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OF

NEW SOUTH WALES

FOR

1916.

(INCORPORATED 1881.)

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NOTICE.

The Royal Society of New South Wales originated in 1821 as the "Philosophical Society of Australasia"; after an interval of inactivity, it was resuscitated in 1850, under the name of the "Australian Philosophical Society," by which title it was known until 1856, when the name was changed to the "Philosophical Society of New South Wales"; in 1866, by the sanction of Her Most Gracious Majesty Queen Victoria, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

TO AUTHORS.

Authors of papers desiring illustrations, are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink, so as to admit of the blocks being prepared directly therefrom, in a form suitable for photographic "process." The size of a full page plate in the Journal is $4\frac{1}{4}$ in. $\times$ $6\frac{3}{4}$ in. The cost of all original drawings, and of colouring plates must be borne by Authors.

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PUBLICATIONS.

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FORM OF BEQUEST.

I bequeath the sum of £   to the ROYAL SOCIETY OF NEW SOUTH WALES, Incorporated by Act of the Parliament of New South Wales in 1881, and I declare that the receipt of the Treasurer for the time being of the said Corporation shall be an effectual discharge for the said Bequest, which I direct to be paid within   calendar months after my decease, without any reduction whatsoever, whether on account of Legacy Duty thereon or otherwise, out of such part of my estate as may be lawfully applied for that purpose.

[*Those persons who feel disposed to benefit the Royal Society of New South Wales by Legacies, are recommended to instruct their Solicitors to adopt the above Form of Bequest.*]

LIST OF THE MEMBERS

OF THE

Royal Society of New South Wales.

P Members who have contributed papers which have been published in the Society's Transactions or Journal; papers published in the Transactions of the Philosophical Society are also included. The numerals indicate the number of such contributions.

‡ Life Members.

Elected.		
1908		Abbott, George Henry, B.A., M.B., Ch.M., Macquarie-street; p.r. 'Cooringa,' 252 Liverpool Road, Summer Hill.
1877	P 5	Abbott, W. E., 'Abbotsford,' Wingen.
1904		Adams, William John, M. I. MECH. E, 175 Clarence-street.
1916		Allen, William John, "Oriel," The Boulevard, Strathfield.
1898		Alexander, Frank Lee, c/o Messrs. Goodlet and Smith Ltd., Cement Works, Granville.
1916		Alexander, James Maclean, M. INST. C.E., 25 O'Connell-street.
1905	P 1	Anderson, Charles, M.A., D.Sc. *Edin.*, Australian Museum, College-street.
1909	P 8	Andrews, E. C., B.A., F.G.S., Geological Surveyor, Department of Mines, Sydney.
1915		Armit, Henry William, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 30-34 Elizabeth-street.
1878		Backhouse, His Honour Judge A. P., M.A., 'Melita,' Elizabeth Bay.
1894	P 23	Baker, Richard Thomas, F.L.S., Curator, Technological Museum.
1894		‡Balsille, George, 'Lauderdale,' N.E. Valley, Dunedin, N.Z.
1896		Barff, H. E., M.A., Warden of the University of Sydney.
1908	P 1	Barling, John, L.S., 'St. Adrians,' Raglan-street, Mosman.
1895	P 9	Barraclough, S. Henry, B.E., M.M.E., ASSOC. M. INST. C.E., M. I. MECH. E., Memb. Soc. Promotion Eng. Education; Memb. Internat. Assoc. Testing Materials; Professor of Mechanical Engineering in the University of Sydney; p.r. 'Marmion,' Victoria-street, Lewisham.
1906		Basnett, Nathaniel James, Punch-st., Mosman.
1894		Baxter, William Howe, L.S., Chief Surveyor, Existing Lines Office, Railway Department, Bridge-street.
1877		Belfield, Algernon H., 'Eversleigh,' Dumaresq.
1909	P 2	Benson, William Noel, D.Sc., Professor of Geology, The University, Otago, Dunedin.
1916		Birrell, Septimus, "Florella," Dunslaffnace-st., Hurlstone Park.
1913		Bishop, Joseph Eldred, Killarney-street, Mosman.
1915		Bishop, John, 24 Bond-street.
1905		Blakemore, George Henry, 4 Bridge-street.
1888		‡Blaxland, Walter, F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, Fremantle, West Australia.
1893		Blomfield, Charles E., B.C.E. *Melb.*, 'Woombi,' Kangaroo Camp, Guyra.

Elected		
1898		Blunno, Michele, Licentiate in Science (Rome), 'Havilah,' No. 1, Darlinghurst Road, Darlinghurst.
1907		Bogenrieder, Charles; M.A., No. 2 Little's Avenue, Balmain.
1879		‡Bond, Albert, 131 Bell's Chambers, Pitt-street.
1910		Bradley, Clement Henry Burton, M.B., Ch.M., D.P.H., Demonstrator in Physiology in the University of Sydney.
1876		Brady, Andrew John, L.K. and Q.C.P. *Irel.*, L.R.C.S. *Irel.*, 175 Macquarie-street, Sydney.
1916		Bragg, James Wood, B.A., c/o Gibson, Battle &Co. Ltd., Kent-st.
1891		Brennand, Henry J. W., B.A., M.B., Ch.M. *Syd.*, 'The Albany,' Macquarie-st., p.r. 'Wobun,' 310 Miller-st., North Sydney.
1914		Broad, Edmund F., 'Cobbam,' Woolwich Road, Hunter's Hill.
1878		‡Brooks, Joseph, J.P. L.S., F.R.A.S., F.R.G.S., 'Hope Bank,' Nelson-street, Woollahra.
1913	P 1	Browne, William Rowan, B.Sc., Assistant Lecturer and Demonstrator in Geology in the University, Sydney.
1906		Brown, James B., Resident Master, Technical School, Granville; p.r. 'Aberdour,' Daniel-street, Granville.
1898		‡Burfitt, W. Fitzmaurice, B.A., B.Sc., M.B., Ch.M. *Syd.*, 'Wyoming,' 175 Macquarie-street, Sydney.
1890		Burne, Alfred, D.D.S., Buckland Chambers, 183 Liverpool-st.
1916		Burn, Forbes, Goorianawa Station, Gular, N.S.W.
1907		Burrows, Thomas Edward, M. INST. C.E., L.S., Metropolitan Engineer, Public Works Department; p.r. 'Balboa,' Fern-street, Randwick.
1909		Calvert, Thomas Copley, ASSOC. M. INST. C.E., Department of Public Works, Newcastle, N.S.W.
1904	P 9	Cambage, Richard Hind, L.S., F.L.S., Under Secretary for Mines, Department of Mines, Sydney; p.r. Park Road, Burwood. (President 1912). *Hon. Secretary.*
1907		Campbell, Alfred W., M.D., Ch.M. *Edin.*, 183 Macquarie-street.
1876		Cape, Alfred J., M.A. *Syd.*, 'Karoola,' Edgecliff Road, Edgecliff.
1897	P 4	Cardew, John Haydon, M. INST. C.E., L.S., 75 Pitt-street.
1901		Card, George William, A.R.S.M., Curator and Mineralogist to the Geological Survey, Department of Mines, Sydney.
1891		Carment, David, F.I.A. *Grt. Brit. & Irel.* F.F.A., *Scot.*, 4 Whaling Road, North Sydney. *Vice-President.*
1909		Carne, Joseph Edmund, F.G.S., Government Geologist, Department of Mines, Sydney.
1903	P 2	Carslaw, H. S., M.A., Sc.D., Professor of Mathematics in the University of Sydney.
1913	P 2	Challinor, Richard Westman, F.I.C., F.C.S., Lecturer in Chemistry, Sydney Technical College.
1909	P 2	Chapman, H. G., M.D., B.S., Assistant Professor of Physiology in the University of Sydney. *Hon. Treasurer.*
1913	P 5	Cheel, Edwin, Botanical Assistant, Botanic Gardens, Sydney.
1909	P 17	Cleland, John Burton, M.D., Ch.M., Principal Assistant Microbiologist, Department of Public Health, 93 Macquarie-st.
1913	P 1	Cooke, William Ernest, M.A., F.R.A.S., Government Astronomer and Professor of Astronomy in the University of Sydney, The Observatory, Sydney.
1896	P 2	Cook, W. E., M.C.E. *Melb.*, M. INST. C.E., Water and Sewerage Board, North Sydney.

Elected		
1904	P 2	Cooksey, Thomas, Ph.D., B.Sc. *Lond.*, F.I.C., Government Analyst; p.r. 'Clissold,' Calypso Avenue, Mosman.
1913		Coombs, F. A., F.C.S., Instructor of Leather Dressing and Tanning, Sydney Technical College; p.r. 55 Willoughby Road, North Sydney.
1916		Coote, Edmund James, 492 George-street, Sydney.
1876		Codrington, John Frederick, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, L.R.C.P. *Edin.*, 'Roseneath,' 8 Wallis-street, Woollahra.
1906		Colley, David John K., Superintendent, Royal Mint, Sydney.
1882		Cornwell, Samuel, J.P., Brunswick Road, Tyagarah.
1909	P 2	Cotton, Leo Arthur, M.A., B.Sc., Assistant Lecturer and Demonstrator in Geology in the University of Sydney.
1892	P 1	Cowdery, George R., Assoc. M. Inst. C.E., Blashki Buildings, Hunter-st.; p.r. 'Glencoe,' Torrington Road, Strathfield.
1886		Crago, W. H., M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 185 Macquarie-st.
1912		Curtis, Louis Albert, L.S., 'Redlands,' Union-street, Mosman.
1875		Dangar, Fred. H., c/o W. E. Deucher, 12 and 14 Loftus-street.
1890		Dare, Henry Harvey, M.E., M. Inst. C.E., Commissioner, Water Conservation and Irrigation Commission, Perpetual Trustee Chambers, Hunter-street, Sydney.
1876	P 3	Darley, Cecil West, M. Inst. C.E., Australian Club, Sydney, 'Longheath,' Little Bookham, Surrey, England.
1910		Darnell-Smith, George Percy, B.Sc., F.I.C., F.C.S., Department of Agriculture, Sydney.
1886	P 21	David, T. W. Edgeworth, C.M.G., B.A., D.Sc., F.R.S., F.G.S., Professor of Geology and Physical Geography in the University of Sydney. (President 1895, 1910.)
1909		Davidson, George Frederick.
1892	P 1	Davis, Joseph, M. Inst. C.E., Director-General, Public Works Department, Sydney.
1885	P 3	Deane, Henry, M.A., M. Inst. C.E., F.L.S., F.R. Met. Soc., F.R.H.S., 'Campsie,' 14 Mercer Road, Malvern, Victoria. (President 1897, 1907.)
1894		Dick, James Adam, B.A. *Syd.*, M.D., Ch.M., F.R.C.S. *Edin.*, 'Catfoss,' Belmore Road, Randwick.
1915	P 1	Dick, Thomas, J.P., Port Macquarie.
1875	P 12	Dixon, W. A., F.I.C., F.C.S., 'Girton,' McLaren-st., North Sydney.
1916		Dixon, Jacob Robert L., M.R.C.S., L.R.C.P., The University, Syd.
1906		Dixson, William, 'Merridong,' Gordon Road, Killara.
1876		Docker, His Honour Judge E. B., M.A., 'Mostyn,' Billyard Avenue, Elizabeth Bay.
1913		Dodd, Sydney, D.V.Sc., F.R.C.V.S., Lecturer in Veterinary Pathology in the University of Sydney.
1913	P 2	Doherty, William M., Analyst, Department of Public Health, Sydney.
1908	P 3	Dun, William S., Palæontologist, Department of Mines.
1916	P 1	Enright, Walter J., B.A., High-street, West Maitland, N.S.W.
1908		Esdaile, Edward William, 54 Hunter-street.
1879	P 4	Etheridge, Robert, Junr., J.P., Curator, Australian Museum; p.r. 'Inglewood,' Colo Vale, N.S.W.

