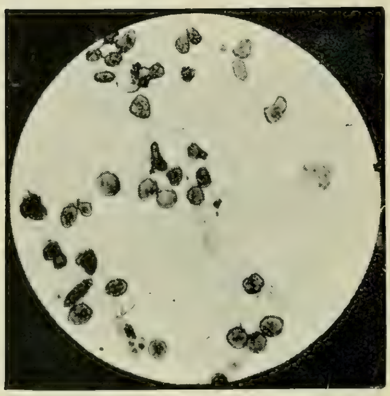


FIG. 2.

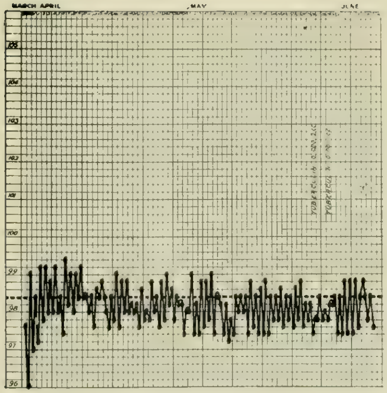


FIG. 3.

Plate II.

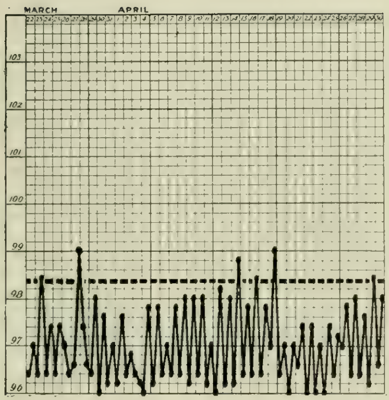


FIG. 4.

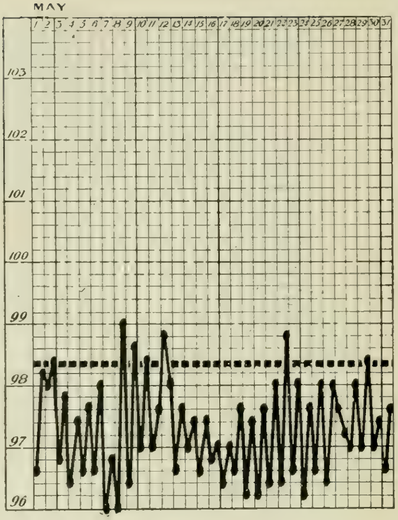


FIG. 5.

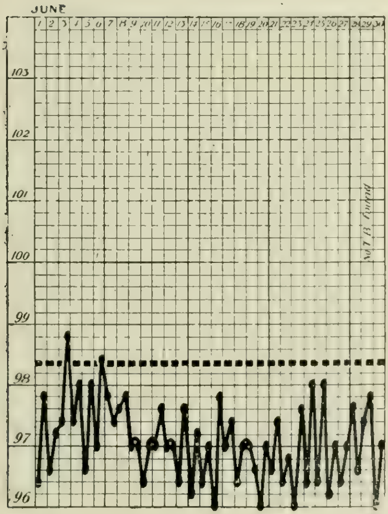


FIG. 6.

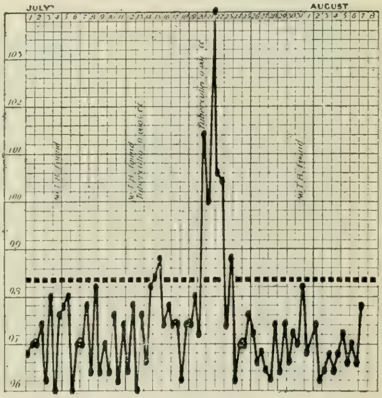


FIG. 7.

Fig. 8.

Fig. 9.

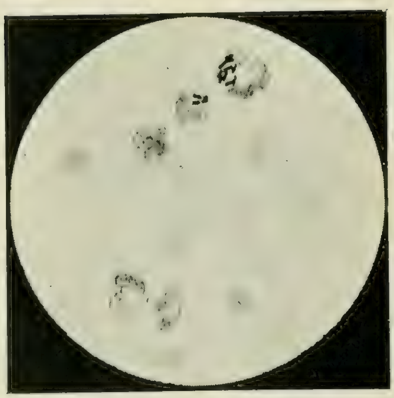


Fig. 10.

PLATE. III

Fig. 8.—A lung completely excavated by tubercular disease.

Fig. 9.—A mixture of tubercle germs, white blood corpuscles, and salt solution has been incubated. The germs are not attacked by the blood corpuscles.

Fig. 10.—A mixture of tubercle germs, white blood corpuscles, and blood serum has been incubated. The germs have been attacked, and are seen lying in the bodies of the white blood corpuscles.

6.—THE ACIDITY OF MILK.

By H. G. CHAPMAN, M.D., B.S.

(Published in Proc. Linn. Soc., New South Wales, vol. XXXIII., 1908.)

7.—PRECIPITANT REACTIONS IN RELATION TO STATE MEDICINE AND HYGIENE.

By Professor D. A. WELSH, M.A., B.Sc., M.D., M.R.C.F.

(Published in the *Australian Medical Gazette*, vol. XXVI., 1907.)

8.—SOME ASPECTS OF DISTRICT NURSING.

By LISTER FOSTER.

9.—THE USE OF PRESERVATIVES AS APPLIED TO CERTAIN FOOD ADJUNCTS.

By P. C. MITCHELL.

Section J.

MENTAL SCIENCE AND EDUCATiON.

1.—THE MOTIVATION OF SCHOOLWORK.

By E. A. RILEY, M.A.

[ABSTRACT.]

The point of view brought forward in the paper is largely that of Dr. John Dewey, formely of Chicago University.

Science enables us to foretell in the region with which it deals. If we apply this criterion to education, can we claim that there is such a thing as a science of education ? Education aims at the production of a certain type of individual, but cannot guarantee the outcome. We shall probably never reach a stage when the result of the educative process can be foretold with the certainty of a chemical reaction. Still, we can even now foretell in a large way. Education has reached a stage of scientific development comparable, say, to that attained by meteorology. It is a science in the making. The results of many sciences are being availed of by the educationist, and scientific method is being applied to educational problems.

In pre-school learning the child learns almost entirely from first-hand experience. He masters a spoken language, learns a great number of facts about man and nature, and acquires a large range of muscular skill. During this period he learns without effort almost, he learns only what seems worth while, and he learns without constraint. This attitude should be retained within the schoolroom, which should provide an environment containing all the elements to which it is desirable that the pupil should be adjusted.

Experience, it has been said, is the best of schoolmasters, but the fees are heavy. I wish to insist that experience is the only true schoolmaster, and the fees are not necessarily heavy. The teachers guidance keeps the fees down. The function of the school is to provide such an environment as will give the necessary breadth and depth of experience to convert the irresponsible child into the fully responsible adult. The teacher is needed because the child has not adequate criteria of judgment.

Science is an abstract of experience. There is only one way to bring knowledge and the child into organic relationship, viz., to reduce its abstractions once more to experience. Symbolic statement can never take the place of experience. Power to reproduce the symbols

must not be taken to signify an understanding of the experience symbolised. Deduction has its place in education; but it should arise only from the results built on inductions made at first hand by the pupil.

Must everything to be learned be learned through first-hand experience? Yes, unless it merely duplicates experience already gained.

The nervous system is merely an apparatus to secure adaptation, and schooling is an artificial arrangement of experience so ordered as to produce in the individual in a few years a development which has taken the race ages to reach.

Educative capacity has been produced by human environment, hence the possibility of education. The potentiality in the child is insistent for development. The teacher provides the necessary stimuli.

Impulse is always the starting-point. The results of impulsive action are sometimes unsatisfactory. The child because of this dissatisfaction begins to control impulse. When the self of impulse fails to satisfy, then the ideal self begins to emerge. The creation of the ideal as a motive is a high function of the school. But the ideal as a motive is not got by formal instruction in morals. Æsthetic presention is the teacher's great duty in morals. When the child is shown a brightly colored picture he feels, "How beautiful." In song, myth, and story the teacher presents concrete ideals of conduct in suchwise that the child feels "How grand, how noble!" Ideals are more akin to æsthetics than to logic.

Since human environment is continually changing we must have a progressive curriculum. Compulsory Latin, *e.g.*, is an anachronism.

The child's impulsive tendencies must be judged not by their actuality but by the direction of their outcome. In avoiding the Scylla of considering that whatever is is right in the child one must not fall into the Charybdis of supposing that childhood is an evil to be escaped from.

The school studies must demonstrate their worth to the child himself at all times. The school should be so organised that there arise obstacles in the child's path which he feels he must overcome, because they are preventing the functioning of his experience. Each obstacle provides a problem for solution. How different the child's attitude to these real problems from his attitude to the artificial ones of the textbook of arithmetic. To teach a child to solve problems to obtain results which are absolutely worthless, both to himself and others, is to manufacture stupidity in the school. Motive should always be intrinsic. It should grow out of the material itself in relation to the needs of the mind of the learner. The school environment should appeal to the pupil's native and acquired interests, and at the same time present obstacles, either intellectual or practical, to the functioning of the self in the desired direction. The problems should have their source in the school studies, not in the teachers.

Froebelian principles must have full play in the primary school if there is to be adequate motivation. Man has reached his present stage of intelligence mainly through the use of his hands. This is a consequence of natural selection, for mental action embodied in muscular activity has had much more to do with the preservation of the race than has purely mental action. Hand work must come to its own; not as a thing apart, but as an aid to all subjects. With primitive man thought has no excuse for being, except as an aid to activity. So, too, with the child.

If studies have to demonstrate their worth to the child, will the formal studies cease? By no means. Take for examples the multiplication tables. These will be obtained by experiment. But let cases arise sufficiently often which demand the knowledge of multiplication facts for their adequate handling, and the child will soon consider the teacher who helps him by a formal lesson to master the facts as a benefactor, and not a taskmaster. The same is true of all formal studies.