Elected		
1896		Fairfax, Geoffrey E., *S. M. Herald* Office, Hunter-street.
1868		Fairfax, Sir James R., Knt., *S. M. Herald* Office, Hunter-st.
1887		Faithfull, R. L., M.D., *New York*, L.R.C.P., L.S.A. *Lond.*, 'Wilga,' 18 Wylde-street, Potts Point.
1902		Faithfull, William Percy, Australian Club.
1910		Farrell, John, 68½ Pitt-street, Sydney.
1909	P 1	Fawsitt, Charles Edward, D.Sc., Ph.D., Professor of Chemistry in the University of Sydney.
1881		Fiaschi, Thos., M.D., M.Ch, *Pisa*.
1888		Fitzhardinge, His Honour Judge G. H., M.A., 'Red Hill,' Beecroft.
1879		‡Foreman, Joseph, M.R.C.S. *Eng.* L.R.C.P. *Edin.*, 'Wyoming,' Macquarie-street.
1905		Foy, Mark, 'Eumemering,' Bellevue Hill, Woollahra.
1904		Fraser, James, M. INST. C.E., Chief Commissioner for Railways, Bridge-street; p.r. 'Arnprior,' Neutral Bay.
1907		Freeman, William, 'Clodagh,' Beresford Road, Rose Bay.
1899		French, J. Russell, General Manager, Bank of New South Wales, George-street.
1881		Furber, T. F., F.R.A.S., c/o Dr. R. I. Furber, 'Sunnyside,' Stanmore Road, Stanmore.
1906		Gosche, W. A. Hamilton, 24½ Pitt-street, Sydney.
1897		Gould, Senator The Hon. Sir Albert John, K.C.M.G., 'Eynesbury,' Edgecliff.
1916		Granger, James Darnell, Ph.D., Manager of Chiswick Polish Co. of Australia, Mitchell Road, Alexandria.
1916		Green, Victor Herbert, 7 Bent-street, Sydney.
1899	P 1	Greig-Smith, R., D.Sc. *Edin.*, M.Sc. *Dun.*, Macleay Bacteriologist, Linnean Society's House, Ithaca Road, Elizabeth Bay. (President 1915.) *Vice-President*.
1912		Grieve, Robert Henry, B.A., 'Langtoft,' Llandaff-st., Waverley.
1912		Griffiths, F. Guy, B.A., M.D., Ch M., 135 Macquarie-st., Sydney.
1891	P 16	Guthrie, Frederick B., F.I.C., F.C.S., Chemist, Department of Agriculture, 137 George-street, Sydney. (President 1903).
1880	P 4	Halligan, Gerald H., L.S., F.G.S., 'Riversleigh,' Hunter's Hill.
1912		Hallmann, E. F., B.Sc., Biology Department, The University, Sydney.
1892		Halloran, Henry Ferdinand, L.S., 82 Pitt-street.
1909		Hammond, Walter L., B.Sc., Hurlstone Avenue, Summer Hill.
1916		Hamilton, Arthur Andrew, Botanical Assistant, Botanic Gardens, Sydney.
1912		Hamilton, A. G., Lecturer on Nature Study, Teachers' College, Blackfriars.
1887	P 8	Hamlet, William M., F.I.C., F.C.S., Member of the Society of Public Analysts; 'Strathallen,' Blaxland Ridge, viâ Richmond, N.S.W. (President 1899, 1908).
1916		Hardy, Victor Lawson, 'The Laurel,' 43 Toxteth Rd., Glebe Pt
1912		Hare, A. J., Under Secretary for Lands, 'Booloorool,' Monte Christo-street, Woolwich.
1905	P 2	Harker, George, D.Sc., Assistant Lecturer and Demonstrator in Organic Chemistry in the University of Sydney.

Elected		
1913	P 1	Harper, Leslie F., F.G.S., Geological Surveyor, Department of Mines, Sydney.
1884	P 1	Haswell, William Aitcheson, M.A., D.Sc., F.R.S., Professor of Zoology and Comparative Anatomy in the University of Sydney; p.r. 'Mimihau,' Woollahra Point.
1900		Hawkins, W. E., 88 Pitt-street.
1916		Hay-Dalrymple, Richard T., Chief Commissioner of Forests, N. S. Wales; p.r. Goodchap Road, Chatswood.
1914		Hector, Alex. Burnet, 481 Kent-street.
1891	P 3	Hedley, Charles, F.L.S., Assistant Curator, Australian Museum, Sydney. *Vice-President.* (President 1914.)
1899		Henderson, J., F.R.E.S., 'Wahnfried,' Drummoyne.
1916		Henderson, James, 'Dunsfold,' Clanalpine-street, Mosman.
1884	P 1	Henson, Joshua B., ASSOC. M. INST. C.E., Hunter District Water Supply and Sewerage Board, Newcastle.
1905		Hill, John Whitmore, 'Willamere,' May's Hill, Parramatta.
1914		Hoare, Robert R., Staff Paymaster, Royal Navy, Garden Island, Sydney.
1892		Hodgson, Charles George, 157 Macquarie-street.
1916		Hoggan, Henry James, Consulting Engineer, 'Lincluden,' Frederick-street, Rockdale.
1901		Holt, Thomas S., 'Amalfi,' Appian Way, Burwood.
1905		Hooper, George, Assistant Superintendent, Sydney Technical College; p.r. 'Branksome,' Henson-street, Summer Hill.
1891	P 2	Houghton, Thos. Harry, M. INST. C.E., M. I. MECH. E., 63 Pitt-st. *President.*
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1913		Hudson, G. Inglis, J.P., 'Gudvangen,' Arden-street, Coogee.
1904		Jaquet, John Blockley, A.R.S.M., F.G.S., Chief Inspector of Mines, Department of Mines.
1905	P 8	Jensen, Harold Ingemann, D.Sc., Treasury Chambers, George-street, Brisbane.
1916 1907	P 1	Johnston, Stephen Jason, B.A., D.Sc., Lecturer and Demonstrator in Zoology, The University, Sydney.
1909	P 13	Johnston, Thomas Harvey, M.A., D.Sc, F.L.S., Lecturer in Biology in the University of Queensland, Brisbane.
1867		Jones, Sir P. Sydney, Knt., M.D. *Lond.*, F.R.C.S. *Eng.*, 'Llandilo,' Boulevarde, Strathfield.
1911		Julius, George A., B.Sc., M.E., M. I. MECH. E., Culwulla Chambers, Castlereagh-street, Sydney.
1907		Kaleski, Robert, Holdsworthy, Liverpool.
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873	P 3	Keele, Thomas William, L.S., M. INST. C.E., Commissioner, Sydney Harbour Trust, Circular Quay; p.r. Llandaff-st., Waverley.
1914		Kemp, William E., A.M. INST. C.E., Public Works Department, Coff's Harbour Jetty.
1887		Kent, Harry C., M.A., F.R.I.B.A., Dibbs' Chambers, Pitt-street.
1901		Kidd, Hector, M. INST. C.E., M. I. MECH. E., Cremorne Road, Cremorne.

Elected		
1896		King, Kelso, 120 Pitt-street.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.C.S. *Irel.*, 'Northcote,' Sir Thomas Mitchell Road, Bondi.
1881	P 23	Knibbs, G. H., C.M.G., F.S.S., F.R.A.S., L.S., Member Internat. Assoc. Testing Materials; Memb. Brit. Sc. Guild; Commonwealth Statistician, Melbourne. (President 1898.)
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Double Bay.
1911	P 2	Laseron, Charles Francis, Technological Museum.
1913		Lawson, A. Anstruther, D.Sc., F.R.S.E., Professor of Botany in the University of Sydney.
1916		L'Estrange, Walter William, 'Orrville,' The Avenue, Strathfield.
1906		Lee, Alfred, 'Glen Roona,' Penkivil-street, Bondi.
1909		Leverrier, Frank, B.A., B.Sc. K.C., 182 Phillip-street.
1883		Lingen, J. T., M.A. *Cantab.*, University Chambers, 167 Phillip-street, Sydney.
1906		Loney, Charles Augustus Luxton, M. AM. SOC. REFR. E., Equitable Building, George-street.
1916		Loubét, Paul René, M.D., B.Sc., Blackall District Hospital, Blackall, Queensland.
1884		MacCormick, Sir Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 185 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., Ch.M, *Edin.*, 24 College-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co., Ld., Hunter-street, Sydney.
1876		Mackellar, The Hon. Sir Charles Kinnaird, M.L.C.. M.B., C.M. *Glas.*, Equitable Building, George-street.
1912	P 1	MacKinnon, Ewen, B.Sc., Agricultural Museum, George-st. N.
1899		MacTaggart, J. N. C., M.E. *Syd.*, ASSOC. M. INST. C.E., Water and Sewerage Board District Office, Lyons Road, Drummoyne.
1903		McDonald, Robert, J.P., L.S., Pastoral Chambers, O'Connell-st.; p.r. 'Wairoa,' Holt-street, Double Bay,
1891		McDouall, Herbert Chrichton, M.R.C.S. *Eng.*, L.R.C.S. *Lond.*, D.P.H. *Cantab.*, Hospital for the Insane, Gladesville.
1906		McIntosh, Arthur Marshall, 'Glenbourne,' Hill-st., Roseville.
1891	P 2	McKay, R. T., L.S., ASSOC. M. INST. C.E., Geelong Waterworks and Sewerage Trusts Office, Geelong, Victoria.
1880	P 9	McKinney, Hugh Giffin, M.E., Roy. Univ. *Irel.*, M. INST. C.E., Sydney Safe Deposit, Paling's Buildings, Ash-street.
1903		McLaughlin, John, Union Bank Chambers, Hunter-street.
1901	P 1	McMaster, Colin J., L.S., Chief Commissioner of Western Lands; p.r. Wyuna Road, Woollahra Point.
1894		McMillan, Sir William, K.C.M.G., 'Darrah,' 311 Edgecliff Road, Woollahra.
1916		McQuiggin, Harold G., B.Sc., Demonstrator in Physiology in the University of Sydney; p.r. 'Berolyn,' Beaufort-street, Croydon.
1909		Madsen, John Percival Vissing, D.Sc., B.E., P. N. Russell Lecturer in Electrical Engineering in the University of Sydney.

Elected		
1883	P 29	Maiden, J. Henry, J.P., I.S.O., F.R.S., F.L.S., F.R.H.S., Hon. Fellow Roy. Soc. S.A.; Hon. Memb. Roy. Soc, W.A.; Netherlands Soc.for Promotion of Industry; Philadelphia College Pharm. Southern Californian Academy of Sciences; Pharm. Soc. N.S.W.; Brit. Pharm. Conf.; Corr. Fellow Therapeutical Soc., Lond.; Corr. Memb. Pharm. Society Great Britain; Bot. Soc. Edin.; Soc Nat. de Agricultura (Chile); Soc. d'Horticulture d'Alger; Union Agricole Calédonienne; Soc. Nat. etc., de Chérbourg; Roy. Soc. Tas.; Roy. Soc. Queensl.; Inst. Nat. Genévois; Hon. Vice-Pres. of the Forestry Society of California; Diplomé of the Société Nationale d'Acclimatation de France; Linnean Medallist, Linnean Society; N.S.W. Govt. Rep. of the "Commission Consultative pour la Protection Internat. de la Nature"; Government Botanist and Director, Botanic Gardens, Sydney. *Hon. Secretary.* (President 1896, 1911.)
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1897		Marden, John, M.A., LL.D., Principal, Presbyterian Ladies' College, Croydon, Sydney.
1908		Marshall, Frank, B.D.S. *Syd.*, 'Beanbah,' 235 Macquarie-street.
1914		Martin, A. H., 'Glengarriff,' Nea-street, Chatswood.
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1916		Milne, Edmund, Commissioner for Railways, Public Works Building. Bridge-street, Sydney.
1889	P 8	Mingaye John C. H., F.I.C., F.C.S., Assayer and Analyst to the Department of Mines, p.r. Campbell-street, Parramatta.
1879		Moore, Frederick H., Union Club, Sydney, c/o Dalgety's Ltd., London.
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1915		Murphy, R. K., Dr. Ing., Chem. Eng., Consulting Chemical Engineer and Lecturer in Chemistry, Technical College, Sydney.
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1893	P 3	Nangle, James, F.R.A.S., Superintendent of Technical Education, The Technical College, Sydney; p.r. 'St. Elmo,' Tupper-street, Marrickville.
1891		‡Noble, Edward George, L.S., 8 Louisa Road, Balmain.
1893		Noyes, Edward, ASSOC. INST. C.E., ASSOC. I. MECH. E., c/o Messrs. Noyes Bros., 115 Clarence-street, Sydney.
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1896		Onslow, Col. James William Macarthur, 'Gilbulla,' Menangle.