The memorising of *ex cathedra* statements on the part of the teacher must cease, and with it the dreary repetitions of the old-time school. Repetition is the main means of memorising meaningless matter: but such matter will have no place in the school which aims at motivation of school work.

Matter must neither be mastered by pure effort or swallowed in sugar coating. If of the right kind, and presented at the proper time, so as to demonstrate its worth, it will be mastered with joy, despite the labor involved, because it is recognised as a means to a desired end. Interest is always present when the object or idea is identified by the learner with the self.

School must become a part of real life, and cease to be a sort of limbo. This will be effected if school life is a real personal experiencing on the part of the pupil if the studies demonstrate their own worth to him, if it provides an arena for the working out of purposes felt by the pupil to be his own, and if it is connected at all points with the pupil's life outside the school.

The pupil who is habitually stimulated by the presence of opportunity, and not by the domination of a master, must achieve power of initiative and civic worth.

2.—LITERATURE FOR CHILDREN.

By B. S. ROACH.

[ABSTRACT.]

Reference was made to the coincidence of having as the President of the Science Congress Dr. Howitt, whose parents, William and Mary Howitt, did so much for children's literature during the last century. After a brief analysis of the stages passed through by the child's mind in the development of a taste for literature, De Condillac's generalisation—" The experience traversed by the child epitomises the history of the race "—was stated, and it was shown how the fairy story was appreciated by primitive man as it is by the child of to-day. The old fairy story was then contrasted with the efforts of modern writers of the same class of literature. Hans Christian Andersen excelled all others in his fairy stories. The brothers Grimm possessed greater learning, but lacked Andersen's spontaneity and simplicity. The next writer discussed was " Lewis Carroll," the pseudonym of an Oxford don, who lived a dual literary existence, writing mathematical works and a series of children's books, of which the best is " Alice in Wonderland." Then followed an account of books dealing with Greek mythology, and Eastern tales, of which the " Arabian Nights " is a type. Books narrating adventures met with when civilised man, in settling a new country, came in contact with savage life, came next. The " Secret of the Australian Desert," by Ernest Favenc, and " The Captain-General," by W. J. Gordon, were commended. Such books, Mr. Roach said, helped to keep in boys the spirit of adventure, which had been such an important factor in expanding the British Empire. " Treasure Island " and " Kidnapped " were books of another class of adventures, and as they were written by a man of genius they were among the treasures of children's literature. Books relating to school life, such as " Tom Brown's Schooldays," were touched upon, and it was stated that up to a certain period girls would read with equal enjoyment the books ostensibly written for boys. The periodicals such as *The Boys' Own Paper* and *The Girl's Own Paper* were highly praised, and their matter contrasted with that in similar periodicals of the last generation. The poetry read by children was next briefly mentioned. In conclusion, Mr. Roach emphasized the importance of inculcating a habit of reading in the young, and spoke of the danger of reading being neglected through the great stress laid on examinations and the time being used in teaching other subjects.

3.—EDUCATIONAL METHOD, WITH SPECIAL REFERENCE TO THE TEACHING OF MATHEMATICS AND PHYSICAL SCIENCE.

By W. R. JAMIESON, B.Sc.

[ABRIDGED.]

Educational method scarcely yet justifies its inclusion among the departments of science. The term education is here used in the more restricted sense of mental training and regarded as an application of psychological science, a branch of knowledge which has only recently been brought within the sphere of experimental research. When in the future more exact knowledge is available as to the processes of the mind, and especially as to its development, the right method to follow in the training of the young will be more clearly evident. In the meantime we must make the most of the knowledge acquired by experience, and it is by virtue of such experience in the course of which I have been led to changes in method that I venture to deliver the following remarks. My experience has been acquired in the region of science, and its results are appropriately made known before an association whose avowed function is the advancement of science. Whatever may be the immediate origin of new acquisitions to science, its general advancement is largely dependent upon the earlier stages of scientific training. It is with this phase of the subject that I propose particularly to deal. There has been a marked awakening in England during recent years in regard to the urgent necessity for improvements in the teaching of science through all its stages.

No more searching criticism may be applied to present-day methods than a comparison with those advocated by Huxley, who first gave an impetus to the movement which has since been steadily gaining momentum, of sound training in scientific method.

The distinctive feature of scientific method should be that the learner deals with things and not with mere words. The greatest difficulty to encounter in securing the efficiency of scientific training is the thraldom of symbols, whether of words, the vehicle of ordinary description, or of the special symbols of mathematics and science. How often do we find that a scholar has no real knowledge of things apart from their symbolic representation. This difficulty can only be met by supplying and ever keeping prominent a concrete basis of actuality. Only to the extent that the learner is able to draw correct conclusions from that which he is aware of by his own perception can we claim to have rightly cultivated the scientific faculty. By scientific method we mean, in brief, the acquisition of knowledge by inferences drawn from the observations of experience and experiment. The learner is in direct contact with reality and is not relying on words uttered or read, of whose meaning he may form totally inaccurate mental pictures. Now, in order to draw right inferences from phenomena, it is necessary in the first place that he should observe correctly and fully. The cultivation of the powers of observation is the first step to ensure in a scientific training. This is nowadays accepted as a truism, and yet how much we often fall short of making this an essential feature. How much easier is it for a teacher to unload a bundle of information stamped with the authority of lecturer or text-book than to put the learner in the way of acquiring the same knowledge at first hand. To the extent that final results are placed before the learner is his scientific training short-circuited. Dogmatic teaching is to be avoided, and the textbook relegated to its right place—and that a very inferior one—so that the learner may acquire the habit of trusting his own senses in preference to the dicta of the book.

Looking back on my own experience as a student, I see various stages through which scientific teaching has evolved. When first I studied chemistry it was with the sole aid of little Roscoe—no experiments, no laboratory. Next I attended lectures accompanied with demonstrations, and later on I came into contact with actual investigation. I well remember the inspiration which I felt when attending lectures on work which had been the special study of the lecturer, and seeing the apparatus from which new and important scientific results had been obtained. There was all the difference between science and non-science. I felt that I had entered the inner shrine. Previously I had gazed upon the outer walls, surveyed its external appearance, but here was the delight attaching to a view of the inner mysteries. Borrowing Huxley's metaphor, I now saw the faces of the pictures which had formerly been turned to the wall. To come into touch as a student with actual scientific research is a priceless boon. The inspiration drawn from the latter is a lasting source of delight; the alternative is, to say the least, deadening. That the atmosphere in scientific training should reek of research is generally admitted. Professor Armstrong has long advocated the heuristic method on this principle in even the most elementary work. A former teacher of mine once remarked to me that there is not the simplest work handled in the laboratory which may not be the subject of scientific research. It is not meant that valuable results meriting publication should be sought after, but the spirit of inquiry into actual facts should be vigorously inculcated. How infinitely fuller of meaning is anything actually observed in the laboratory or elsewhere than that which we merely read or hear. What is life itself but the accumulated inferences drawn from daily experience, the more successful as our observation has been closer and our inferences more accurate?

The mind of the youth being in course of development is unable to appreciate and clearly realise the information unloaded before him from the stores of knowledge acquired by those of greater years. He must see for himself ere the knowledge becomes incorporated into his being. I repeat that the advantages derivable from a proper training in science depend upon the close contact on the part of the learner with actual things.

I do not intend to deal with scientific as compared with literary and classical training; yet it is interesting to note that in the teaching of literature the scientific method is asserting itself. Learners after the old fashion first acquainted themselves—supposedly—with certain definitions, grammatical rules, laws of syntax, armed with which they were to discover the thoughts embodied in the writings of English authors, and further to depict their own thoughts for other readers. But will not everyone admit that a knowledge of English literature and composition is properly attained by the experimental method of trial and error through reading and writing. A child learns to read and gradually to understand the full meaning of what he reads. Gradually also he learns to appreciate the definitions of the parts of speech, the full meaning of inflections and laws of syntax. This is the final and not the initial stage of his acquirement of a knowledge of the structure of the English language. If a long experience is necessary for the attainment of a real knowledge of English literature and composition, in the course of which that knowledge is gradually systematised by means of definitions, laws, and rules, is not a much longer experience requisite to draw out the thoughts of ancient writers clothed in the garb of a dead language ? To learn a foreign language, and more particularly a dead language, and also at the same time to clearly appreciate the thoughts expressed in terms of it, constitute a double object whose attainment requires for the average youth the expenditure of a considerable amount of time. With an overburdened curriculum the matter of compulsory classical training resolves itself thus—is it worth the time ? To my mind it is not. Many of us have in post-student days undertaken the labor of acquiring a foreign language in order to be conversant with the results of scientific research. How relatively easily we are able to make out the sense of the author when we are familar with the subject matter. The schoolboy has no glimmering of the story until he has construed the passage. Matthew Arnold, an ardent classicist, considered that Cicero and Homer would always be caviare to the average schoolboy. So far as concerned the requirements of the average youth, he recommended the study of the Latin Vulgate. Provided with a knowledge of the English language, a boy may rationally acquire a knowledge of a foreign language by comparing the expression of known subject matter in that language with its expression in the mother tongue.

The average boy parts with Latin and Greek forever when he leaves school. The sum total of his classical knowledge is negligibly small. For this reason I think his time would be more profitably employed in studying the mother tongue. Tangible results may here be attained. The boy should leave school with a good knowledge of English literature, which he may increase in after-life. He is also provided in this way with a mental recreation of inestimable value. If further language study is desirable to give greater mental breadth, a modern language would be preferable, to be taught in the early stages by word of mouth.

I anticipate that one result of the extension of our knowledge of psychological science will be to justify the application of scientific method to all branches of knowledge, whether literary or those commonly denominated scientific. Didactic teaching does not reckon with the mental development of the learner as a predominant factor in the training process. The mental processes in the young are essentially inductive. Intelligent life is first aroused by sense impressions. Inductions are formed consciously or unconsciously. To the young mind the mental operation of logical deduction is quite foreign. All knowledge which may be tested by the touchstone of reality, all science in fact, is essentially and fundamentally empirical. We who have felt the inspiration of science probably when younger thought it possible for science to ultimately unriddle the mystery of the universe. As the mind matures, we come to realise that the role of science is not to solve the riddle of the universe, but to supply a wider extent of knowledge from which to construct a more reliable basis for the right ordering of our actions. For the better comprehension and utilisation of the vast store of knowledge, its various items are pigeonholed and labelled as generalisations or laws. In a given subject the classification should be proportionate to the range of work. In the teaching of geometry and chemistry by generally prevalent methods, we may see a disproportionate classification. In chemistry, the various items are isolated, each item as it were going into a separate pigeonhole. . On the other hand, in the teaching of geometry by Euclid's system, all the items are bundled into one huge pigeonhole, so that here, also, we lack that classification so essential to a clear comprehension of the subject. The teaching of geometry by a system elaborated by an ancient Greek philosopher strikes me as an unparalleled educational anachronism. It is true that for many years a powerful attack has been directed against this anachronism, but the result has been rather by way of a treaty than of an overwhelming victory. It is little to our credit that the citadel has withstood so well the onslaughts made on it. Were the educational fallacy involved in the Euclidean mode of teaching geometry once fully realised, I am sure that its death knell would be instantly rung. Certain arguments have been advanced against the abolition of Euclid. They have been repeated almost since the period of my earliest recollection. Euclid, it is claimed, provides excellent mental training, and further, if it were abolished, what would take its place? To put the matter plainly for the latter claim, the centralised examination system largely in vogue requires an accurately specified syllabus. Euclid admirably suits this requirement. The necessity for a dead-level platform in geometrical teaching to supply the facilities for centralised examination long delays a much needed reform. Geometrical teaching is not alone in suffering disability from this cause. Professor Perkin, in a presidential address to the British Association a few years ago, condemned the inferior type of teaching in practical chemistry described as test-tubing. He attributes its long continuance solely to the facility with which it lends itself to examination. We may trace, I believe, the great development of the present examination system to the institution by Lord Macaulay of competitive examinations to supersede the older system of nomination. As a rival to the method of nomination, no doubt the Indian Civil Service Examination was at that time preferable. The lofty position which this service has always taken in popular estimation has drawn the youths of highest talents within its circle, and set a mark upon its competitive examinations as the aim of the ambitious and talented. Yet the arguments adduced by Macaulay in favor of adopting this method of appointment expose the cardinal defect of the examination system. Sir George Trevelyan, in his "Life of Macaulay," quotes Macaulay's justification of the system which he instituted. "It is said, I know, that examinations in Latin, in Greek, and in mathematics are no tests of what men will prove to be in life. I am perfectly aware that they are not infallible tests; but that they are tests, I confidently maintain . . . . . . Whether the English system of education be good or bad is not now the question. Perhaps I may think that too much time is given to the ancient languages and to the abstract sciences. But what then? Whatever be the languages, whatever be the sciences in any age or country which it is the fashion to teach, the persons who become the greatest proficients in those languages and those sciences will generally be the flower of the youth; the most acute, the most industrious, the most ambitious of honorable distinction. If the Ptolemaic system were taught at Cambridge instead of the Newtonian, the senior wrangler would, nevertheless, be in general a superior man to the wooden spoon. If instead of learning Greek we learned the Cherokee, the man who understood the Cherokee best, who made the most correct and melodious Cherokee verse, who comprehended most accurately the effect of the Cherokee particles, would, generally, be a superior man to him who was destitute of those accomplishments. If astrology were taught at our universities, the young man who cast nativities best would generally turn out a superior man. If alchymy were taught, the young man who showed most activity in the pursuit of the philosopher's stone would, generally, turn out a superior man." The competitive system of examination is associated with a uniform type of teaching, no matter whether it be modern or ancient. It tends to perpetuate former-time methods, and to discount divergences from a stereotyped plan. The centralised system of external examination tends to a uniformity which retards the progress of improved educational methods. The ideal in teaching, however difficult of attainment, is the antithesis to this, namely, to reach the mental faculties of the individual. England has in recent years given us an example in decentralisation. When I was a student that famous examining body, the University of London, stood out prominently as granting by its degrees a hall mark very generally coveted. No proof of training was required, but merely the satisfactory accomplishment of an examination held by examiners whose merit it was to be otherwise absolutely ignorant of the candidates who came forward. Germany was looked askance at with its multitude of degree-conferring universities. But what is the position to-day? Quite otherwise. Numerous universities have arisen in various centres in England, each conferring its own degree, and with this advantage, that a known type of training corresponds to each degree. The same decentralisation has been secured in the establishment of secondary and technical schools throughout the length and breadth of England.

These are under local control, and conducted in harmony with local conditions. The weakness of external examination is that the examiner cannot be certain that a correct answer to a question guarantees a real knowledge on the part of the candidate. He is not certain whether the written words are opaque or transparent to the candidate. Take the case of a Euclid examination. I have frequently seen examiners' reports, and I have had personal experience myself to the effect that candidates do the set bookwork satisfactorily, but in the majority of cases fail lamentably with problems to be solved. The examiner has no certainty that the candidate really knows what he correctly reproduces; in fact, the failure to apply his assumed knowledge is *prima facie* evidence that he does not understand. It is the same with chemistry. A certain amount of work is got up, correctly reproduced at the examination; but is there any guarantee that the student has a real knowledge of what he correctly describes? The *viva-voce* examination would be far preferable to the written paper. An examiner could cross-examine a candidate, then soon form a fairly reliable opinion as to his capability. He could find out what a candidate knows rather than what he does not know. Written papers by external examiners tend to artificiality, and to a magnification of detail of the subject. With a limited scope of work questions on important matter cannot be repeated frequently, and the examiner after a time is generally in the unenviable position of groping into dark corners of the subject for some novelty. Rightly, however, a knowledge of the important principles should be insisted on every time. Often it seems that the examiner assumes the candidate's knowledge of all that is essential, and tests him only on the unimportant matters of detail. This reacts on the teaching, and the pupil acquires a distorted view of his subject; the details are magnified and the general principles shrunken.

It would be a great improvement to allow candidates at written examination the use of books—say, one textbook and his own notebook. This would do away with mere pretence of knowledge. It would tend to much more effective training by obviating the great expenditure of energy absorbed in memorising so much description. A boy's school training should prepare him in every way for his work in the world. When he has passed from school into the world he is free to refer to books for any information he requires. The important thing to him is whether he is able to make use of that information. Would it not be better to realise this during his education? I have more than once allowed candidates the use of a notebook in a mathematical examination. In such a case the questions all ask for something to be done, and the candidate can fall back on his notes for, say, some formula which he requires. The strain on a boy during his training would be immeasurably relieved were the huge demand made on his memory for examination purposes cancelled. Ample time would then be available for developing his power to think, which, after all, is the great object to attain.

This provision, together with the co-operation of the teacher, would enable examinations now of doubtful utility to perform a useful function. This innovation may seem strange to those who have long thought that a teacher is not capable of examining his own pupils. The teacher, who is expected to stand at a high moral elevation, is thought unable to exercise impartiality in examination. This one obstacle prevents the only competent judge from exercising the function of examiner. However, it is being gradually recognised that the teacher should have at least an equal voice in examining. Professor Sir Wm. Ramsay, in an address a few years ago to the students of University College, Bristol, said that a teacher who is not to be trusted to examine is not to be trusted to teach. The following extract from *Nature*, November 8th, 1906, shows that these views are in course of recognition :—" The last report of the Scotch Education Department, dealing with secondary education in Scotland, directs attention to a new departure in the method of awarding leaving and intermediate certificates. The report states that last year the aid of the teacher was actively enlisted in determining the question of success or failure, and that much weight was attached to a pupil's school record as properly attested by his teacher in the allocation of school bursaries. The secretary puts upon record that events have completely justified the confidence of the department. The teachers as a body have risen to the responsibility that was placed upon them. Of course, there were cases of miscalculation by the teacher, but these were rare exceptions. The success which this Scottish experiment has met in the direction of humanising the methods of appraising knowledge and intellectual training with the object of selecting the best pupils should encourage those responsible for examinations south of the Tweed to increase their efforts to abolish the mechanical character of many of the current tests to which young students are subjected."

With a properly organised State educational system the need for examinations would largely disappear. Many of us hope to see in every sufficiently populated centre a complete local system of education, with an even gradation from primary school to secondary, and thence to technical school. In any school at the present time the teacher passes the pupil on from grade to grade when he proves himself fit for promotion. It is to the interest of the teacher to deal in any grade with material of as uniform a character as possible. The teacher has all to lose by moving up a pupil who is incompetent for the higher work. When the highest grade of the school is reached the boy would pass into the hands of the teacher of the higher grade school. Here the boy might undergo examination, in which the teachers of the two schools would co-operate, to decide as to the fitness of the boy to enter the higher grade school. In America, I believe, even this examination is often not called for. The university, for example, employs an inspector who studies the work of schools from which pupils enter the university, and, if satisfied, allows the teacher to pass in those pupils whom he considers eligible for entrance.

History repeats itself, and the system of nomination which was superseded by Lord Macauley 150 years ago is now undergoing revival. In the case of both the Rhodes Scholarships and the 1851 Exhibition

Research Scholarships—both of considerable value—the examination test has been superseded by the more reliable method of nomination.

As year after year passes by there is a tendency to add to the number of subjects of a school curriculum. It is on this account all the more necessary that the strain on the memory should be reduced to a minimum, and further desirable that all superfluous portions of a subject be excised. A teacher should have a reason for every part of the subject which he teaches, just as an examiner should be able to say why it is important that the candidate should know what he is asked about. The importance of mathematics in education is fully realised, yet I do not think we can give satisfactory reasons for much that is taught. Take arithmetic, for instance. Twenty years ago arithmetic seemed to be dealt with largely from the commercial aspect. This, perhaps, is not strange in a country whose prosperity was due to its commerce, and at a time when scientific training was practically unknown in schools. Interest, discount, exchange and barter, alligation, medial and alternate partnership, stocks and shares, loomed large on the boy's arithmetical horizon. Most of these rules have passed into oblivion, though a vestige remains in stocks and shares which still remain a *sine qua non* for a boy's arithmetic proficiency. Personally I think that with the exception of interest, which is a mere matter of percentage, the problems of the stock exchange, of the insurance office, and of the discounter's profession are best omitted from a general course of arithmetic. They are part of commercial arithmetic, and are best taught by a specialist in the technical school.