Elected		
1875		O'Reilly, W. W. J., M.D., Ch.M. Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 171 Liverpool-street, Hyde Park.
1891		Osborn, A. F., ASSOC. M. INST. C.E., Water Supply Branch, Sydney, 'Uplands,' Meadow Bank, N.S.W.
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1899		Pearse, W., Union Club; p.r. 'Plashett,' Jerry's Plains, viâ Singleton.
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1879	P 7	Pittman, Edward F., ASSOC. R.S.M., L.S., 'Carnarvon,' Bayswater Road, Darlinghurst.
1881		Poate, Frederick, L.S., Surveyor-General, Lands Department, Sydney; p.r. 'Clanfield,' 50 Penkivil-street, Bondi.
1879		Pockley, Thomas F. G., Union Club, Sydney.
1887	P 10	Pollock, J. A., D.Sc., F.R.S., Corr. Memb. Roy. Soc. Tasmania; Roy. Soc. Queensland; Professor of Physics in the University of Sydney.
1896		Pope, Roland James, B.A., *Syd.*, M.D., C.M., F.R.C.S., *Edin.*, 183 Macquarie-street.
1910		Potts, Henry William, F.L.S., F.C.S., Principal, Hawkesbury Agricultural College, Richmond, N.S.W.
1914		Purdy, John Smith, M.D., C.M. *Aberd.*, D.P.H. *Camb.*, Metropolitan Medical Officer of Health, Town Hall, Sydney.
1893		Purser, Cecil, B.A., M.B., Ch.M. *Syd.*, 139 Macquarie-street.
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1916		Read, John, M.A., Ph.D., B.S Professor of Organic Chemistry in the University of Sydney.
1906		Redman, Frederick G., P. and O. Office, Pitt-street.
1914		Rhodes, Thomas, Civil Engineer, Box 109, Post Office, Broken Hill.
1909		Reid, David, 'Holmsdale,' Pymble.
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Elected		
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1913		Scammell, W. J., Mem. Phar. Soc. *Grt. Brit.*, 18 Middle Head Road, Mosman.
1905		Scheidel, August, Ph.D., Managing Director, Commonwealth Portland Cement Co., 4 O'Connell-street.
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1882		Sinclair, Eric, M.D., C.M. *Glas.*, Inspector-General of Insane, 9 Richmond Terrace, Domain; p.r. 'Broomage,' Kangaroo-street, Manly.
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1912		Smart, Bertram James, B.Sc., Public Works Office, Lithgow.
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1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1916		Smith, Stephen Henry, Department of Education, Sydney.
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Elected		
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1878		Thomas, F. J., 'Lovat,' Nelson-street, Woollahra.
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1913		Thompson, Joseph, M.A., LL.B., Vickery's Chambers, 82 Pitt-street, Sydney.
1913		Tietkens, William Harry, 'Upna,' Eastwood.
1916		Tilley, Cecil E., Demonstrator in Geology, The University, Sydney.
1916		Tillyard, Robin John, M.A., B.Sc., F.E.S., 'Kuranda,' Mount Errington. Hornsby, N.S.W.
•1879		Trebeck, P. C., Bourimbla, Bowan Park, N.S.W.
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1913		Ullrich, Richard Emil, Accountant, 43 Bond-street, Mosman.
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1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'BayView House,' Tempe.
1890		Vicars, James, M.E., Memb. Intern. Assoc. Testing Materials; Memb. B. S. Guild; Challis House, Martin Place.
1892		Vickery, George B., 78 Pitt-street.
1903	P 3	Vonwiller, Oscar U., B.Sc., Assistant Professor of Physics in the University of Sydney.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, The Hon. J. T., F.R.C.I., Fellow of Institute of Bankers *Eng.*, 'Wallaroy,' Edgecliff Road, Woollahra.
1910		Walker, Charles, 'Lynwood,' Terry Road, Ryde.
1910		Walker, Harold Hutchison, Major, C.M.F., 'Vermont,' Belmore Road, Randwick.
1901		Walkom, A. J., A.M.I.E.E., Electrical Branch, G.P.O., Sydney.
1891	P 2	Walsh, Henry Deane, B.A.I. *Dub.*, M. INST. C.E., Commissioner and Engineer-in-Chief, Harbour Trust, Circular Quay. (President 1909.)
1903		Walsh, Fred., J.P., Capt. C.M.F., Consul-General for Honduras in Australia and New Zealand; For. Memb. Inst. Patent Agents, London; Patent Attorney Regd. U.S.A.; Memb. Patent Law Assoc., Washington; For. Memb. Soc. German Patent Agents, Berlin; Regd. Patent Attorn. Comm. of Aust; Memb. Patent Attorney Exam. Board Aust.; George and Wynyard-streets; p.r. 'Walsholme,' Centennial Park, Sydney.

Elected		
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1916		Warden, Robert Alexander, President, Government Savings Bank, N.S.W., Moore-street, Sydney.
1913	P 4	Wardlaw, Hy. Sloane Halcro, D.Sc. *Syd.*, 87 Macpherson-street, Waverley.
1883	P 17	Warren, W. H., LL.D., WH. SC., M. INST. C.E., M. AM. SOC. C.E., Member of Council of the International Assoc. for Testing Materials, Professor of Engineering in the University of Sydney. (President 1892, 1902.)
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, Macquarie-st.
1910		Watson, James Frederick, M.B., Ch.M., Australian Club, Sydney, p.r. 'Midhurst,' Woollahra.
1910		Watt, Francis Langston, F.I.C., A.R.C.S., 10 Northcote Chambers, off $16\frac{1}{2}$ Pitt-street, City.
1911		Watt, R. D., M.A., B.Sc., Professor of Agriculture in the University of Sydney.
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1910	P 1	Wearne, Richard Arthur, B.A., Principal, Technical College, Ipswich, Queensland.
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1907		Welch, William, F.R.G.S., 'Roto-iti,' Boyle-street, Mosman.
1881		‡Wesley, W. H., London.
1892		White, Harold Pogson, F.C.S., Assistant Assayer and Analyst, Department of Mines; p.r. 'Quantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL D. *Dub.*
1909		White, Charles Josiah, B.Sc., Science Lecturer, Sydney Training College; p.r. 'Byrntryird,' 49 Prospect Rd. Summer H.
1908	P 1	Willis, Charles Savill, M.B., Ch.M. *Syd.*, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H., *Lond.*, Department of Public Instruction, Bridge-street.
1890		Wilson, James T., M.B., Ch.M. *Edin.*, F.R.S., Professor of Anatomy in the University of Sydney.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1906	P 6	Woolnough, Walter George, D.Sc., F.G.S., Professor of Geology in the University of Western Australia, Perth.
1916		Wright, Gilbert, Lecturer and Demonstrator in Agricultural Chemistry, Department of Agriculture, The University, Sydney.
1916		Youll, John Gibson, Perpetual Trustee Chambers, Hunter-st.

Honorary Members.

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M.—Recipients of the Clarke Medal.

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1900		Crookes, Sir William, Kt., O.M., LL.D., D.Sc., F.R.S., 7 Kensington Park Gardens, London W.

Elected		
1905		Fischer, Emil, Professor of Chemistry in the University of Berlin.
1911		Hemsley, W. Botting, LL.D. (*Aberdeen*), F.R.S., F.L.S., V.M.H., Formerly Keeper of the Herbarium, Royal Gardens, Kew; Korresp. Mitgl. der Deutschen Bot. Gesellschaft; Hon. Memb. Sociedad Mexicana de Historia Natural; New Zealand Institute; Roy. Hort. Soc. London; 24 Southfield Gardens, Strawberry Hill, Middlesex.
1914		Hill, J. P., D.Sc., F.R.S., Professor of Zoology, University College, London.
1908		Kennedy, Sir Alex. B. W., Kt., LL.D., D. ENG., F.R.S., Emeritus Professor of Engineering in University College, London, 17 Victoria-street, Westminster, London S.W.
1908	P 57	*Liversidge, Archibald, M.A., LL.D., F.R.S., Emeritus Professor of Chemistry in the University of Sydney, 'Fieldhead,' George Road, Coombe Warren, Kingston, Surrey. (President 1889, 1900.)
1915		Maitland, Andrew Gibb, F.G.S., Government Geologist of Western Australia.
1912		Martin, C. J., D.Sc., F.R.S., Director of the Lister Institute of Preventive Medicine, Chelsea Gardens, Chelsea Bridge Road, London.
1894		Spencer, Sir W. Baldwin, K.C.M.G., M.A., D.Sc., F.R.S., Professor of Biology in the University of Melbourne.
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1915	M	Thomson, Sir J. J., O.M., D.Sc., F.R.S., Nobel Laureate, Cavendish Professor of Experimental Physics in the University Cambridge.

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OBITUARY 1916-17.

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1893 *Professor Ralph Tate, F.L.S., F.G.S.

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1895 Robert Etheridge, Junr., Curator of the Australian Museum, Sydney.

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1902 *F. Manson Bailey, C.M.G., F.L.S.

1903 *Alfred William Howitt, D.Sc., F.G.S.

1907 Walter Howchin, F.G.S., University of Adelaide.

1909 Dr. Walter E. Roth, B.A., Pomeroon River, British Guiana, South America.

1912 W. H. Twelvetrees, F.G.S., Government Geologist. Launceston, Tasmania.

1914 A. Smith Woodward, LL.D., F.R.S., Keeper of Geology, British Museum (Natural History) London.

1915 Professor W. A. Haswell, M.A., D.Sc., F.R.S., The University, Sydney.

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1889 Thomas Whitelegge, F.R.M.S., Sydney, for paper entitled 'List of the Marine and Fresh-water Invertebrate Fauna of Port Jackson and Neighbourhood.'

1889 Rev. John Mathew, M.A., Coburg, Victoria, for paper entitled 'The Australian Aborigines.'

1891 Rev. J. Milne Curran, F.G.S., Sydney, for paper entitled 'The Microscopic Structure of Australian Rocks.'

1892 Alexander G. Hamilton, Public School, Mount Kembla, for paper entitled 'The effect which settlement in Australia has produced upon Indigenous Vegetation.'

1894 J. V. De Coque, Sydney, for paper entitled the 'Timbers of New South Wales.'

1894 R. H. Mathews, L.S., Parramatta, for paper entitled 'The Aboriginal Rock Carvings and Paintings in New South Wales.'

1895 C. J. Martin, D.Sc., M.B., F.R.S., Sydney, for paper entitled 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).'

1896 Rev. J. Milne Curran, Sydney, for paper entitled 'The occurrence of Precious Stones in New South Wales, with a description of the Deposits in which they are found.'

ISSUED JANUARY 30th, 1917.

Vol. L. **Part I.**

JOURNAL AND PROCEEDINGS

OF THE

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OF

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By R. GREIG-SMITH, D.Sc.

[*Read before the Royal Society of N.S. Wales, May 3, 1916.*]

Part I.—General.

PERHAPS the strongest evidence that we as a Society possess regarding the seriousness of the European War is the fact that many of our members have left us for the front. We are glad that the fortune of war is with us and that these brave members are still on active duty. Some who left have returned, and we greet these as men who have done all that men can do and we welcome them home again. They are Dr. Alfred Campbell, Sir Alexander MacCormick and Dr. E. S. Stokes. Our absent members are the following:—

Dr. H. J. W. Brennand,
Prof. T. W. E. David,
Dr. J. A. Dick,
Dr. Thomas Fiaschi,
Dr. J. F. Flashman,
Mr. C. F. Laseron,
Mr. J. N. C. MacTaggart,
Mr. F. Marshall,
Mr. A. M. McIntosh,
Prof. J. A. Pollock,
Dr. J. S. Purdy,
Mr. H. B. Taylor,

Lieut.-Col. A. J. Onslow Thompson, (killed in action).

While these gentlemen have responded to the battle cry, we on our part have been steadily pursuing our way, doing our utmost to advance the civilisation that the enemy is endeavouring to destroy. That our efforts are meeting with some recognition, and that our Society possesses some of the best scientific minds of the day has been shown by the recent election of two of our members to the Fellowship of the Royal Society of London. It is a pleasure to know that Australian science is being recognised, and we congratulate Mr. Maiden and Prof. Pollock upon having obtained the honour to which we all aspire.

Our Society has during the past year done much good work, and the papers which have been read at the monthly meetings have been well up to the standard of previous years. Our energies have been amplified by the formation of a new Section, that of Public Health and Kindred Sciences. This section had its first meeting in October in the presence of our Vice-Patron, Sir Gerald Strickland, Governor of the State. Under the chairmanship of Sir Thomas Anderson Stuart, and with Dr. Willis as the sectional secretary, the section has made some valuable contributions to military public health.

We have unfortunately suffered through the death of several members, many of whom had been with us for very many years, and while we miss them and regret their departure, we realise that they have done their duty and have advanced our knowledge and assisted in pioneering the way for future generations.

LUDWIG HERMANN BRUCK was senior partner in a firm of medical agents and importers. He founded the Australasian Medical Gazette, and to him it owed the first fifteen years of its existence, although it was considered to be the official organ of the Victorian, South Australian and New South Wales branches of the British Medical Association. In 1894 he sold the Gazette to the New South Wales Branch. Mr. Bruck enjoyed the confidence of a large number of medical men in Australia, in his capacity as a medical agent, and in 1896 he published a valuable though small pamphlet dealing with the relations of the medical profession with the Friendly Societies. He was elected to the membership of the Royal Society in 1903, and he continued a member to the time of his death, on August 14th, 1915, at the age of 66 years.

Mr. EDWARD ROSS FAIRFAX, son of the late Hon. John Fairfax, M.L.C., and brother of Sir James Fairfax, was a member of our Society for thirty-eight years, and during the earlier part of his membership was a prominent figure at the meetings. Latterly he lived in England. For many years he was a partner in the firm of John Fairfax and Sons, proprietors of the "Sydney Morning Herald" and the "Sydney Mail." His many friends in Sydney held him in high esteem. He died on August 2nd, at the age of 72 years.

Mr. WILLIAM RUFUS GEORGE was elected to the Society in 1876. At one time he was a contractor, but subsequently was the principal in a firm of Sydney photographers. Outside of his professional work he took a deep interest in the methods of vehicular propulsion. He was one of those friends of science who believed in it, and did his best to further its advancement. He died on December 11th at the age of 82 years.

Mr. LAWRENCE HARGRAVE was a well-known figure at our meetings which he attended regularly even to the June meeting preceding his death on July 6th, 1915, at the age of 65 years. The son of the late Mr. Justice Hargrave, he was born in England but came to Australia in 1866 at the age of sixteen. Being of a mechanical turn of mind, he entered an engineering firm in Sydney, where he received the training that subsequently enabled him to construct the models and build the engines, etc., which his inventive genius designed. It was as an engineer and explorer that he first developed, and he took no small share in the early exploration of British New Guinea. He formed one of a party of adventurers who equipped the "Maria" for an exploring expedition. On her way north this unseaworthy old craft was wrecked in February 1872 on the coast of North Queensland. A considerable number of her company were killed by the aborigines, but Hargrave was fortunate in escaping with his life and returned to Sydney. Joining a scientific expedition organised by Sir William Macleay, he sailed from Sydney in the "Chevert," in May 1875. But too short a visit was made to New Guinea to satisfy Hargrave, who accordingly left the "Chevert" at Cape York in September. With Petterd and Broadbent, he then joined O. C. Stone in an excursion inland from Port Moresby. Their discoveries in this direction are recorded by Stone in "A few Months in New Guinea." In May 1876, Hargrave joined D'Albertis as engineer of the "Neva," in which they ascended the Fly River further than any European had previously penetrated into the interior of Papua. The hardship and exposure of this journey induced severe attacks of fever, and in September 1876 he concluded his travels and came back to Sydney.

He worked for some years as an assistant astronomical observer at the Sydney Observatory under the late Mr. H. C. Russell, but gave this up and devoted many years to the study of æronautics, and the success of the present day æroplanes is largely dependent upon Hargrave's invention of the box-kite. He first studied the motions involved in the flight of birds, and prepared models embodying the principles of the various movements. The success of the models convinced him of the possibility of mechanical flight, and although he did not prepare a complete machine, he was so satisfied with the result of his work that he gave his ideas upon the subject to this Society in August 1884. The models which served to illustrate his papers are now in the Technological Museum, Sydney. The continuance of his investigations led him to the invention of the cellular or box kite, which he described in 1895. It is as the inventor of this kite that his name is so well known, for it has been used by practically every military nation in the world for signalling purposes and by scientists for meteorological investigations. It does not follow that our æroplanes would not have been invented but for the box-kite, only it is certain that his invention hastened the evolution of the æroplane in no small degree. It is upon his invention that other men have built and have become famous. Latterly he devoted some attention to the meaning and significance of certain rock carvings and markings upon the rocks around Port Jackson and the Hawkesbury River. Mr. Hargrave was of a quiet and retiring disposition, and preferred to discuss the various subjects in which he was interested, and in which he had a deep knowledge, to a small circle of friends rather than to a large audience. His familiar face will be sadly missed by those members of our Society who rarely saw his favourite seat vacant at the meetings.

By the death of GEORGE DENTON HIRST, F.R.A.S., which occurred at Mosman, Sydney, in May 1915, amateur astronomy in New South Wales lost one of its ablest supporters. In business he was a wine and spirit merchant, and his principal hobby was astronomy, for which he maintained a keen interest for over forty years. Besides the observing work he did, his advice and practical help were always available to those in difficulties, and often on Sunday mornings a small gathering of amateurs met at his home and criticised each other's observations. In 1874 he observed the Transit of Venus at Woodford, N.S.W., and his report on it is published in the Memoirs of the Royal Astronomical Society, Vol. XLVII. As an astronomical draftsman Mr. Hirst had no equal in Australia. His drawings of Mars were marked with the same skill and delicacy as those of N. E. Green of England. His papers on Mars and Jupiter, accompanied by drawings, are published in the Journal of the Royal Society of N.S.W., Vols. X and XIV. To the British Astronomical Association he contributed papers on double stars, wiring of astronomical instruments, and on astronomical drawing, as well as observations and sketches of Mars and Jupiter. To the Royal Astronomical Society he contributed a useful list of measures of Southern Double Stars (Monthly Notices, Vol. LXX). He continued a member of the Royal Society of N.S.W. since 1876, and of both the Royal Astronomical Society and of the British Astronomical Association since 1895.

Mr. JOSIAH MULLENS, before he came to Australia, was clerk in charge of the Stock Exchange Department of Drummond's Bank in London. He landed in Melbourne in 1852 when it was little more than a collection of canvas tents, then he came to Sydney and entered the firm of George Alfred Hill to which he was the gold-buyer. Leaving the firm, he started business on his own account as a share-broker, and two years after the establishment of the Sydney Stock Exchange he was elected its Chairman, which office he held for fifteen years. Of studious and retiring habits, he was interested in Egyptology and antiquarian investigations, especially in the work of the Palestine Exploration Society and of the discoveries of ancient civilisation in Babylonia, Arcadia and the East. He was an authority on archæology and was a well-informed Egyptologist, as became a man who was the president of the Australian branch of the Egypt Exploration Fund. As a trustee of the Sydney Art Gallery, he rendered active service in the interests of that institution. He was a member of the Royal Geographical Society, and was elected to the Royal Society of N.S. Wales in 1877. He was a frequent attendant at our meetings until a few years before his death, which occurred on October 22nd, at the ripe age of 89 years.

Mr. F. MANSON BAILEY, C.M.G., was awarded our Clarke Memorial Medal in 1902 in recognition of the work he had done as Botanist to the Queensland Government, in increasing our knowledge of Australian botany. His father was the Colonial Botanist of South Australia, and he undoubtedly inherited the talents which he displayed from the time when in 1875, he became Botanist to a Board appointed to deal with the diseases of plants and animals. He had a varied experience as a young man, partly in the gold-fields of Victoria, partly in New Zealand and finally in Queensland, where he interested himself in private business. In 1881, he was appointed Colonial Botanist and was enabled to devote all his time to a subject for which he was peculiarly adapted. From 1874, publication succeeded publication from his pen, and the descriptions of new plants followed one another in such rapid succession, that it is difficult to estimate the total number of additions that he made to the Queensland flora. They are certainly very considerable. As his last publication appeared in April 1915, he may be said to have died in harness, on June 25th, 1915, at the advanced age of 88 years.

Part II.—Science and Industry.

We are on the eve of an industrial change and there are signs that science is about to receive some of the recognition that is due to it. The war has shown that in the past, we have neglected many of our opportunities when we have allowed the enemy to make so much headway in certain industries. This would never have occurred had we been alive to the fact that our primary and secondary industries must rest upon a purely or upon a partially scientific foundation. There are few that are independent of science.

Our dependence upon Germany for the bulk of our anilin dyes has shown the British Government, more forcibly than any other thing could have done, as that industry has a purely scientific basis, that the Nation has erred in its neglect of science. Although the value of the dyes imported from Germany in 1913 reached the comparatively small sum of one and three-quarter millions of pounds sterling, yet it is a "key" industry, and the shortage of dyes during the war seriously influenced the textile and other industries which aggregate annually to about two hundred millions of pounds sterling. Science has not only made the dye industry, but has also created the production of synthetic drugs and perfumes in which Germany has a practical monopoly.

The war has made it clear that our empire should be self reliant; we should be able to make everything and be independent of all other countries. And what applies to the Empire also applies, although with less force, to our Continent of Australia. It may not be economically sound to make an article for a shilling which we can import for sixpence, but it is exceedingly useful in an emergency when the article cannot be obtained. Under free-trade the inhabitants of Great Britain considered it to be thrift to be able to buy sugar for $1\frac{3}{4}$d per pound while it cost the people living at the door of the continental sugar mill, where the same sugar was refined, 6d per pound, but it made them dependent upon a possible enemy for their supplies.

The necessity for economy.

The cost of the war is rapidly mounting up, and this cost must be met in the future. The Britain, with its huge increase in the national debt of from two to four thousand millions, will be different from the Britain of the pre-war days. The same applies to our Continent of Australia. Taxation will be greater and labour will not lower its reward, so that the spending power of the individual will be lessened. How then is the situation to be met?

There is only one way, and that is in the economy of production, whether it be by the utilisation of labour-saving devices, by a saving of useless labour, by the concentration of many isolated fields of labour, for the saving of the cost of transportation and by the co-operation of similar industries not for the purpose of raising prices but for the purpose of reducing working expenses. Mr. Lloyd George in an interview (*Sydney Morning Herald*, Jan. 26th, 1916), said :—

"A new industrial Britain is being developed under the great pressure of war. We are increasing and improving our industrial resources almost incredibly. We have introduced scores of millions worth of automatic machinery which will have an enormous effect on the industries when the war is over. In addition we are adding to our already great army of industrial workers. We shall need all to repair the ravages of the war. The country therefore, instead of being impoverished, will be richer. Everything constituting real wealth will be better organised, equipped and trained and there will be a better disciplined nation."

Our existence depends upon Science.

Our legislators have already seen the writing on the wall; they know that a change in our methods of thought is inevitable, that a scientific spirit must be developed in the nation in order to meet and cope with the new conditions. Science and industry must both be mobilised, and they must work harmoniously together. The value of science is unfortunately not appreciated to the extent that it ought to be. The war, however, is bringing home to the masses how much the nation is dependent upon scientific research for its existence. This is a scientific war in which all the available resources of science are being utilised to enable us to win, that we may confer upon the world the advantages of civilisation untrammelled by military despotism. All the engines of destruction used in the war are the creation of scientific thought, the result of patient research and experiment in our scientific laboratories, and the power behind all this is the scientist quietly plodding in his obscure laboratory, unheard of and unseen. The nation believes that he exists, but as he does not believe in posing before the public, he is permitted to remain in the background and is ignored. It is unfortunate that in this world a man is put at his own valuation, and as the scientist cares little for the opinion of the world and lives entirely in his work, he is not accorded the credit that is due to him.

This is unfortunate for science, as with its public recognition the work would be better paid, and it is probable that more and possibly better men would be attracted to its services. We scientists must endeavour to alter our ways. It will not do to follow the methods of the past and be contented with the publication of our work in the scientific journals of our societies. We have got to impress the public with the results of our labours, that they may be trained to acknowledge that we are working not only for the scientific but also for the common good. It behoves us to get into the limelight, not for our own sakes, but for the advantage of the science we love. Unless we do so the other professions will continue to get the plums of office, and science will again be the Cinderella she was before War, the fairy god-mother, brought her before the public gaze.

Science should be fostered.

In the fierce industrial war that will follow, as an aftermath, the present conflict of arms, the applications of science will perforce be fully developed, and it is hoped that with this the status of the scientific worker will be improved. He should be enabled to pursue his work without any anxiety as to ways and means. His apparatus should be of the best and his emoluments such that he is on a par with professional trained men of his own mental standard. It is unfortunate that the bread and butter sides of our universities are always full, while the purely scientific students are wofully few and far between. If we are to advance as a nation this must cease, and it can only be by the purely scientific worker being recognised at his true value. Men should be attracted to and not driven from scientific investigation.

Science, however, must mobilise itself if it is to gain the status and importance that is its right. The scientist in Australia is generally working at a matter which no other man is investigating. His subject may be of remote industrial utility, and although it may be of absorbing scientific interest, still the same interest and the same scientific enthusiasm could be obtained upon a work which might appeal directly to the industrial community. It would probably be advantageous if there could be more combination of work among us, for as a rule, no two men see a matter from the same point of view, and it is the little differences in the point of view that suggest experiments that open up new lines of thought.

Combination among workers.

It is this combined working that has given Germany its pre-eminence in certain industries. German scientists are less brilliant than those of the allied nations, but they have the faculty of plodding that amounts to genius. They peg away at a subject until they make it a success, and especially have they been interested in industrial science and in making it an economic success. Organisation and co-operation have been the key-note of their economic as well as of their primary military successes. It is up to us to work more together and more in co-operation with our industries. Our scientists are waiting for our industrialists to come to them with their troubles, but it is just at this point where there is a stumbling block. The industries will not admit that they have anything to gain from science, it will require the pinch of poverty to stimulate their perception.

At present there is a considerable amount of industrial waste, because it is believed that it will not pay to be utilised. Some of these avenues of waste I shall refer to subsequently.

The chiefs of most of our industries are not scientific. They are purely business men, and business has little time for science. There are some exceptions such as the Colonial Sugar Refining Co., which recognises science and which has risen to the pre-eminence that it has attained largely through scientific methods of work and finance. The company trains its young men in its own chemical laboratory; they come for a course of microbiology in my laboratory, then they go to the University for courses in various subjects which will augment their scientific training, and make them more efficient chemists. The company knows that it pays to train its assistants in this manner, and the methods of the company should be an object lesson to every Australian manufacturer.

A scientific man will rarely ever be a commercial man, and there are few large industries which would place its chief scientific worker on a par with its chief manager. Even in the Government service scientific workers are not on a higher level than the clerical staff. For the nation to progress this must be altered, but I am afraid this will not occur until the people, as a whole, are imbued with a more scientific spirit. And for this to take place we must start at the root of the matter and have more science taught in our schools. Once a scientific spirit is aroused, more advantage will be taken of the scientific teaching available in the secondary schools and technical colleges, and the leaven having started to work, the nation will in time be benefited.

The value of Science.

As a people, we rely upon the Government for guidance and assistance, but the Government is a business pure and simple, and has all the good and bad traits of a business. In the past it has not understood the value of science. In the future we hope for much. The war should have shown our Government heads the value of science, for it is by scientific methods and with the products of science, that we hope to emerge successfully from the present contest. The guns we use are scientific instruments, shells are made in a scientific manner and filled with scientifically prepared chemicals, and everything connected with the gun is so scientifically accurate that the shell can fall a few yards in front of our advanced trenches. Our aeroplanes are scientific inventions fitted with scientific appliances. The same with our ships of war, and our submarines with their devastating torpedoes. The use of gas and the life saving mask are applications of science. Surely with all this demonstration of science before us at the present time, the Government and the people must realise the value of science. They are backing science to win, and if it does win, are they going to ignore the winner? I cannot think that they will.

It is curious that although the utilisation of science has been so extensively made within the past two years, the British Government suggested that the British Universities should not fill any unoccupied chairs till after the war, and that some institutions and departments should be closed so that the staffs might seek employment elsewhere, and relieve the institutions of the payment of their salaries. And at the same time while the ink was still wet upon this note, it actually appointed three new judges each with a salary of £5,000, and a secretaryship to a Lord Chancellor with a stipend of £2,000.

I should like to ask what has law done to enable us to win this greatest war in history upon which our freedom depends? Yet our legal appointments are more highly considered than our scientific. What has clerical work done to win the fight? Yet our Government pays many of its clerks better than its scientists. This is a scientific war, and all future wars will be scientific whether they be military or industrial. Are we preparing ourselves for the industrial struggle that is looming in the near future? From what is happening in England and Australia there are indications that a certain scientific awakening has begun to take place in the ideas of our legislators.