Another application of the pruning knife should be to recurring decimals. I have a vague recollection of rules for recurring decimals which caused me considerable perplexity at school. I have never had occasion to teach arithmetic, and I have never needed the rules in my own calculations, so that I am ignorant of their nature at the present moment. Any special rules for dealing with recurring decimals are unnecessary, because five significant figures—or six at the outside—are sufficient for all practical purposes to represent magnitudes. With six figures we have a degree of accuracy of at least one in a hundred thousand, and at most one in a million. It is rarely one has to do with quantity whose measurement justifies more than five figures. Every teacher knows how difficult it is to correct in pupils the abuse of figures. It is best, I think, to insist on restricting numbers to five or six figures, on the understanding that the purpose is not to shorten the work but to drop all figures which are meaningless. In most arithmetical textbooks it is the custom to require decimal sums to be worked out to a definite number of decimal places, irrespective of the total number of figures. This is illogical. The result should be required correct to five significant figures, irrespective of the decimal place. Working on this principle no notice need be taken of recurring decimals: the five significant figures are made up without taking particular notice of any recurrence.

In dealing with the simplification of arithmetical expressions the result is often left as an integer, with a fraction of a high and incommensurable denomination. Of what meaning is the number $23\frac{15}{37}$, for example? What quantity is measured in thirty-sevenths? No very complex arithmetic expressions need be given to the pupil to simplify; in actual work the use of decimals obviates the need for using such. In the ordinary case, in practice the numerator and denominator each consists of several factors to be multiplied and the denominator divided into the numerator. The result is taken out in decimals to five significant figures, and the decimal portion converted, if necessary, into aliquot parts of the quantity involved.

The subject of proportion is one of great importance, and one capable of improvement in its treatment. Originally it was taught as the rule of three, with the dot symbols of proportionality. There was no great power in this. A modern treatment is that known as the unitary method, a method which I consider unsatisfactory because illogical. One might cite many instances. The following will suffice: The volume of a gas is directly proportional to its absolute temperature. If the volume of a quantity of gas at the absolute temperature 350° c. is 293 c.c., what is its volume at 372° c.? According to the unitary method we ask—if the volume is 293 c.c. at 350° c. what is its volume at 1° c.?; from which is obtained its volume at 372° c. The result is correct, but the proportionality does not hold down to 1° c., and there is no meaning in the volume obtained at 1° c. The proportionality between two quantities is best represented as a fraction. For example, The proportion between the above two temperatures is $\frac{372}{350}$, and the proportion between x, the required volume, and the given volume is $\frac{x}{293}$. These fractions are identical in value, and x may be easily calculated. Again, the subject of proportion should include not only simple proportion, but also inverse proportion and proportionality to any power. In all cases the proportionality would be expressed by the equality of two fractions of the type $\frac{a}{b} = \frac{c}{d}$, and, three of the four quantities being given, the fourth may be calculated according to an obvious and simple rule. As an example: The area of a circle of 8in. diameter is 50·3 square inches, what is the area of a circle of 13in. diameter? The area of a circle being proportional to the square of the diameter, we have the identity $\frac{169}{64} = \frac{x}{50{\cdot}3}$ $\therefore x = \frac{50{\cdot}3 \times 169}{64} = 133$ square inches.

The nature of proportion is illustrated at a later stage by reference to similar triangles, and more especially by its graphical representation the straight line plotted to cartesian co-ordinates.

When the pupil passes from arithmetic to mathematics, generally, he has to encounter a difficulty which requires time and patience for its removal. In arithmetic he is at home with concrete cases, but now he has to pass from the concrete to abstract, from the particular to the general. A single chapter on numerical substitution which prefaces most textbooks on algebra is treating this difficulty very lightly. The average textbook on algebra assumes that this difficulty is really overcome by studying the first chapter, and launches out immediately into the ocean of symbols. From this moment the average boy is lost. He henceforth juggles, and often dexterously, with symbols, but the realities behind the symbols are veiled from his eyes. The late Professor Clifford said that "Algebra which cannot be translated into good English and sound common sense is bad algebra." How many boys can translate their algebra into good English? Beyond time-honored problems on the market price of eggs, or the ages of Tom, Dick, and Harry, there is no interpretation of the symbols in terms of things.

Along with algebra a boy generally takes up the study of Euclid. I have referred already to the unsuitability of Euclid, and will state the reasons. Euclid is a system of geometry. Given a knowledge of geometrical facts, Euclid shows that they are all deducible from a minimum of premises. These premises are arbitrary. The effort is purely philosophical; but the point to recognise is that the geometrical facts are antecedent to and independent of any philosophical system. No deductive process gives any boy a clearer perception of the fact that the join of two points on the circumference of a circle lies within the circle, than he acquires from his sense of sight. The boy in the first place should acquire his knowledge of geometry. His inductions may be classified, but there is no importance attaching to the fact that they are all capable of deduction from certain arbitrary assumptions. There is no more certain theorem in education than that the concrete must precede the abstract, and yet it is disregarded when a boy has to pass through the portals of metaphysics to learn that the angles at the base of an isosceles triangle are equal.

Another serious defect in the teaching of mathematics, to my mind, is its specialisation. The various branches are kept separate instead of combined into a harmonious whole. I will outline what I consider to be a sound, useful, and intelligent course of mathematics within the range of the average schoolboy. To meet the difficulty which the student experiences in passing from the particular to the general, every symbol used refers to something definite and apparent to the pupil. This is accomplished by basing the work largely on mensuration. In the experimental study of mathematics it should be regarded as the first stage of physics. The pupil should make actual measurements himself as far as possible, draw to scale, measure and calculate results. The common geometrical surfaces are thus dealt with. After working out calculations in particular cases of the same type, he passes to the general case, using symbols instead of letters. He thus obtains the formula suiting the general case. For example, he draws and calculates the area of various equilateral triangles. He then expresses the area of an equilateral triangle as a function of its side, and from the formula deduces the side as a fraction of the area, from which he can construct an equilateral triangle of definite area. He learns to measure, to calculate, to generalise, to operate upon algebraical symbols.* At the same time he learns the most important geometrical facts.† The nature of loci is taught as greatly facilitating the generalisation of geometrical truths. Further, he learns the theory of limits and the nature of symmetry, which are both powerful means of understanding geometrical truths. As a good instance of generalisation we may consider the deduction of many useful facts from the theorem established experimentally that the locus of points equidistant from two given points is the perpendicular bisector of their join. By the aid of this we may co-ordinate the usual methods of drawing perpendiculars, bisecting angles and straight lines and combined with the idea of limits the drawing tangents to circles, &c. The circular measure of angles should be considered here as furnishing the basis for the practical construction of equal angles, drawing parallels, &c. The nature of limits is well brought home by inscribing a square in a circle, bisecting the quadrants, and re-bisecting until further bisection is beyond the power of practical construction. The pupil learns to regard a tangent as the limit of a chord. All this is quite within the range of the average boy when treated experimentally and not merely formally; and he prepares himself well for the later work and the application of mathematics.

Then the solution of equations is dealt with, and the equations to be solved are plotted on squared paper. I am accustomed to have all the mathematical work done in squared paper books, with the exception of mere arithmetical computation, which is made in a scribbling book, and the results recorded in the squared paper book. The pupil learns how to plot a straight line, and to regard the linear equation $y = ax + b$ as the symbolical representation of simple proportion. He learns experimentally the nature of the trigonometrical tangent, the relation between the trigonometrical tangents of perpendiculars and parallels, and draws perpendiculars and parallels in this way; how to calculate the length of the join of two points, the co-ordinates of the mid point of the join, and other facts of the analytical geometry of the straight line. Suitable physical data are supplied

* The inductive method is ever kept prominent. We want a student, for example, to understand the geometrical nature of a prism. A large number of solids are shown the pupil, cryst allographic models being serviceable on account of their variety. The teacher picks out and groups together all prisms. The pupil examines them, to find out their distinguishing characters. If his answer is too comprehensive he may be shown other solids which, on his saying, would be included in this group; on the other hand, if his distinction is too restricted, some of the solids placed in the group would be excluded. When the pupil has learnt in this way how to distinguish prisms from other solids, the prisms may be divided by the teacher into two groups—right and oblique. The pupil is to discover the basis of this differentiation. Then, again, the right prisms may be divided into square, rectangular, hexagonal, &c. The knowledge gained by the class in this way is far deeper than that gained by a didactic treatment of the definition of a prism, though this would occupy only a few minutes.

† No time is wasted over any proof that the opposite vertical angles of two intersecting straight lines are equal. The *pons asinorum* vanishes into thin air as the pupil realises the symmetry of an isosceles triangle.

which plot out to a straight line. He learns, also, how to deduce the equation to a given line drawn on the paper. Linear equations are solved graphically and then by calculation.

Then the parabola is studied by plotting physical data, such as the displacement curve of a freely-falling body, the area of an equilateral triangle as a function of its side, &c. Its focus and disectrix are obtained by construction. Also in this connection the differential of a function is dealt with on the principle of limits, and applied to the construction of tangents and normals at any point of the parabola. It is sufficient for some time that the pupil should be able to differentiate a power of the independent variable. Then, in this connection he studies the solution of quadratic equations. Here, again, we call in mensuration to furnish concrete instances. The area of the total surface of a cylinder, or of a cone, is a quadratic fraction of its radius; the volume of a conical frustum is a quadratic fraction of the radius of one end. These problems on the cone and cylinder are worked out by solving quadratics from formula and graphically by parabolic intersections with a straight line.

The rectangular hyperbola is the next curve studied as representing inverse proportionality. The reciprocals of numbers are plotted against the numbers and physical data are supplied for plotting. The function is differentiated, and tangents and normals drawn therefrom. The so-called simultaneous quadratics are solved where one equation is the hyperbola and the other the straight line, or the parabola and straight line are solved.