The Institute of Science and Industry.

In Britain the Government has appointed an Advisory Council of Scientific and Industrial Research consisting of many prominent scientists and captains of industry, while in Australia the Commonwealth Government is considering the establishment of the Commonwealth Institute of Science and Industry. It is proposed that the functions of this Institute should be to promote the investigation of matters pertaining to the primary and secondary industries, and the co-ordination and direction of research and experimental work in order to prevent overlapping. The scheme includes the teaching of science in primary and secondary schools, the technical training of apprentices, enabling the staffs of our universities to devote more time to research, establishing a laboratory for standardising instruments and measures, and giving science a status in the public life. The scheme is far-reaching, and naturally will have to be well considered before a movement is made towards its establishment. Let us hope that like many political matters it will not be postponed until the public forgets the necessity for its foundation.

A scientific habit of thought.

It is understood that the scientific enlightenment of the nation should begin in the schools, for it is only by bringing the boy up in a scientific atmosphere that we can hope to develop a scientific inclination. It should be allowed to soak into the receptive and expanding mind. The Churches have recognised that they must get at the adult through the child. The adult is generally too old to become religious, and accordingly the Churches devote much of their capital to the upkeep of their schools, where the teachings of the Church are slowly absorbed and become a faith. It is after the manner of a faith that we would like to see the principles of science being absorbed by the coming generation.

In discussing the foundation of the Institute, the Prime Minister made it clear that his scheme was to reach right down to the primary schools, so as to bring the people into a scientific habit of thought. The same idea was expressed by Mr. Runciman, the President of the Board of Trade, when he said in the British Parliament:—

"I therefore put it down as one of the first necessities of this country, if she is to hold her own during times of war and when war is over, that we must improve our research methods, the education of our people and the training of our young men. We should not attempt to economise on the money we now spend on technical colleges and modern appliances. There are other directions in which we can cut down expenditure with less national damage."

The British Government should be now realising the absurdity of having in the past given so prominent a place in their civil service examinations to classical subjects and so secondary a position to science. An examinee can obtain a possible 3,200 marks in the humanities as against 2,400 in natural science subjects. At Woolwich, science was made compulsory only a few years ago while at Sandhurst it is still optional. This is the only European military school where science is not compulsory. The nation has ignored science generally, and the heads of the Government are wofully ignorant of all matters scientific. It seems as if they will not seek advice in case their absolute ignorance should be made apparent. According to the British Medical Journal, the case is quoted of a public statement by a member of the British Government, unchallenged when made, that his colleagues should be excused for not having prevented the exportation of lard to Germany since it had only recently been discovered that glycerine, used in the manufacture of explosives, could be obtained from lard. The "recently been discovered" is pitiable.

Scientific Journalism.

While we are waiting for the scientific enlightenment of the masses, a certain amount of leavening might be done by the press. Papers are read at the meetings of the scientific societies, and, in course of time, are published in the scientific journals, where, as far as the public are concerned, they rest. They ought to be abstracted and done up in a pleasing way for public consumption. The scientific man cannot do this, he is too scientific and exact. The ordinary journalist on the other hand, is too unscientific and inexact. It has been said that the scientist is the only man who has something to say, and is the only man who does not know how to say it. What we want is a happy medium between the two extremes, that is a scientific journalist to "write up" the proceedings of the scientific societies for the newspapers. I have in mind the articles by Ray Lancaster, which appeared in English newspapers and then in book-form under the title of "Science from an Arm-chair."

All scientific papers are not suitable for such abstraction, but, among the many, there are generally a few from which much interesting information might be gleaned and used for the general education. The official abstracts are usually so technical that no newspaper editor cares to publish them. We should remember Gilbert's lines:—

> " He who'd make his fellow creatures wise
> Must learn to gild the philosophic pill."

I believe it would be distinctly advantageous to our Society if we were to employ a journalist to write up short pithy pleasing articles upon some of the papers submitted at the monthly meetings. Although we exist for the publication of scientific papers, there is no reason why we should not endeavour to pass on our advances in science to the general public.

Some years ago, while acting as temporary secretary to a scientific society, I sent short popular abstracts to the newspapers. They were published, and I hope they were useful; at any rate they served to keep the name and the work of the Society at which the papers were read before the public notice.

Most weekly journals publish a science column, but I do not believe that this is effective enough. I should like to see a short scientific article, so attractively written, that when placed in the daily papers beside the report of a football match or of a prize fight, the public would read it first. Indeed I am so impressed with the importance of the matter, that I would welcome the scientific articles being written in the American style, or in any other style that would get at the public. The heading should attract the eye, the opening paragraph should convey the idea that something wonderful is about to follow, then should come the gist of the information expressed in non-technical language, and at the end the name of the Society should be introduced. We generally give the name of the Society first, and as a consequence the public is frightened and loses some valuable information.

State Representation.

While the future individuals of the nation are being imbued with a scientific spirit, work can be done in investigating matters of immediate importance. The proposed Institute of Science and Industry has had suggested to it certain questions for consideration by the Preliminary Advisory Council, and as time goes on other matters will naturally be brought forward. As one who is keenly interested in the scheme, I should like to see it progress rapidly and smoothly, but at the present I have certain misgivings. If we were a united Nation, the scheme would be certain to succeed from the start, since it should be entirely under the Commonwealth wing. But we are not a unified Nation, and it appears to me that there are certain vested interests that may delay the full realisation of the objects desired. At the present moment, the Commonwealth has the laboratories of the Customs and Excise. The States have the various departmental laboratories directly under their control, and indirectly they control the Universities through the public purse. I am sure the originators of the scheme look to the universities to do much of the necessary research work, until such time as the Commonwealth is able to establish its own research laboratories. Looking at the matter in a critical way, I do not think these State Governments have been sufficiently considered, and as they have the vested interests of laboratories and finance, I fear the scheme may not rapidly eventuate. If the staffs of the Universities are to have more time for research work, it will entail the appointment of assistants to ease the present teaching routine, and the new appointments will necessarily mean increased funds. If these funds are to be supplied by the Commonwealth, my criticism falls to the ground, but, so far, I gather that the Commonwealth intends only to supply the necessary laboratory equipment that is lacking. The inculcation of science into the rising generation must necessarily be done in the State Schools, and the scientific training of craftsmen in the State Technical Colleges. Thus it seems to me that while the Commonwealth takes the kudos, the States will have to do most of the work, and to pay the piper for some time at least. I note that the Ministers of Agriculture of the several States have been included as ex-officio members of the Preliminary Advisory Council, and if this will obviate any friction that may threaten to occur, the scheme should succeed. But this State at the present time is not doing its utmost to assist research as I shall show later on in the case of Mr. H. G. Smith, and I have my doubts about the sincerity of any sudden conversion. However, the *post-bellum* conditions may alter matters, and I sincerely trust it will. Although the State laboratories exist for conducting routine work, a certain amount of research work has been done in the past, indeed it is difficult to prevent scientific men from investigating. Among the list of subjects proposed by the committee as being pressing, two are being attacked by the States. Mr. Froggatt is engaged upon the sheep fly-pest, and the eradication of the prickly pear is being dealt with under the ægis of the Queensland Government.

Research Fellowships of the Linnean Society.

While the whole scheme of the proposed Institute emanates scientific research, it is strange that the Linnean Society of New South Wales was neither represented on the Committee nor is represented on the Preliminary Advisory Council. Thanks to the far-sightedness of the late Sir William Macleay, the Linnean Society occupies the unique position of having under its control five University graduates who are wholly occupied in scientific research. No other institution in Australia or even in the Southern Hemisphere has the same potentiality for conducting research work. The Society might well have been a nucleus around which the research part of the scheme might have been built. I cannot understand how its claims have been ignored.

The scientific flame has been and will continue to be kept alight by the existing scientific societies of which our own society is by no means the least important. They have done much for science, and it would have been courteous for the members of the Conference convened by the Prime Minister, who organised the formation of the Committee, to have asked the Australian Scientific Societies to nominate at least one representative.

Recently formed Associations.

Since the commencement of the war, several associations or committees of scientists and industrialists have been formed, and these, as well as certain existing societies, have undertaken investigations into the means of improving the conditions necessitated by the war or likely to occur when the war is over.

Some scientific workers have banded themselves together, under the title of the Australasian Chemical Association, with the object of compelling the public to recognise the value of analytical work by having to pay higher fees, and of obtaining legislation to hall-mark the importance of chemical analysis. This is a step in the right direction, for the higher the fee a man can command, the more important he is considered to be. I should suggest that one of the first matters this association should deliberate upon, is the question of restricting the name of chemist to one who works with chemicals, and, by legislation, compelling the retailer of drugs to confine himself to the designation of pharmacist. The status of chemical science has suffered, and is suffering, from the inability of the public to distinguish between the scientific chemist and the pharmacist.

The kind of work outlined by the Association should have been taken up by the local Fellows and Associates of the Institute of Chemistry, which as an examining body would have more prestige than a mere Association. I believe the Australian fellows are communicating among themselves with something of this idea in view.

Our local branch of the Society of Chemical Industry is doing good work by preparing and classifying lists of Australasian manufacturers who are making certain chemicals. This is a step in the direction of mobilising our chemical industry and enabling us to see how the industry stands at the present time, and it will show our users of chemicals where such can be obtained, and our manufacturers in what directions their energies could be employed in preparing new lines.

The Munitions Committee, while devoting its energies to furthering the production of shells, has by means of a chemical section, been enquiring into the resources of materials for warlike purposes and investigating the possibilities of some of them. The use of grass-tree gum for the production of picric acid has been shown to be out of the question, as the acid can be obtained cheaper from coal-tar. The use of Posidonia fibre for preparing gun-cotton and the resources of the country in glycerine, nitric and sulphuric acids, and the possibility of growing cotton have been reported upon.

The National Industries Committee consists of members of the University staff, of representatives of Commercial Associations and of the Government. It has for its objects the consideration of methods for increasing the efficiency of the whole industrial system, by the establishment of new industries, by the elimination of enemy influence and by the development of new markets. The committee is seeking to obtain information from representative firms as to the extent that their respective industries have been dependent upon the enemy for raw or intermediate material and machinery. Especially is it enquiring into the manner in which the want of these has been met, and the extent to which they are being or can be made in Australia. In the event of their not having been made here, the committee proposes to examine the factors which have prevented their manufacture. In the case of articles which are made locally, and which have been competing with enemy goods, information is sought as to the conditions which would entail the goods being manufactured completely in Australia.

The Government formed a Patents Investigation Board to financially assist the preliminary testing of any invention, likely to be useful to the public, and to promote the utilisation of the invention. By February 4th of this year over one hundred specifications had been lodged, and of these thirty were of a military nature. It is unfortunate that the general percentage of inventions submitted to such bodies, which are likely to become useful, is so low. Mr. Balfour, First Lord of the Admiralty, announced in the British Parliament, on February 17th, 1916, that of 1,000 inventions submitted, 999 were useless, and of the remainder a large percentage had been anticipated. The consideration of so much husk for so small a kernel, involves a great deal of labour to the members of the Board, who are patriotically giving their services to the State.

Although our own Society was established to assist science by the publication of papers, it seemed to the Council that it would be only right for the Society, at the present time, to offer its services to the Government in connection with any scientific matter arising out of the present war, on which the Government might desire its assistance. The Premier on behalf of the Government cordially accepted the offer.

The existence of these various Committees and Boards is a sign that we feel that we are passing through a critical time, and are about to enter a still more strenuous time, when the local industries will require all the help they can get, to be so established that they will not be vitally affected by the unfavourable conditions that will follow the war. We expect an extended wave of commercial depression to follow the war, and each industry must be capable of utilising every available resource to remain solvent.

They are also a sign that we are waking up to the fact that we ought to be a self-supporting community, and although this may be an impossibility for a continent with five and a half millions of people, still we should be able to supply all the necessities for our maintenance and for our defence. The Committees are doing work which will be of material assistance in this direction.

The Function of the Bureau of Science and Industry.

The fact of their inception has shown the necessity for a combined effort, and the establishment of the Institute of Science and Industry is the embodiment of our views. The Institute is intended to give a stimulus to scientific industrial research, which in turn will react upon our educational institutions, and bring them and our industrial community to realise the commercial value of science more fully. The manufacturer has hitherto looked askance at science, and has devoted his attention to the commercial side of his business, believing that by advertising and business tactics, he could do more for himself than by invoking the aid of science to help him to cheapen and improve his products.

This was emphasised by the Commercial Intelligence Committee of the Board of Trade, which has recently recommended the British Government—

"To give assistance for scientific research in industry. Although British manufacturers and workmen have not always appreciated scientific investigation or technical training, the German technical institutions have given valuable assistance. The Committee believes an extensive scheme of State aid for industrial research, which the Privy Council Committee recently established, would be of great value if manufacturers co-operate. Large funds are needed."

The importance of scientific research in industrial matters has evidently been made clear through the investigations of the Committee, which had for its Chairman the President of the Associated Chambers of Commerce of Great Britain. The Committee has apparently found that the scientific institutions are willing to co-operate, and this was only to be expected. The attitude of scientific men is, and has always been, such that they are only too glad to be able to help those who seek their assistance. The apathy has been with the manufacturers and others, who have either been too ignorant to know that advice was required, or who were afraid to try any novelty, that is, to experiment. They have been quite content to go on as they have been doing, and as their fathers have done before them; they forget that it is only by experiment or trial that an improvement can be effected.

Industry does not understand the aims of Science.

I may be wrong, but I do not think that in this continent at least, the time is yet ripe for the manufacturers to co-operate with our scientists. They appear to be unable to get away from the idea that there is some ulterior motive in the scientist trying to help them without gain or reward. It is not a business method. They cannot understand that science is not a business, but a calling, and that the scientist tries to benefit others because it is his nature. He must progress, and if he has to work upon purely academic matters, instead of purely industrial matters, it is the fault of the manufacturer, who will neither voluntarily supply the material nor divulge his troubles.

When I came to Australia as an economic microbiologist I called upon several manufacturers who used microbiological methods in some parts of their work, and I offered my services gratuitously to assist them in any difficulty they might have, but I was informed that they never had any irregularity in their processes. I wanted to help industry, but unfortunately industry did not respond to my advances, and the hopelessness of obtaining material from manufacturers upon which to do research work was quickly brought home to me. I have the feeling, born of experience, that the manufacturer thinks nothing of services for which he does not have to pay.

I remember getting the manager of the dairy department of a large Sydney firm to experiment with Conn's aroma bacillus. The experiment was made, and the butter made with the bacillus was judged to be worth a half-penny a pound more than the control butter. Yet nothing was made of the experiment. This is a case where science can aid industry, but the scientist cannot take each and every butter factory manager by the throat and force him to use the bacillus and get more for his butter. If the butter of the State were improved by even the fraction of one half-penny a pound, the gain to the farmer and to the State would be considerable.

The great problem is to get the manufacturer, whether on a large scale or in a small way of business, to himself endeavour to improve his methods. Long familiarity so accustoms an individual to a process, that he cannot see when an improvement can be effected. It is the outsider with a critical eye who can see where leakages are occurring, especially when he is a trained observer as most scientists are. Unfortunately the manufacturer does not care to have men of this stamp examining his processes. He is afraid that his trade secrets may be given to rival manufacturers. I doubt if he would lay his troubles before a body of men such as the Council of the proposed Institute of Science and Industry. There would be more likelihood of his unburdening himself to one man. The personal element is strong in human nature, and the agent of a firm can generally do more in the way of business than the firm itself. We should proceed exactly as a new business firm would proceed, by appointing agents and allowing them to break the ground. I fear that the spasmodic advertisement that the Institute will receive through occasional paragraphs in the newspapers, about the work it is doing or proposes to do, will never enable it to get into close touch with the secondary industries, and it is these that we want to reach.

A Technical Adviser.

In order to bridge the chasm between the research laboratory and the factory, I would suggest that the Institute should arrange, through the necessary and proper channels, to get each University to appoint a trained scientist with the status and emoluments of a University professor, as a Technical Adviser with the duty of giving advice to manufacturers. To overcome the idea that he will give away trade secrets, he should be sworn not to divulge what he sees in the factories. At the same time, however, he should be allowed to exercise his discretion in the publication of matters of general scientific interest. During the first two years of his office he should be required to visit all the manufacturers in the State at least once and probably twice. The first call would probably simply be an introduction, while the second would enable the manufacturer to know him better, and a greater familiarity would be more likely to induce the manufacturer to explain his methods, and at any rate he would know to whom to apply when trouble should arise. Behind the Adviser would be the resources of the Institute, and he could allocate any piece of industrial research to the most suitable investigator. The manufacturer would be protected, for the Adviser alone would know from what source the material was obtained. I feel that the conservatism of the manufacturer must be considered in any scheme that is promoted, and the natural diffidence in bringing forward his troubles or his methods under review, would best be overcome by having an individual whom he could approach and who would be responsible for the safe-guarding of his interests. After the initial pioneering work had been done, the Adviser could undertake research in the direction in which he was best adapted.

Losses by Small Manufacturers.

The small manufacturers are continually suffering losses through ignorance of scientific principles, and to have such a scientific Adviser to whom he could appeal would be a relief. For example, confectioners who have been making confectionery for years, will suddenly find that their boiled sugar becomes brown while the sweets are being made. They do not know why it should do so, and at once blame the sugar. They naturally complain to the Colonial Sugar Refining Company, which, after investigating matters, finds that the sugar is being overheated, or is being heated for too long a time, so that the cane-sugar is converted into invert-sugar which darkens. When the cause of the trouble is pointed out the trouble ceases. They are fortunate in having the scientific staff of the C. S. R. Company to refer to. Other manufacturers would not have the same advantage. Another example is that of a manufacturer of condensed milk who found nodules growing in his manufactured product. He blamed a dash plate in his condenser, and as this had been supplied by the Colonial Sugar Refining Co., he complained to the company, which referred him to me. Upon investigation I found that the trouble was microbic, and due to the milk becoming infected prior to sealing up. There must be thousands of other cases about which we never hear, but which could speedily be put right by a trained scientific man.

In England, at the beginning of the war, the Board of Trade appointed a committee of representatives of manufacturers and men of science, and of this a sub-committee dealt with different branches of the chemical trade. Among other matters, this sub-committee examined the manufacture of barytes. It was admitted that the German barytes were better ground than the English, and yet a barytes miner could not be found who owned a microscope. The committee examined the barytes microscopically at various stages of the grinding, and showed how the English product could be made of the same fineness as the German. One can hardly imagine a manufacturer grinding a substance, and not controlling the grinding by microscopical examination.

The Adviser would be able to suggest in which direction a by-product could best be utilised; that is to say, he could act as an information bureau. For example, a firm about to start the manufacture of carbonate of soda desired to know how it could dispose of its waste hydrochloric acid. My informant, who was appealed to, made enquiries, and found that a certain soap-making firm could take all the hydrochloric acid.

Eighteen years ago, Mr. Houghton, in the Annual Address to the Engineering Section of this Society, said: "The low rate of ocean freights and facilities for communication tend to place all countries on a level, and if we aspire to be a manufacturing country or an exporting country we must be prepared to sell as good or a better article than others at the lowest price; to enable that to be done it is necessary that there shall be no waste product unutilised, for it is out of these by-products that the profit is generally made."

These remarks are true at the present time, and in addition we have the knowledge that competition will be keener in the future than it has been in the past. At present, owing to the lack of freight, competition is virtually at a stand-still, but when the freight is released from the demands of war, a keen competition will suddenly develop, and there will probably be a considerable amount of dumping of accrued stocks. The competition will lower prices, and then the utilisation of the utilisable waste will be considered. The competition should be anticipated, and the psychological moment for the consideration is now.

Utilisable Waste.

The question naturally arises, what is utilisable waste? It is largely but not wholly a financial question, for what may be the utilisable waste of one year may not be that of the next, on account of a fluctuation in the cost of material or of labour, or of the price of the saved product. That there is much waste of labour is undoubted, and this is where the recently introduced American system might save a considerable amount by minimising the unnecessary movements of the workmen. Labour-saving devices and machinery are being introduced by manufacturers, for in Australia it is labour that is the expensive item in the factory. There is no advantage ultimately to labour, in two men doing work which one could do. We have seen that Mr. Lloyd George has said, that scores of millions worth of automatic machinery have been introduced into Britain, and that being true for Britain how much more should it be necessary here where wages are comparatively high.

While the economising of labour applies to existing industries, the question of the establishment of new industries is bound up with the matter of the stability of labour. In Australia, labour appears to think that it is being exploited by capital; it does not realise that it is feeding upon capital, that capital produces labour and that capital has its rights just as much as labour. It will not risk a possible 7% when it can get a safe 4½% in Government Stock. For the starting of new industries capable of employing more labour, some security must be given by labour to ensure there being a steady supply at a price sufficient to justify the expenditure of capital. It is in this direction that labour should mobilise itself.

Waste Tinplate.

But beyond the waste of labour there is the waste of materials which might be saved if consideration were given to the matter. Large factories can save where small factories cannot, largely for the reason that the latter do not consider the saving to be of sufficient importance. Take the case of waste tinplate. That from a large Sydney company was, before the war, bought by a Melbourne firm which found that it could pay for the waste and pay for the freight to Melbourne and yet make a profit. Smaller companies having from three to five tons of waste per week have to pay 5/- per ton to have it tipped. As it is so bulky, there is a considerable amount of grumbling, and it is a matter of a short time when it will have to be sent out to sea at a cost of about 10/- per ton.

For a firm to pay 30/- to 50/- a week to get rid of a waste material is a small matter, but still it is a useless expenditure. It is considered that the smaller firms in Sydney will have a weekly aggregate of about 200 tons of waste tinplate, which at present is being buried. There used to be 5% of tin on tinplate, but recent improvements in the manufacture have reduced this to about 3%. A calculation upon these data shows that 312 tons of tin are being thrown away annually, and with tin at say, £170 per ton (it is at £200 to-day) the money involved is approximately £53,000.

Sending the waste to sea at a cost of 10/- per ton will entail an aggregate expenditure of about £5,000 annually by the small factories.

In the utilisation of this waste there is the possibility of the utilisation of waste hydrochloric acid and waste zinc.

The loss in the utilisation of our fuel is perhaps an example of the greatest national waste. The matter is claiming some attention in England, and our Australian engineers know that there is an immense amount of fuel lost as heat, but the profits in the industries appear to be sufficiently great to cover the loss, and the waste heat will not be utilised until the profits shrink as they probably will after the war.

Coke By-products.

One of the greatest sources of loss is the use of the wasteful beehive coke-oven in the manufacture of coke. In Durham, the home of the coke industry, the by-product coke oven is superseding the bee-hive oven, but this has only been brought about by the Germans threatening to oust the Durham coke by coke made from Durham coal. The profits accruing from the utilisation of the by-products enabled this to occur. Curiously enough the Durham by-product ovens are made of German or Belgian firebricks, because the English brickmakers will not scientifically blend their clays, but insist on using the clays as they are found naturally. As an instance of the rapid replacement of the beehive oven by the by-product oven, Prof. Bone shows that the ammonium sulphate produced by the coke works in England rose from 17,000 tons in 1903 to 64,000 in 1908, and to 133,000 in 1913, and although he calculates that the beehive oven will disappear in a few years, he suggests that in the public interest the Government should fix a time limit beyond which no beehive oven should be allowed to be in operation.

In proportion to the capital outlaid, the recovery of the coal by-products is one of the most profitable of the chemical industries. Except in the Broken Hill works at Newcastle, where 66 ovens are working very satisfactorily, we have no by-product coke ovens in New South Wales, and all the valuable by-products are thrown into the air. All the coke, outside of the gas works, is made by the beehive oven. Let us see therefore exactly what is being wasted, and to bring the matter nearer home, let us consider the waste in New South Wales. In 1913, 298,612 tons of coke were produced in this State, exclusive of that obtained in gas works, which amounted to 768,055 tons. As coal yields from 60 to 65% of coke, the beehive ovens used half-a-million tons of coal. A ton of coal yields 8,341 cb. feet of gas, 20 – 35 lbs. of ammonium sulphate, 56 – 112 lbs. of tar, and 2 – 3½ gallons of crude benzole, of which from 65% to 70% is obtained as finished products.

A slight calculation shows that in New South Wales we wasted, during ten months of 1913, over four thousand million cubic feet of gas, from 4,400 to 7,800 tons of ammonium sulphate, from 12,500 to 25,000 tons of tar, and from one million to one and three-quarters of a million gallons of crude benzole.

W. Corin, in the "Australasian Engineer" for January of this year, considers that the results to be obtained would justify the conversion of the beehive coke ovens to by-product ovens. He considers that the whole of the South Coast coke would yield the following by-products:—

5,000 tons ammonium sulphate at £13 ...	£65,000
11,500 tons of tar at £3	34,500
800,000 gallons of Benzole at 3/-	120,000
128,000 gallons of Toluol at 3/10d.	24,500
Gas for 200 million units of electrical energy, but taking 96 millions at ¼d. per unit...	100,000
	£344,000
Value of the Coke produced	£209,000

Corin's figures are apparently for the minimum quantities, doubtless due to the belief that the South Coast coal, compared with English coal, is poor for the production of by-products.

There may be some difficulty with regard to the utilisation of the gas, just as there is trouble connected with the fire-bricks and the building of the ovens, but even if we look at the matter in the most pessimistic way, and compare the values of the groups of by-products with that of the coke, we feel that something should be done to prevent what appears to be a scandalous waste of valuable material.

Fat Waste.

Quite a number of industries have fatty bodies as a waste product, and the question of their utilisation has been discussed. The recovery of wool fat for the manufacture of lanoline, the waste soapy and fatty waters from the wool scouring, the fat in bones, in meat meal and in fish meal are a few examples. Even the fat in old sewage beds in which I found 2% might be considered. For the recovery of fat from solid materials it is usual to employ steam as with bones, meat and fish meals. A certain amount is always left behind, and to remove this a cheap solvent would be necessary. The only one available at present is benzine, but our climatic temperature is too high for its economic use as for the greater part of the year one must work near its boiling point. Before the residual fats can be economically extracted a less volatile, equally effective and cheap solvent must be obtainable. If trichlorethylene could be manufactured cheaply, there would be some hope for the recovery of these fats. But there is another aspect of the case that must be considered, and that is that in our climate, bones and fleshy material quickly decay, and putrid fat is not sought after by soapmakers and others, although if it were cheap enough, some means might doubtless be devised for deodorising it.

Kerosene.