Then the circle is studied on the same plan. The functional equation differentiated, tangents and normals drawn, simultaneous quadratics solved where one equation is that of the circle.

Similar triangles are dealt with; the proportionality of corresponding sides shown, and this proportionality expressed by the trigonometrical ratios. Simple theorems connecting these ratios are established.

The course above outlined has given me much greater satisfaction and led to more useful results than the orthodox treatment of algebra and Euclid, from which I have gladly escaped.

We come now to a subject, the teaching of which has been the occasion for much discussion, and for many attempts at improved methods—chemistry. The search for new methods in the teaching of this subject has arisen on account of didactic methods into which teachers had drifted in dealing with a subject essentially experimental. Two methods in particular have gained prominence of recent years, the heuristic and the historic method. The former is the method strongly advocated by Professor Armstrong, and carried out successfully, I believe, in Irish secondary schools. According to the latter method the pupil retraces the ground covered by early experimenters, in discovering, for example, the nature of combustion, and the existence and properties of the commoner gases. I can see no special force in this method. It is difficult to put oneself in the particular circumstances surrounding the life and work of investigators living some centuries ago.

The heuristic method requires essentially that the pupil should make his own knowledge as far as possible, and stands for the experimental, as against the didactic method. Its value is therefore undeniable. When first I taught chemistry it was by the orthodox method of lectures delivered in the classroom, combined with the usual course of qualitative analysis carried on simultaneously in the laboratory. After a time I became dissatisfied. I noticed a lack of cohesion between the unfolding of prescriptions in the lecture-room and the dead routine of cut-and-dry analysis in the laboratory. Then I remembered that chemistry was an experimental science, and should be learned in the laboratory, and I took it as my guiding principle that the pupil should acquire his knowledge in the laboratory, and that the lecture-room work should be based on this. I came to realise that the memorising of brief and altogether inadequate bookish descriptions of the preparation and properties of hundreds of different substances, of which the pupil knew practically nothing, represented no actual gain of power to the student. After much trying I evolved a method in which the lecture-room dwindled almost out of sight, and the laboratory occupied its right place as almost the sole factor in the acquirement of a knowledge of chemistry. It is interesting to know that in recent years the practice has been coming into vogue of designing the scientific department of a school without any provision for lecture-room. This is the case in the new buildings of Christ's Hospital and Dulwich College. As I regard the matter, in the first stages of experimental science the student works entirely in the laboratory under the teacher's guidance. As he advances, and acquires an ordered knowledge of chemical phenomena, systematic theorising may be very gradually introduced. The far greater proportion of the work done must always be experimental. Pure lecturing can only be effective in proportion as the listener is on the same plane as the lecturer with regard to ability and interest in the subject.

One can hardly conceive anything less adequate to the acquirement of the spirit of scientific method than the plan of attending descriptive lectures in the lecture-room, simultaneously with carrying out formal qualitative analysis in the laboratory. Neither is there any co-ordination between the two parts of the work, nor does either in itself constitute the adequate treatment intended. The more common type of chemical textbook introduces the pupil to a description of substances, the great majority compound, classified according to the elements. This system, admirably suited to a work of reference, enables the learner to acquire a knowledge of chemistry to the same extent as a dictionary would enable him to acquire a knowledge of literature. It ignores the established educational axiom of the necessity of proceeding from the known to the unknown. Hydrochloric acid should come before hydrogen, and water before oxygen, as the more familiar should always precede the less familiar. The first thing which I put before a student commencing the study of systematic chemistry is hydrochloric acid. It has definite and easily observed properties, and is, apart from chemical constitution, no more complex than hydrogen or chlorine.

Water is an entity of no more complexity, apart from chemical constitution, than hydrogen and oxygen. One might even go so far as to omit the phrase, "apart from chemical constitution," for many elements—for example, carbon—have a more complex constitution than the compound water. The common textbook classification of substances based on the periodic classification of the elements produces in the minds of pupils the fallacious idea that an element necessarily has a simpler constitution than a compound. I should like to say here that I have found in my teaching great need for names to distinguish the elementary radicals from the elementary substances. We have many names for compound radicals, but none in general use for simple radicals. Ostwald, in his textbooks, has given names to many simple ions, distinct from the names of the elements themselves, but they are largely metallic ions. Thus water is a compound of 11 per cent. hydryl and 89 per cent. oxyl, applying these names to the simple radicals H and O. Water is a compound of hydryl and oxyl; oxygen is a compound of oxyl with itself, so hydrogen is a compound of hydryl with itself. A dilute solution of hydrochloric acid contains free hydryl, but not free hydrogen. The atomic weights refer to the radicals sulphyl and phosphyl, and not to the known solids.

I will briefly describe what I have found to be a good way to get pupils to appreciate the more important principles of chemistry by working in the laboratory. The pupil is given some hydrochloric acid, a substance of common occurrence outside the laboratory; then he is given some zinc, a material with which he is already familiar, and he has to dissolve the zinc in the acid. This leads to a knowledge of hydrogen incidentally, and to that of zinc chloride mainly. He is given other metals to test in the same way, to find out which, like zinc, are soluble, and, in the case of the soluble metals, to extract their chlorides. Then he studies the action of acids on litmus, he is given sodium hydroxide to neutralise and extract sodium chloride. The nature of alkalies is dealt with. Ammonium chloride is prepared, ignited, and also mixed with lime.

A metallic oxide, such as copper oxide, is next dissolved in the acid, and the copper chloride obtained. Also a metallic hydroxide, such as that of iron dissolved up, and the chloride extracted. Then a metallic carbonate is dissolved, and the chloride obtained. Lastly lead chloride is obtained by precipitation, and the pupil finds out what other chlorides may be obtained in this way. With those chlorides which he finds insoluble he tries the solvent action of given liquids, by which he works out the means of distinguishing them. So far this work is systematised under five modes of forming metallic chlorides.

Then he obtains potassium chloride from chlorate, with the object of observing the properties of oxygen. He next performs the reverse process, namely, obtaining the acid from the chloride, and then by oxidation generates chlorine. The chlorides are finally compared with one another.

Sulphuric acid is next taken, and similar work done under the same five headings, which affords the opportunity for repetition of the same chemical principles. He has studied the insoluble sulphates, and at this stage is able to recognise a chloride and a sulphate, and the metals which form an insoluble chloride or sulphate.

Nitric acid is dealt with next on the same plan, nitrates being formed by the general methods, and the same general principles explained. The production of nitric acid from nitrates is carried out, and oxidation and reduction studied by experiments with ferrous sulphate, potassium permanganate, and nitric acid. The complementary nature of oxidation and reduction is brought out, and the wider meanings of these, as signifying the increase or decrease in negative radical, whether the simple oxygen radical or the negative radical of an acid.

Hydrobromic and hydriodic acids are next dealt with. Bromine and iodine are studied, and converted by aqueous sulphuretted hydrogen into the halogen acids, from which, by neutralisation, the salts are obtained. From these salts the elements are reproduced, differences being observed, so that they may be each recognised.

Carbonates, sulphites, and phosphates are next dealt with, studying in the same way the most important reactions which may be grouped under these headings. All through the work, which is very inadequately described here, the student is led to find out as much as possible for himself. Chemical equations are eschewed, the chemical changes involved being represented by less abstract methods. A great number of chemical changes are metathetical, and easily represented without the use of symbols. For example, the precipitation of silver chloride is represented thus—

$$\begin{array}{lllcl} \text{Silver} & \diagdown\!\!\!\diagup & \text{nitrate} & \rightarrow & \text{Sodium nitrate} \\ \text{Sodium} & \diagup\!\!\!\diagdown & \text{chloride} & & \text{Silver chloride} \end{array}$$

Also the production of copper chloride from copper oxide, thus—

$$\begin{array}{lllcl} \text{Copper} & \diagdown\!\!\!\diagup & \text{oxide} & \rightarrow & \text{Copper chloride} \\ \text{Hydrogen} & \diagup\!\!\!\diagdown & \text{chloride} & & \text{Hydrogen oxide} \end{array}$$

The last exercise is on the sulphides, salts of hydrosulphuric acid, excluding metals, which he has learnt to form in soluble chlorides. All other metallic salts are first examined, and divided into two classes, according as their sulphides are soluble or insoluble in water. Some he finds to be insoluble in hydrogen chloride, others soluble in hydrogen chloride, but insoluble in ammoniacal solution. These are further tested for solubility in other solvents, and a scheme of classification drawn up. He has already learnt how to recognise chlorides, bromides, phosphates, &c., and he is now conversant with the principles of qualitative analysis.

As a rather more complicated instance of the method of representing the trend of chemical reactions, we may consider the oxidation of a chloride with manganese dioxide and sulphuric acid. The net result is regarded as the combined effect of at least three components—

Manganese dioxide → [Manganous oxide] + [Oxygen]

Manganous / Hydrogen × oxide / sulphate → Manganous sulphate / Hydrogen oxide

Sodium / Hydrogen × chloride / sulphate → Sodium sulphate / [Hydrogen chloride]

[Hydrogen chloride] / [Oxygen] → Hydrogen oxide / Chlorine

The arrow replaces the sign of equality to represent the dynamical character of chemical reaction. The principle of mass action is always kept prominent.

No charts are used for qualitative analysis. After going through the above course the student is capable of performing ordinary qualitative analysis by the aid of his own notes, and of doing it in a rational way. A student who was capable of dealing with this work when taking it up would, at the end of the year, have a clear conception of the elementary principles of chemistry. In the next year he should perform quantitative analysis, estimating the metallic and acid radicals in pure salts, obtaining at the same time some knowledge of the purification of salts. He would become familiar with the quantitative aspect of the chemical theory of quantivalence. He would at this stage have a solid foundation on which a sound superstructure could be erected if necessary. Such a foundation should, I think, be laid before dealing with any broad generalisations involving the ultimate constitution of matter. It is not necessary up to this stage to have the orthodox knowledge of the nature of atoms and molecules.