The manufacture of kerosene from a seam of shale near Capertee and Newnes was started some years ago with capital largely contributed by British subscribers. The concern was a failure, not on account of the quality of the shale, but because the management was defective and the plant unsuitable. Just as shales differ in various parts of the world, so must the plant and especially the retorts be adapted for their economic utilisation. What may suit one shale may not suit another. At Newnes the retorts were unsuitable. The affairs of the old company were acquired by Mr. John Fell of Sydney, who modified the retorts so successfully, that while instead of getting approximately 10,000 gallons of oil daily from 64 of the old retorts, he was able to get the same quantity from 12 to 16 of the modified type. We have here an instance of the value of scientific research. Although severely handicapped by the type of railway, and by the locality in which the works are situated, the industry promised to be a success. So much so, that Mr. Fell cancelled his Borneo contracts and relied entirely upon the Newnes supplies. The inhabitants were returning to the deserted township of Newnes when the men suddenly struck work, demanding a rise from 12/- to 15/- a day. The industry could not pay this, and as an offer of sharing half the profit was rejected by the men, the works were closed down. The strike was settled by arrangement, and the men who remained in or returned to the township, started work three weeks later.

Tannin Extracts.

The preparation of tannin extracts is an industry that might be developed in this State. We import a considerable amount although we possess excellent barks. That of the Black Cypress Pine, *Callitris calcarata*, grows extensively on certain ironstone ridges west of the Dividing Range, where the land, which is eminently suitable for the growth of this tree, is useless for other purposes. The bark contains on an average 23% of tannin, and it differs from wattle bark in being quite free from gum. It is sent to Sydney, where it is landed at half the price of imported wattle bark. What is required are central evaporating establishments close to the ridges, where the bark can be extracted and the liquor evaporated in vacuum pans. We have the idea in the factory system of butter making. Attention was called to the commercial possibilities of this bark in 1902 by H. G. Smith, and F. A. Coombs showed that it produced a heavier and better leather than wattle bark extract.

Native Timber.

The amount of waste that is going on through the non-utilisation of our native timber has been before us for many years. We have immense stores of wood suitable for most purposes, and yet we import timber to the value of three millions annually, while the export is only one third of that. We know that our wood can be utilised, but the fault appears to lie with the public, who are not aware of our capabilities in this direction. There is even a prejudice against certain woods, apparently for the same reason that there was, up to a few years ago, a prejudice against articles of Australian manufacture. As the latter prejudice has for the most part disappeared, it is to be hoped that our native timbers will soon be assessed at their true value. It is possible that the war, by reason of the heavier freights, will compel a greater utilisation of our native woods, and break down the popular ignorance with regard to them. It is satisfactory to know that certain Government Departments are, in their specifications for tenders, insisting on the employment of Australian woods.

Eucalyptus Oils.

In the oils of our indigenous trees, we have a huge national asset. From the leaves we can obtain three kinds of eucalyptus oils, the purer medicinal oils, the cheaper forms used for flotation purposes and those used for perfumery. The chemistry and economic uses of these have been investigated by H. G. Smith, who has really put them upon a sound basis and has done some really valuable work with them. Most of his work has appeared in the pages of this Journal. In 1902 he showed how the pure medicinal oils can be obtained in the ordinary country still by fractional distillation, that is by removing the distillate that comes over in the first hour from the remainder. The pure oil comes over first, the rest is contaminated with phenols. Twelve years afterwards, his researches bore their first fruit when the distillers began to fractionate. The practice enables the pure oil to be obtained from a greater number of species.

Leaves from the various groups of Eucalyptus give different oils upon distillation, that is, the ethereal products are mixtures chiefly of cineol or eucalyptol and of geraniol in varying proportions. Those oils in which geraniol predominates are capable of being utilised in manufacturing perfumery, geraniol and citronellol being the chief ingredients in 'Otto of Roses.' The shortage of perfumes caused by the war has induced our manufacturers to utilise the oils obtained from the geraniol group—*Eucalyptus Macarthuri*, *Callitris tasmanica*, and *Darwinia fascicularis*. The exploitation of our natural oils for perfumery should be assisted, and there is need of scientific research in developing new fragrant compounds from the lesser known components of the essential oils. Mr. H. G. Smith informs me that he has in view the production of vanilla from the common Tea-tree, *Melaleuca bracteata*, the leaves of which contain 1% of methyl-eugenol. If one of the methyl groups could be replaced by hydroxyl, we should obtain eugenol, which by oxidation yields vanilla. In fact with regard to the eucalyptus and other oils we have a state of affairs analogous to the condition of the coal tar oils before Germany began to examine them scientifically and systematically.

A Khaki Dye.

In myrticolorin, discovered by H. G. Smith, we have a khaki coloured dye which is easily prepared, and which is absolutely fast. It is obtained by extracting the powdered leaves of the Red Stringy Bark with hot water and allowing the dye to separate from the solution on cooling. This is an industry which should be established. As a by-product, we should have either wood or charcoal from the trees which have to be felled to obtain the leaves.

H. G. Smith.

I should like to say a few words about the work done in the Technological Museum. It was undoubtedly founded as a museum, but thanks to the energy of the staff it has developed and is really a Technological Institute. There is an extensive and excellent collection of industrial appliances and natural products, but there are also the laboratories in which so much pioneering work has been done by Mr. H. G. Smith, in collaboration with Mr. R. T. Baker, largely in their own spare time. It is a sad fact that when the Curator and Assistant Curator retire, as they shortly will, there is no one who has been trained to take either of their places. Their methods, which have taken years of careful and patient study to evolve, will be lost, and a condition of affairs will be reached similar to that which we experienced in the case of Farrer, our noted wheat experimentalist, who, working for a pittance of a salary, bequeathed to the Nation his rust-proof wheats. What is the use of neglecting a man during his life-time and raising a monument to him when he is dead? When the country finds a research worker like Mr. H. G. Smith it should do all it can to assist him in the good work. His work is classical, and is the foundation upon which huge industries will in the future be established. Yet he is now working alone in his laboratory when he should have a staff of trained assistants working under him, discovering the industrial possibilities of our natural products. It would pay the State. His memorial should be raised now in the form of a research laboratory of which he should be the director. We have money to spend upon a luxury like the Conservatorium of Music, but apparently none to assist research which would lead to the establishment of new industries.

State utilisation of Waste.

There are certain directions in which our State Government is moving to utilise waste. There is for example the hydro-electric scheme to make use of the waste power of the Shoalhaven and other rivers. There is the scheme to establish a number of fish depôts at various parts of the coast, so that the fishermen may be able to dispose of their entire catch. At present, they expect to be paid for one basket out of every ten they send to market; the other nine are condemned and become fish manure. The State is about to instal an up-to-date vacuum plant for the utilisation of the fish offal.

In the gas that collects in septic tanks, we have an example of the utilisation of a waste product from a waste material. Sewage in its anærobic fermentation gives off a mixture consisting chiefly of hydrogen and marsh gas. It is inflammable, and can be utilised in gas engines for the production of power. This is being done at Parramatta and at North Sydney. Mr. Smail has informed me that the sewage from about 20,000 people gives about 1,500 cb. ft. of gas daily, which for the production of power is equal to 825 cb. ft. of coal gas. From this we see that the sewage contributed by an individual daily yields 10·8 cb. in. of gas of the value of 6 cb. in. of coal gas, and an approximate annual value of $\frac{3}{4}$d. The saving is small, but it is a good example of waste-utilisation.

Various Industries.

There is no waste in the manufacture and refining of sugar and in the grinding of wheat. In the dairying industry there does not appear to be any waste at present as owing to the high value of stock, all the by-products of milk, such as separated milk and whey, are being entirely utilised. We, however, import casein and milk-sugar from New Zealand, both of which could be made locally. The whey returned from the cheese makers contains a small amount of proteid, 1%, and milk-sugar, 5%. Every 100 gallons of whey which the farmer takes home from the factory contains the equivalent of 70 ℔s. of pollard which has a value of 3/9d. The same quantity of whey would yield theoretically 50 ℔s. of milk-sugar, which at the low figure of say 6d. per ℔. would be worth 25/-. There appears to be room for a profitable production of a certain quantity, say 5 tons, of lactose, but if the industry became large, the difficulty of disposing of the product might be considerable.

It is the same with lanolin about the utilisation of which we have heard so much of late. A ton could be disposed of easily enough, but there would be a difficulty in disposing of say 400 tons, and the lanolin or cholesterin could be used for no other purpose than as a vehicle for ointments, the demand for which is limited. It is useless for soap-making. Enough is now being made in Sydney for local requirements.

It seems strange that the by-products of the wine industry are not worked up in this country where the vine is grown. At the beginning of the war, tartaric acid and bitartrate were practically unobtainable. Theoretically we should be able to produce about four and a half tons of acid from our five million gallons of wine, but most of it is lost in cleaning the barrels and vats. It is a pity the argol deposit and lees cannot be saved, as the production and refining of the acid is a comparatively simple process.

Another anomaly is the manufacture of gelatine and of glue. Gelatine is not made here, but there appears to be no reason why it should not be done. We have all the raw material. Some glue is made, but I understand the bulk is shipped to Europe to be refined.

We import oxalic acid although we could easily obtain it from the bark of some of our Eucalypts which contain 16% of calcium oxalate. The bark has simply to be extracted with dilute hydrochloric acid and the oxalic acid crystallised out from the liquid.

Science the Helpmate of Industry.

We should bear in mind that the scientist can only suggest methods for the utilisation of trade waste. The probability of the suggestion being economically successful must always rest with the manufacturer, who has to consider the cost of the plant, the expense of labour, and the value of the won product. There may be so fine a balance between the cost of the utilisation and the value of the product, that there is not a sufficient margin to enable a fair profit to be made. The cost of plant made locally may be prohibitive, while an imported plant may enable the process to be started without a handicap. The process may not pay at first, until enough experience is gained to, as it were, short circuit some of the original methods. Again, a rise in the market price of a substance may enable the secondary industry to be established. There are so many things to be considered by the manufacturer, that there is little wonder that he is generally content to throw away possibilities, and devote his energies to his primary products.

As an instance of the set-back a manufacturer may get in attempting to utilise a by-product, I may quote the following case. The plant was designed by a French engineer, who was supposed to know all about the industry. He was told the quantity of waste which would have to be dealt with, but when the plant was put up it was found that it could deal with only a third of the desired quantity. Small as the plant was, however, it just managed to clear the expense of labour; the cost of the plant was not met. In a year the plant collapsed, but the experience gained was invaluable, as it showed the manufacturer what the size of the plant should be and how to work the process, so that when a new and efficient plant is put down, the utilisation of the waste will be a commercial success.

In the utilisation of by-products, each factory may have a different waste to deal with, and the plant for its utilisation has to be designed and tested, so that frequent modifications of the original method may have to be made. As in a new industry, there is rarely a royal road to success, so in the working up of the by-products the manufacturer has to feel his way carefully, or the expense will be greater than the income.

The instances that I have given of the possible utilisation of trade waste and of our natural products, show that there is a real need of something being done to save what are really national losses. They are instances which go to show how necessary it is for us to do something to stop the loss, and it was doubtless with this idea that the preliminary meetings of the Institute of Science and Industry were held. It was felt that these two departments have been separate for too long, and that the time had come for their amalgamation. It needed the war to quicken our perceptions and enable us to see that they can help one another. It is now up to Industry to greet Science as a helpmate.

Part III.—Some Aspects of Soil Fertility.

When we consider the fertility of a soil, we naturally take into account all the factors that go to produce or are likely to be employed in obtaining a good crop. The measure of the fertility is the crop itself, and this is influenced by the nature of the soil, its texture, its capacity for holding a suitable amount of water and air, its composition which determines the food materials likely to be at the disposal of the plant roots, the labour required to maintain its physical condition, the climate which guarantees an adequate rainfall and suitable temperature, the drainage either natural or artificial to remove an excess of water and so on.

These factors have an influence upon the changes that are taking place in the soil, whereby the constituents are altered into substances, some of which are injurious, some of which are beneficial. The nature and extent of these changes may be controlled, and experience has shown how the soil should be treated to obtain a maximum amount of the beneficial substances.

We may look upon the soil as being a vast laboratory in which the workers are the micro-organisms, while the management sees to it that the ventilation and the water and drainage arrangements are efficient, and that the quantity of material necessary for the workers is always ready. The workers are specialists. Some for example, attack proteid, reducing the combined nitrogen to ammonia and no further, others attack the ammonia and convert it to nitrite, while yet another group change the nitrite to nitrate. Some forms can only attack urea converting it into ammonia. Many convert nitrate to free nitrogen, while others reverse the procedure in part and elaborate the useless free aerial nitrogen into valuable combined nitrogen. There are very few substances in the soil that are not attacked by micro-organisms directly or indirectly; the mineral fragments are slowly dissolved, and even the hitherto supposedly immune paraffin can be utilised by certain bacteria as a source of carbon.[1] I have shown that even the familiar *Bac. prodigiosus* is capable of decomposing it.[2]

The flora and fauna of the soil are liable to fluctuation. The seasons have a certain influence on account of the variations in the temperature; some groups of bacteria have a maximum efficiency in winter, others in summer. The repeated wetting and drying of the soil has an influence in destroying the more delicate kinds. The changes that are made in the number of the bacteria by treatment of the soil in different ways have only recently been determined, and this has been largely due to the fact that an increase in the fertility can be obtained through an alteration in the nature and extent of the flora, by means of heat or by disinfectants. The most important work has been done with the volatile disinfectants, as, having performed their work, they simplified matters by disappearing from the soil, leaving behind a state of affairs which brought about an increase in the crop subsequently grown in the soil.