In conclusion, I think that this association might with advantage identify itself closely, as the mother association does, with the work of maintaining the best methods in the teaching of science.

4.—NEURITIS, NEURASTHÆNIA, AND MENTAL DISEASES.

By A. D. LEITH NAPIER, M.D., F.R.S. (Ed.)

EXCHANGES AND PRESENTATIONS

MADE BY THE

AUSTRALASIAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

The Association's Report for 1904, Vol. X., has been forwarded to the following Societies and Institutions. Should the publication not have arrived, the Institution concerned is requested to communicate with the Permanent Hon. Secretary, the University, Sydney, in order that inquiry may be made.

* *Exchanges of Publications have been received, since Vol. X. (Dunedin,* 1904 *Session) was issued, from the Societies and Institutions distinguished by an asterisk.*

Argentine Republic.

Buenos Ayres ..	.. *National Library.
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Austro-Hungary.

Brunn ..	.. Naturforschender Verein.
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FRANCE—*continued.*

Paris ..	.. *Comptoir Geologique de Paris.
" ..	.. Ecole Nationale des Mines.
" ..	.. Museum d'Histoire Naturelle.
" ..	.. Société d'Encouragement pour l'Industrie Nationale.
" ..	.. *Société Geologique de France.
Rennes ..	.. The University.
Toulouse ..	.. *Académie des Sciences, Inscriptions et Belles Lettres.

NEW CALEDONIA.

Noumea ..	.. Government Library.

GERMANY.

Berlin ..	.. *Deutsche Chemische Gesellschaft.
" ..	.. *Gesellschaft fur Erdkunde.
" ..	.. Königlich Preussische Akademie der Wissenschaften.
Bremen ..	.. Naturwissenschaftlicher Verein.
Bonn ..	.. Naturhistorischer Verein der Preussischen Rheinland.
" ..	.. Niederrheinische Gesellschaft für Natur-und-Heilkunde.
Brunswick ..	.. Verein fur Naturwissenschaft zu Braunschweig.
Carlsruhe ..	.. Naturwissenschaftlicher Verein.
Cassel ..	.. Verein fur Naturkunde.
Dresden ..	.. *Verein fur Erdkunde.
Elberfeld ..	.. *Naturwissenschaftlicher Verein.
Frankfurt a/m	.. Senckenbergische Naturforschende Gesellschaft.
Freiburg (Baden)	.. Naturforschende Gesellschaft.
Freiberg (Sax.)	.. *K. Sachsische Berg-Akademie.
Giessen ..	.. Oberhessische Gesellschaft fur Natur-und-Heilkunde.
Görlitz ..	.. Naturforschende Gesellschaft.
Göttingen ..	.. Königliche Gesellschaft der Wissenschaften.
Halle, A.S. ..	.. Kaiserliche Leopoldina Carolina Akademie der Deutschen Naturforscher.
Hamburg ..	.. Naturhistorisches Museum.
" ..	.. Verein fur Naturwissenschaft.
Hanover ..	.. Naturhistorisches Gesellschaft.
Heidelberg ..	.. *Naturhistorisch-Medicinischer Verein.
Jena ..	.. *Medicinisch Naturwissenschaftliche Gesell.
Königsberg ..	.. Königliche Physikalisch-Okonomische Gesellschaft.
Leipzig ..	.. Königliche Sächsische Gesellschaft der Wissenschaften.
" ..	.. Verein fur Erdkunde.
Marburg ..	.. Gesellschaft zur Beförderung der gesammten Naturwissenschaften.
Munich ..	.. Königlich Bayerische Akademie der Wissenschaften.
Stuttgart ..	.. *Verein fur Vaterlandische Naturkunde.
Würzburg ..	.. Physikalisch-Medicinische Gesellschaft.

GREAT BRITAIN AND THE COLONIES.

Birmingham	.. Midland Institute.
"	.. Free Library.
"	.. *Philosophical Society
Bristol ..	.. *Naturalists' Society.
Cambourne ..	.. *Mining Association.
Cambridge ..	.. Philosophical Society.
" ..	.. University.
Kew ..	.. Royal Gardens.
" ..	.. National Physical Laboratory.
Leeds ..	.. Yorkshire College.
" ..	.. Philosophical and Literary Society.
" ..	.. *University.
" ..	.. Yorkshire Geological and Polytechnic Society.

GREAT BRITAIN AND THE COLONIES—*continued.*

Liverpool	Geographical Society.
"	*Literary and Philosophical Society.
London	Agent-General (two copies).
"	Anthropological Institute of Great Britain and Ireland.
"	British Museum, Bloomsbury.
"	" South Kensington.
"	Chemical Society.
"	Colonial Office, Downing Street.
"	*Geological Society.
"	*Guild Hall.
"	Institute of Chemistry.
"	Institute of Civil Engineers.
"	Iron and Steel Institute.
"	Library, South Kensington Museum.
"	Linnean Society.
"	Lords Commissioners of the Admiralty (the Corporation of Trinity House).
"	Museum of Practical Geology.
"	*Patent Office Library.
"	*Physical Society of London.
"	*Royal Astronomical Society.
"	Royal Colonial Institute.
"	Royal Geographical Society.
"	*Royal Historical Society.
"	Royal Institution of Great Britain.
"	Royal College of Science, and School of Mines.
"	Royal Society.
"	Society of Arts.
"	University of London.
"	*Victoria Institute.
"	War Office (Intelligence Division).
Manchester	*Victoria University.
"	Literary and Philosophical Society.
"	Geological Society.
"	Owens College.
Mirfield	*Yorkshire Geological and Polytechnic Society.
Newcastle-on-Tyne ..	*Natural History Society.
" ..	North of England Institute of Mining and Mechanical Engineers.
" ..	Society of Chemical Industry.
Oxford	Bodleian Library.
"	Radcliffe Library.
Penzance	Royal Geological Society of Cornwall.
Windsor	*The King's Library.
York	Yorkshire Philosophical Society.

AFRICA.

Capetown	South African Philosophical Society.
"	Geological Commission.
Pietermaritzburg ..	Government Geologist (Surveyor-General's Department)

CANADA.

Halifax (Nova Scotia)	Nova Scotian Institute of Science.
Hamilton (Ont.) ..	*Hamilton Association.
Montreal	Natural History Society of Montreal.
"	McGill University Medical Library.
Ottawa	Geological and Natural History Survey of Canada.
"	*Literary and Scientific Society.
"	*Royal Society of Canada.

CANADA—*continued.*

Quebec	..	.. Literary and Historical Society.
Toronto	..	.. Canadian Institute.
"	..	.. University.
Winnipeg	..	.. Manitoba Historical and Scientific Society.

CEYLON.

Colombo	..	.. *Royal Asiatic Society.

INDIA.

Aligarh	..	.. Anglo-Oriental College.
Bombay	..	.. Royal Asiatic Society (Bombay Branch).
Calcutta	..	.. Asiatic Society of Bengal.
"	..	.. *Geological Survey.
Madras	..	.. Central Museum.

IRELAND.

Dublin	..	.. National Library of Ireland.
"	..	.. *Royal Dublin Society.
"	..	.. Trinity College.

JAMAICA.

Kingston	..	.. *Institute of Jamaica.

MALTA.

Malta	..	.. Public Library.

MAURITIUS.

Port Louis	..	.. Royal Society of Arts and Sciences.

NEW BRUNSWICK.

St. John	..	.. Natural History Society of New Brunswick.

NEW SOUTH WALES.

Sydney	..	.. Australian Museum
"	..	.. Botanic Gardens.
"	..	.. *Department of Fisheries.
"	..	.. Department of Mines and Agriculture.
"	..	.. Department of Public Instruction.
"	..	.. Government Statistician.
"	..	.. Linnean Society of N.S.W.
"	..	.. N.S.W. Board of International Exchanges.
"	..	.. *Observatory.
"	..	.. Parliamentary Library.
"	..	.. Public Library.
"	..	.. Royal Society of N.S.W.
"	..	.. School of Arts.
"	..	.. Technological Museum.
"	..	.. University.

NEW ZEALAND.

Auckland	..	.. Auckland Institute.
Christchurch		.. Canterbury College.
"		.. *Philosophical Society.
"		.. Public Library.

New Zealand—*continued.*

Dunedin ..	.. Otago Institute.
Wellington ..	.. *Mines Department.
" ..	.. New Zealand Institute.
" ..	.. *Public Library.
" ..	.. *Registrar-General's Office.
New Plymouth	.. Polynesian Society.

Queensland.

Brisbane ..	.. Parliamentary Library.
" ..	.. Royal Society of Queensland.

Scotland.

Aberdeen ..	.. University.
Edinburgh ..	.. *Geological Society.
" ..	.. Royal Society.
" ..	.. University.
Glasgow ..	.. *Geological Society.
" ..	.. Philosophical Society.
" ..	.. University.
St. Andrew's	.. University.

South Africa.

Cape Town ..	.. *The Observatory.
" ..	.. *S.A., Association for Advancement of Science.

South Australia.

Adelaide ..	.. Parliamentary Library
" ..	.. Public Library, Museum, and Art Gallery of S.A.
" ..	.. Royal Society of South Australia.
" ..	.. University.

Straits Settlements.

Singapore ..	.. Royal Asiatic Society (Straits Branch).

Tasmania.

Hobart ..	.. Parliamentary Library.
" ..	.. Royal Society of Tasmania.
Launceston	.. Geological Survey of Tasmania.

Victoria.

Ballarat ..	.. School of Mines and Industries.
Melbourne ..	.. Australasian Institute of Mining Engineers.
" ..	.. *Commonwealth Bureau of Census and Statistics.
" ..	.. Government Statist.
" ..	.. Mining Department.
" ..	.. Parliamentary Library.
" ..	.. Public Library.
" ..	.. Royal Society of Victoria.
" ..	.. *The Observatory.
" ..	.. University.
" ..	.. Working Men's College.

Western Australia.

Perth ..	.. Parliamentary Library.
" ..	.. Victoria Public Library.

GREECE.

Athens ..	.. University.

ITALY.

Bologna ..	.. R. Accademia delle Scienze dell' Instituto.
" ..	.. University.
Catania ..	.. Accademia Gioenia di Scienze Naturali.
Milan ..	.. R. Instituto Lombardo di Scienze, Lettere, ed Arti.
Modena ..	.. R. Accademia di Scienze, Lettere, ed Arti.
Pisa ..	.. Società Toscana di Scienze Naturali.
Rome ..	.. *Accademia Pontificia de Nuovi Sincei.
" ..	.. R. Accademia dei Lincei.
Sassari ..	.. University.
Turin ..	.. *Reale Accademia della Scienze.,

JAPAN.

Tokyo ..	.. Asiatic Society of Japan.
" ..	.. Imperial University.

JAVA.

Batavia ..	.. K. Natuurkundige Vereeniging in Nederlandsch-Indic.

KOREA.

Seoul ..	.. *Royal Asiatic Society.

MEXICO.

Mexico ..	.. Sociedad Cientifica " Antonio Alzate."

NETHERLANDS.

Amsterdam	.. Académic Royale des Sciences.
Haarlem ..	.. Bibliothéque du Musée Teyler.
" ..	.. Colonial Museum.
Leyden ..	.. University.

NORWAY.

Christiania ..	.. Könige1ige Norske Fredericks Universitet.

PHILIPPINE ISLANDS.

Manila ..	.. *Ethnological Survey.

PORTUGAL.

Coimbra ..	.. Universidade.
Lisbon ..	.. Academia Royale das Sciencias.

ROUMANIA.

Bucharest ..	.. *Meteorological Institute.

RUSSIA.

Helsingfors ..	.. Societas Scientiarum Fennica.
Moscow ..	.. Société Impériale des Naturalistes.
St. Petersburg	.. Académie Impériale des Sciences.
"	.. Institut des Mines.

SPAIN.

Barcelona ..	.. Real Academia de Ciencias.

Sweden.

Stockholm ..	.. K. Svenska Vetenskaps-Akademie.
Upsala ..	.. Université Royale d'Upsala.
" ..	.. *K. Vetenskaps Societaten.

Switzerland.

Basel ..	.. Naturforschende Gesellschaft.
Geneva ..	.. Schweizerische Naturforschende Gesellschaft.
Lausanne ..	.. Société Vaudoise des Sciences Naturelles.
Zurich ..	.. Naturforschende Gesellschaft.

United States of America.

Albany ..	.. New York State Library, Albany.
Baltimore ..	.. Johns Hopkins University.
Boston ..	.. American Academy of Arts and Sciences.
Boulder ..	.. *University of Colorado.
Cambridge ..	.. Harvard University.
Chicago ..	.. *Field Columbian Museum
" ..	.. The John Crerar Library.
Cincinnati ..	.. American Association for the Advancement of Science.
Columbus ..	.. *Geological Survey of Ohio.
" ..	.. University of Missouri.
Concord ..	.. *New Hampshire State Library.
Denver ..	.. Colorado Scientific Society.
Indianopolis	.. Indiana Academy of Sciences.
Lawrence ..	.. Kansas University.
Michigan ..	.. College of Mines.
Madison (Wis.)	.. Wisconsin Academy of Sciences, Arts, and Letters.
Milwaukee ..	.. *Public Museum.
Minneaoplis..	.. Minnesota Academy of Natural Sciences.
Missoula ..	.. University of Montana (Department of Biology).
Montana ..	.. State School of Mines.
Newhaven (Conn.)	.. Connecticut Academy of Arts and Sciences.
" "	.. Yale University.
New York ..	.. New York Academy of Sciences.
" ..	.. *Public Library.
" ..	.. School of Mines, Columbia College.
Paolo Alto ..	.. Leland Stanford, jun., University of California.
Philadelphia	.. Academy of Natural Sciences.
"	.. American Philosophical Society.
"	.. *Commercial Museum.
"	.. *Franklin Institute.
Rochester (N.Y.)	.. Rochester Academy of Sciences.
Salem (Mass.)	.. Essex Institute.
St. Louis ..	.. Academy of Science.
" ..	.. *Missouri Botanical Garden.
San Francisco	.. California Academy of Sciences.
Washington..	.. Bureau of Education (Department of the Interior).
" ..	.. Bureau of American Ethnology.
" ..	.. *Department of Agriculture.
" ..	.. *Library of Congress.
" ..	.. National Academy of Sciences.
" ..	.. Philosophical Society.
" ..	.. Smithsonian Institution.
" ..	.. U.S. Geological Survey.
" ..	.. U.S. National Museum (Department of the Interior).

Uruguay.

Monte Video	.. National Library and Museum.

LIST OF MEMBERS.

ADELAIDE SESSION, 1907.

Abbott, W. E.—Wingen, New South Wales.
Adams, J. H. M.—Broughton College, Waverley, Sydney.
Adams, J. R. G.—Public Library, North Terrace, Adelaide.
Anderson, Professor F.—University, Sydney.
Anderson, W.—St. John's Parochial School, Darlinghurst, New South Wales.
Andrews, E. C., B.A., F.G.S.—Department of Mines, Sydney.
Angus, Professor, B.Sc.—Department of Agriculture, Adelaide.
Ashby, Edwin—Royal Exchange, King William Street, Adelaide.
Auld, W. P.—Third Street, Knightsbridge, South Australia.

Baker, W. H.—Parkside, South Australia.
Barff, H. E., M.A.—University, Sydney.
Barlow, Wm., LL.D.—Morialta Chambers, Victoria Square, Adelaide.
Barton, Robt.—" Arakoon," Irving Road, Toorak, Victoria.
Basedow, H.—Pirie Street, Kent Town, South Australia.
Bayly, Wykeham, A.S.A.S.M.—Mines Department, Melbourne.
Belfield, A. H.—Demaresq, New South Wales.
Bell, A. D., J.P.—Stag Valley Station, Otago, New Zealand.
Benham, Miss E. I., B.Sc.—University, Adelaide.
Berry, Professor R. J. A., M.D.—University, Melbourne.
Bevan, F.—Elder Conservatorium, Adelaide.
Beythien, E.—George Street, Moonta, South Australia.
Black, J. M.—5, Alfred Street, Norwood, South Australia.
Black, Dr.—Weld Club, Perth, Western Australia.
Blackburn, Rev. T., B.A.—Woodville, South Australia.
Boas, J. H., B.Sc.—93, Gover Street North Adelaide
Bollen, Dr. C.—Woodville, South Australia.
Bonython, Sir Langdon—Mount Lofty, South Australia.
Borthwick, T., M.D., C.H.M.—Town Hall, Adelaide.
Bragg, Professor W. H.—University, Adelaide.
Brooks, Joseph—Nelson Street, Woollahra, Sydney.
Brown, H. Y. L.—Government Offices, Adelaide.
Brown, Rev. G., D.D.—Gordon, New South Wales.
Brown, Professor W. Jethro—University, Adelaide.
Brummitt, Dr. R.—Medindie, South Australia.
Brunnick, J. C.—Department of Agriculture and Stock, Brisbane.
Buchanan, A.—Master Supreme Court, Adelaide.
Bundey, Miss, Mus. Bac.—Molesworth Street, North Adelaide.
Burgess, Miss M., B.Sc.—Cross Roads, South Malvern, South Australia.
Byrnell, S. C.—Mines Department, Sydney.
Burns, James—10, Bridge Street, Sydney.

Cambage, R. H.—Park Road, Burwood, Sydney.
Carment, D.—A.M.P. Society, Pitt Street, Sydney.
Catchlove, C. H. L., F.I.A., F.F.A.—67, Middleton Street, Stanmore, Sydney
Cato, Roy H.—Australasian Chambers, King William Street, Adelaide
Catt, J. C.—c/o Captain Inglis, Port Adelaide.
Chambers, John—Motopeka, Hastings, Napier, New Zealand (*Life Member*).

Chapman, R. W., M.A., B.C.E.—University, Adelaide.
Chapman, Dr. H. G.—University, Sydney.
Chapman, W. S.—School of Mines, Adelaide.
Chapman, F., A.L.S.—National Museum, Melbourne.
Chilton, Professor C., M.A., D.Sc.—Christchurch, New Zealand.
Clark, E. V., B.Sc.—Knightsbridge, South Australia.
Clark, M. Symonds—15, Australasian Chambers, King William Street, Adelaide.
Cleland, W. L., M.B., B.S.—Asylum, Parkside, South Australia.
Cleland, J. B., M.D.—Perth, Western Australia.
Clucas, R. J. M.—University, Adelaide.
Cockayne, Leonard, Ph.D.—Christchurch, New Zealand.
Colley, D. J. K.—Royal Mint, Sydney.
Collison, Miss, B.Sc.—King William Street, Adelaide.
Combes, Miss A. H.—Fonthill Lake, Bathurst, New South Wales.
Connor, Rev. G. M., M.A.—Sale, Gippsland, Victoria.
Cooke, W. T., D.Sc.—University, Adelaide.
Cornish, G. P.—Second Avenue, East Adelaide.
Counsell, F. H.—55, Brookman's Buildings, Grenfell Street, Adelaide.
Crago, Dr.—16, College Street, Sydney.
Creswell, Miss—c/o Rev. J. C. Haynes, "Kil-Brae," St. Peters, South Australia
Crompton, T. E.—Gawler Place, Adelaide.
Crump, Miss S. L.—Clarendon College, Ballarat, Victoria.

Dalby, J., B.A.—School of Mines, Adelaide.
Daley, C.—State School, Stawell, Victoria.
David, Professor T. W. E., B.A., F.R.S.—University, Sydney.
Dawes, R. C. H.—Gawler, South Australia.
Dawson, Ed.—Unley, South Australia.
Deane, Hy., M.A., M.Inst.C.E.—Equitable Buildings, George Street, Sydney.
Desmond, J.—Government Veterinary Surgeon, Adelaide.
Dixon, Hugh—100, The Strand, Sydney.
Dixon, Samuel,—Bath Street, New Glenelg, South Australia.
Dobbie, A. W.—10, Baliol Street, St. Peters, South Australia.
Docker, His Honor Judge E. B., B.A.—Sydney.
Dun, W. S.—Mines Department, Sydney.
Dwyer, T. C., B.Sc.—Technical College, Bathurst, New South Wales.

Edwards, L.—Eudunda, South Australia.
Ellery, T. G.—Town Hall, Adelaide.
Ellis, Albert F.—465, Collins Street, Melbourne.
Engelhardt, B. G.—Public School, Henty, New South Wales.
Enys, J. D., F.G.S.—Enys Castle, Penryn, Cornwall, England (*Life Member*).
Evans, George—28, Castlereagh Street, Sydney, New South Wales.

Faithfull, Dr. R. L.—5, Lyons Terrace, Sydney, New South Wales.
Farr, C. Coleridge, D.Sc.—Christchurch, New Zealand.
Farrer, Arthur—Town, Hall Ballarat.
Fennelly, B., A.M. Inst. C.E.—Kilmore, Victoria.
Ferguson, A., B.Sc.—Fourth Avenue, East Adelaide.
Finniss, W. C. M.—Traffic Audit Office, Victoria Square, Adelaide.
Fletcher, J. J.—Elizabeth Bay, Sydney.
Foreman, Dr. J.—141, Macquarie Street, Sydney.
Fowler, T. W., M.C.E.—421, Collins Street, Melbourne.
Fox, Dr. W. R.—90, Collins Street, Melbourne.
Fry, H. K., B.Sc., University, Adelaide.
Fuller, W., University, Adelaide.
Fulton, Robert V., M.B., C.M.—2, Pitt Street, Dunedin, New Zealand.

Gardiner, C. L.—Semaphore, South Australia.
Gault, Dr. A. H.—Lower Mitcham, South Australia.
Gee, L. C. E.—Mines Department, Adelaide.
George, Miss, Advanced School for Girls, Adelaide.
Gill, W.—Conservator of Forests, Adelaide.

Gill, T., I.S.O.—Glen Osmond, South Australia.
Gillen, F. J., F.A.S.—Moonta, South Australia.
Gillingham, J. W.—Waymouth Street, Adelaide.
Girdlestone, Rev. Hy., M.A.—St. Peter's College, Hackney, South Australia.
Goodlet, John H., J.P.—Ashfield, Sydney, New South Wales.
Gordon, David—c/o D. &. W. Murray, Gawler Place, Adelaide.
Goyder, G. A., F.C.S.—12, Pirie Street, Adelaide.
Gray, G. J., B.Sc., B.E.—Park Road, Burwood, Sydney.
Greenway, T. J., F.I.C.—Brookman's Buildings, Grenfell Street, Adelaide.
Greig-Smith, Dr.—Elizabeth Bay, Sydney.
Griffiths, H. H. D.—61, Hurtle Square, Adelaide.
Griffiths, R. F.—King William Street, Kent Town, South Australia.
Gryst, E. F.—Exeter, South Australia.
Gullett, Henry—Wahroonga, New South Wales.
Guthrie, F. B., F.I.C.—Department of Agriculture, Sydney.

Hall, T. S., M.A.—University, Melbourne.
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Hamitlon, Dr. A. A.—25, Angas Street, Adelaide.
Hargreaves, W. A., M.A., B.C.E.—Inspector of Explosives, Port Adelaide.
Harrison, G. R.—Bucroft, New South Wales.
Hay, John, LL.D.—Crow's Nest, North Sydney.
Hayward, W. T., M.R.C.S.—Norwood, South Australia.
Hedley, C., F.L.S.—Australian Museum, Sydney.
Helms, R.—136, George Street, Sydney.
Henderson, J.—City Bank, Sydney.
Heron, J. S.—Pennant Hills, New South Wales.
Higgin, A. J., F.I.C.—School of Mines, Adelaide.
Hill, A. W., M.D.—Grenfell Street, Adelaide.
Hocken, T. M., M.R.C.S., F.L.S.—215, Moray Place, Dunedin, New Zealand.
Hogg, Miss E. G., M.A.—Christ's College, Christchurch, New Zealand.
Holtze, Maurice—Botanic Gardens, Adelaide.
Holtze, Alexis S.—*Garden and Field* Office, Adelaide.
Howchin, W., F.G.S.—University, Adelaide.
Howitt, A. W.—Clovelly Metung, New South Wales.
Hullett, J. W. H.—Engineer-in-Chief's Office, Victoria Square, Adelaide.
Hussey, G. F.—Waymouth Street, Adelaide.
Hustler, A. E.—Unley, South Australia.
Hutton, Captain F. W., F.R.S., F.L.S.—Canterbury Museum, Christchurch, New Zealand (*Life Member*).

Illiffe, J. D., B.Sc.—Flindert Street, Kent Town, South Australia.
Inglis, Captain—Harbormaster, Port Adelaide.
Ingram, Alex.—Hamilton, Victoria.
Irving, James—58, Ann Street, Brisbane.

Jacob, A. F.—Veteran Hall, Prospect, New South Wales.
Jacob, Miss C.—Tormore House, North Adelaide.
Jamieson, W. R.—Agricultural College, Roseworthy.
Jekyll, H. J. C.—Christchurch, New Zealand.
Jones, J. W.—Public Works Office, Adelaide.
Josephson, J. P.—Stephen Court, 77, Elizabeth Street, Sydney.
Jude, Miss G. J., B.Sc.—Charles Street, Norwood, South Australia.

Kater, Hon. H. E., M.L.C.—Moss Vale, New South Wales.
Kernot, Professor—University, Melbourne.
Kitson, A. E.—Department of Mines, Melbourne.
Klaatsch, Professor D. H.—Heidelberg, Germany.
Knaggs, Dr. S. T.—1, Lyons Terrace, Hyde Park, Sydney.
Knibbs, G. H., F.R.A.S.—Commonwealth Statistician, Melbourne.

Lawrie, Professor H., LL.D.—University, Melbourne.
Lawrence, C. A—" Birralee," Albert Road, Strathfield, New South Wales.

Lea, A. M., M.E.S.—Government Entomologist, Hobart.
Ledger, W. H., B.Sc., M.C.E.—School of Mines, Adelaide.
Legge, Colonel, F.L.S., F.R.S.E.—Cullenswood House, Tasmania.
Lendon, A. A., M.D.—North Terrace, Adelaide.
Lenehan, H. A., F.R.A.S.—Observatory, Sydney.
Leschen, Hugo—Pirie Street, Adelaide.
Littlejohn, Dr. E. S.—Young Street, Croydon, Sydney.
Liversidge, Professor A., M.A., LL.D., F.R.S.—University, Sydney.
Lloyd, J. S.—Alma Chambers, Grenfell Street, Adelaide.
Loney, T. Slade—208, William Street, Darlinghurst, New South Wales.
Loughrey, B., M.A., M.D., Ch.B., M.C.E.—1, Elgin Street, Hawthorn, Victoria.
Love, E. F. J., M.A.—University, Melbourne.

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MacLaren, M., B.Sc., F.G.S.—Launceston, Tasmania.
McClymont, J. R., M.A.—Sandy Bay, Hobart, Tasmania.
McColl, Miss A. G.—Post Office, Canterbury, Victoria.
McMurtry, G. C.—Wallaroo, South Australia.
Madsen, J. P. V., D.Sc.—University, Adelaide.
Magarey, W. A., LL.B.—City Chambers, Pirie Street, Adelaide.
Maiden, J. H., F.L.S.—Botanic Gardens, Sydney.
Maitland, A. Gibb—Government Geologist, Perth, Western Australia.
Maitland, Mrs. A. Gibb—Perth, Western Australia.
M'Alpine, D.—Department of Agriculture, Melbourne.
Mann, E. A.—Government Analyst, Perth.
Marshall, Professor P., M.A., D.Sc., F.G.S.—Otago University, Dunedin.
Martin, Alexander—Newmarket Hotel, Adelaide.
Masters, Rev. F. G., M.A.—Holy Trinity Vicarage, Balaklava, South Australia.
Matthews, W. J.—School of Mines, Adelaide.
Mawson, Douglas, B.Sc., B.E.—University, Adelaide.
Mayo, G. G.—116, Franklin Street, Adelaide.
Mellor, John F.—Fulham, South Australia.
Mellor, J. W.—" Holmfirth," Fulham, South Australia.
Mingaye, J. C. H., F.C.S.—Chemical Laboratory, Department of Mines, Sydney.
Mitton, J. E.—Hindmarsh, South Australia.
Molineux, Albert—15, Kent Terrace, Kent Town, South Australia.
Moncrieff, J. C. B.—Payneham Road, St. Peters, South Australia.
Moncrieff, A. B.—Engineer-in-Chief, Victoria Square, Adelaide.
Montgomery, A.—Mines Department, Perth.
Moore, T. B., F.R.G.S.—Strahan, Tasmania.
Moore, M. C.—Mile-End, South Australia.
Moore, H. P.—S.A. Company, North Terrace, Adelaide.
Morgan, P. G., M.A., A.O.S.M.—School of Mines, Waiki, New Zealand.
Morris, C. T.—Molesworth Street, North Adelaide.
Morrison, Miss J. E.—Napier Street, St. Arnaud, Victoria.
Myles, Chas. H.—Wentworth Road, Burwood, Sydney.

Napier, A. D. Leith, M.D., F.R.S.E.—28, Angas Street, Adelaide.
Neill, A. S.—Brougham Place, North Adelaide.
Nicholls, W. H. W., B.A. —447, Glebe Road, Sydney.
Niesche, Dr.—Wakefield Street, Adelade.
Norton, Hon. A.—Baroona Road, Milton, Queensland.
Norton, Mrs. A—Baroona Road, Milton, Queensland.

Onslow, H. P.—Electric Power Station, Adelaide.

Parker, G. A.—Hindmarsh, South Australia.
Parkhouse, T. A.—Traffic Audit Office, Victoria Square, Adelaide.
Parkinson, R.—Bismarck Archipelago (Hotel Metropole, Sydney).
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