Although the beneficial effect that follows the treatment of soil with a disinfectant had been known for a long time, the reason for the increase of the crop had not been investigated. This was specially seen in the treatment of vines or potatoes with the copper-lime spray. In the absence of disease the crop was generally increased by the treatment. We now know that traces of the poisonous copper compound, either directly sprayed upon the soil or washed down by rain from the leaves, acted upon the soil flora. The study of the action of disinfectants really began in 1894, when

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[1] Rahn, Cent. Bakt., 2te, 16, 362; Söhngen, *Ibid.*, 37, 595.

[2] Proc. Linn. Soc. New South Wales, 1914, 538.

Oberlin in Alsace and Girard in France showed that the direct treatment of a soil with the volatile disinfectant, carbon disulphide, resulted in a pronounced increase of the crop. The disinfectant was employed to kill phylloxera, and the treatment was as successful as it had been in 1875 when Kühn used it to check nematodes infecting root crops.

It was not the destruction of the insect pests that caused attention to be paid to the action of the disinfectant, but it was the fact that the crops were increased after the treatment. It was also shown that carbon disulphide cured the soil-sickness of the vine, thus enabling vignerons to re-establish a vineyard affected with sickness without having recourse to fallowing the ground or growing other crops until the sickness had disappeared.

Soil-Sickness.

That carbon disulphide could cure soil-sickness rather confirmed the idea that, as there was generally a sufficiency of fertilising material in such soils, the disease was due to the activities of moulds and bacteria. But Koch in 1899 came to a different conclusion. He found that treatment of the soil, with carbon disulphide or with steam, favoured the subsequent growth of the vines in vine-sick soils. The substances responsible for the disease are apparently either soluble in water or are suspended in it, for extracts of sick soils are able to convey a certain degree of sickness to healthy soils. If the extract is heated, no injurious results are obtained. Although the action of steam upon the soil, or of heat upon the extracts, indicates a probable biological cause, and that the action of carbon disulphide is probably to alter the relations of the groups of the micro-flora, yet Koch[1] considered that the carbon disulphide directly stimulated the plant, much after the manner of the stimulation exerted by the copper-lime spray in the treatment of vines and potatoes.

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[1] Cent. Bakt. 2 te, 5, 660.

Some years later, Hiltner[1] in experimenting with peas, found that repeated growth of the plants in a soil resulted in the development of sickness. This however, seemed to cure itself as it developed in the second and third crops, but disappeared in the fourth, fifth and sixth. Treatment of the soil with carbon disulphide caused the sickness to reappear. This led him to think that the growth of the plant causes an accumulation of toxic substances, but that continued growth produces antitoxins which are destroyed by carbon disulphide. Ponget and Chouchak[2] confirmed the observation of Koch, that extracts of lucerne-sick soils were capable of injuriously affecting healthy plants, but they concluded that the plants secreted substances toxic to themselves.

On the whole, the investigators who have worked with soil-sickness, favour the idea of a plant secretion which is toxic, and therefore discount the possibility of the cause being due to an alteration of the mycological flora, with the increased development of a toxin-producing micro-organism. There appears to be more likelihood of an indirect action being the true cause. Bolley[3] found a mould, *Fusarium lini*, infesting the roots of Linum in a flax-sick soil, and considered that it produced the disease. It is probable that many more similar examples could be found of bacteria and moulds being directly responsible for the various kinds of sickness by the secretion of toxins. The conveyance of the disease by water, and the action of heat and disinfectants, are against the probability of the sickness being due to a toxin directly secreted by the plants. Schreiner and Sullivan[4] isolated crystalline toxins from wheat-sick and cowpea-sick soils which were toxic to these plants, but this does not militate against the idea that the

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[1] Cent. Bakt. 2 te, 21, 536. [2] Comp. Rend. (1907) 145, 1200.

[3] Bull. N. Dakota, Ag. Coll., No. 50. [4] Chem. Zeit., 1908, 410.

toxins were produced by micro-organisms, the growth of which were favoured by certain plant secretions.

Steaming the Soil.

Although Koch showed that steaming the soil cured soil-sickness, and enabled plants to grow satisfactorily, the beneficial effect of steam upon soil was well known to those workers who used the pot method in experimenting with the growth of plants. The reason for the effect, however, appears to have been first sought by Richter[1] in 1896. An increase of the organic constituents soluble in water was obtained, and he concluded that this was the cause of the increased fertility. It was later shown that there was also a liberation of the fixed constituents[2] and a greater availability of the nitrogen of the soil.[3] There is also a production of poisonous substances which are irregular in their action, some plants being decreased, while others are increased. These toxins may be of an acid nature, for they are put out of action by lime.[4]

In testing the respiration of a soil sterilised by steam, and subsequently seeded with bacteria, Fischer[5] showed that although the numbers increased as time went on, the amount of carbon dioxide given off gradually fell away. From this he argued that after a period of fermentative activity, the bacteria became quiescent and although showing an increase in numbers, they had a low fermentative power. He did not consider that the increase in the bacterial numbers resulted from an enhanced availability of the soil constituents, but that it was due to the nutrients, previously locked up in the bodies of the bacteria coming into solution during sterilisation. The increased numbers,

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1 Richter through Fischer, Cent. Bakt. 2 te, 22, 671.
2 König, Hasenbäumer and Coppenrath, *Ibid.*, 17, 261.
3 Dietrich through Fischer, *Ibid.*, 22, 671.
4 Schultz, *Ibid.*, 19, 341.
5 Fischer, Cent. Bakt. 2 te, 22, 671.

however, cause an increased decomposition of the soil nutrients, not only of the nitrogenous organic matter but also of the minerals.

The Action of Dry Heat.

The effect of sterilisation by dry heat appears to have been first seriously considered by Pickering[1] in 1910. Like earlier observers he found that heating the soil at 100° rendered them more fertile, but he also found that a higher temperature caused them to become less fertile. The comparatively low temperature of 100° occasioned an increase of the soluble fertilising matter, while a higher temperature resulted in the additional formation of substances of an actively toxic nature and which tended to arrest the growth of plants. These disappear in time when the soil is kept moist and aerated, the alteration being apparently due to oxidation. The effect of the toxin towards the classes of plants was variable. For example, tomatoes, spinach, clover and other plants were injuriously affected, and the higher the temperature the greater was the quantity of toxin produced and the greater was the toxic effect. Grasses, however, behaved quite the other way, the higher the temperature to which the soil had been subjected the more luxuriant was the growth.

The action of dry heat varies with the temperature applied; a low heat[2] produces ammonia and amines, while a higher (135° – 150°) causes an increase in all the water-soluble substances and the acidity. Several definite chemical substances of a toxic nature, such as guanine, arginine, dihydroxystearic acid, etc., are formed. Jensen[3] found that heat had no effect upon the mineral portions of the soil.

[1] Journ. Agri. Sci., 3, 277.

[2] Schreiner and Lathrop, through Chem. Soc. Repts., 1913, 218.

[3] Jensen, Journ. Roy. Soc. New South Wales, 45 (1911), 169.

Plants grown in a soil which has been heated, generally show a remarkably fibrous root growth,[1] the aerial stems are stouter, and the leaves are larger and deeply coloured. They flower earlier and more abundantly. It is remarkable that, while treating the soil with a volatile disinfectant has much the same defect as dry heat upon the numerical decrease and increase in the bacterial flora, the effect upon plants grown in the soil is quite different. Those grown in disinfected soils do not show the above changes in any marked degree.

The Action of Volatile Disinfectants.

The action of carbon disulphide upon the flora of the soil was first investigated by Hiltner and Störmer[2] who in 1904 showed that the bacteria were considerably reduced in number. This was followed by an increase so pronounced, that at the end of a month after the evaporation of the disinfectant, the original number of $9\frac{1}{2}$ millions per gram of soil had risen to 50 millions. Then the number slowly fell, but remained above the original number. In the untreated original soil, the number remained for some time fairly constant at $9\frac{1}{2}$ millions, and the ratio of the kinds or groups was also constant.

The flora of the normal soil consisted of 75% of non-liquefiers, 20% of streptothrix species and 5% of gelatin-liquefiers. As a result of the treatment with carbon bisulphide, the non-liquefiers were greatly increased, and the streptothrix varieties were strongly reduced,[3] and did

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[1] Russell and Petherbridge, Journ. Agr. Sci., 5, 248.

[2] Cent. Bakt. 2 te., 12, 126.

[3] This was not the experience of Russell and Hutchinson (Journ. Agr. Sci., 3, 111) with toluene. They found that the white and brown streptothrix forms suffered less than the bacteria, and indeed that, after toluening, the white streptothrix was the principal organism present in the soil. The brown streptothrix suffered more than the white from the treatment. Heat differs from toluene and readily destroys the white streptothrix.

not return to their original proportion for at least two years. The denitrifying bacteria, originally fairly numerous, were almost completely destroyed, and did not appear to any extent for two years. The pectin-fermenters which were originally as numerous as the denitrifiers were reduced.

The nitrogen-gathering nodule-former of the Leguminosæ is not destroyed by some disinfectants, such as ether and hydrogen peroxide;[1] on the contrary, its growth is favourably influenced. The ammonia-producing bacteria are increased and the putrefactive processes are less intensive. The nitrifying organisms are apparently temporarily checked but subsequently develop with considerable intensity.

The hindrance which the nitrification receives is an advantage to the soil and crop in a moist climate, for, when the disinfectant is applied in the autumn, nitrates are not formed, and there is consequently no loss of nitrates by the winter rains. In spring, when nitrification becomes active, the nitrates are available for the plant at a time when they are of most value. The destruction of the denitrifiers also helps to conserve the soluble nitrogen.

The alteration in the bacterial flora and the nature of the subsequent fermentation of the soil constituents appear to be the reason for the enhanced fertility. If the soluble soil constituents are increased in amount, they can be present only as traces, for several investigators have failed to detect any change either in the total soluble matter[1] or in the soluble minerals.[2] There is an undoubted production of ammonia[3] which is formed instantaneously.[4]

The inability to detect traces of soluble matter led several authors to agree with Koch's hypothesis that the increased

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[1] Nobbe and Richter, Cent. Bakt. 2te, 14, 234.

[2] Moritz and Scherpe, *Ibid.*, 13, 573.

[3] Heinze, *Ibid.*, 16, 329.

[4] Russell and Hutchinson, Journ. Agr. Sci., 3. 111.

growth of the crop could only occur through a direct stimulation of the plants by traces of the disinfectant, or of its decomposition products. On the other hand, the fact that the action of the disinfectant depends upon the amount added to the soil, larger doses giving greater crops than smaller, led Moritz and Scherpe to adopt the view of Hiltner and Störmer, that the chief effect of the disinfectant lies in the alteration of the bacterial flora. The balance of the microbiological flora is destroyed, the species are reduced, but to different extents, and a way is opened for the development of a new flora derived from the more resistant members of the original flora. The great subsequent multiplication of the bacteria results in a strong decomposition of the insoluble nutrients, and partly through this, and partly because of the increased activity of the nitrogen-gatherers, much assimilable nitrogen is made available for the crop. This is shown by the increased luxuriance of the foliage and by its dark green colour.

Hiltner and Störmer appear to think that the increase in the available nitrogen is partly due to the greater fixation of free nitrogen, and partly to the unlocking of the great store of soil nitrogen. The altered nitrogen, they consider, is converted into bacterial protoplasm, which being insoluble, is not immediately available, but becomes so during the the second season. Kruger and his pupils[1] found an increase some time after treatment, which they believed to be traceable to the increased growth of Azotobacter and similar bacteria. Störmer[2] considered that the disinfectant killed most of the inhabitants of the soil such as worms, insects, spiders, lice, protozoa, mosses, algæ, moulds and bacteria, and that, during the first year, the nitrogenous matter contained in the dead forms came into solution and benefited the crop.

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[1] Kruger, through Heinze, Cent. Bakt. 2 te., 16, 329. [2] *Ibid.*, 20, 282.

The plant stimulation hypothesis presupposes that some of the disinfectant is retained by the soil or at least, that some of the decomposition products remain. So far as carbon disulphide is concerned, and this is the volatile disinfectant upon which most work was done in the early stages, distinct traces of the decomposition product, sulphuric acid, were found up to three months after treatment.[1] As it could not be detected five months after, it was concluded that it had been washed into the subsoil. The presence of the sulphuric acid led to the idea that the mineral constituents of the soil might have been made more soluble, but upon investigating the phosphoric acid, neither water-soluble nor citrate-soluble phosphate could be detected. A treated soil, which was moist when stored, but which slowly dried, contained traces of sulphuric acid, two years after treatment. A watery extract of it was made, and this was found to contain a greater amount of substance precipitable by alcohol than that from a similar control soil. The lime, magnesia, potash, ammonia and sulphuric acid were found in greater amount than in the control, while the phosphoric acid was unaltered and the nitrates were reduced. From this experiment, Heinze considered that the disinfectant acted partly by decomposing to sulphuric acid which acted as a mineral solvent. The disinfectant itself was found as traces in soil, a month after treatment, and the greater the quantity used the greater were the traces.[2]

By 1908 it was known that not only the volatile disinfectants, including such diverse substances as carbon disulphide, chloroform, carbon tetrachloride, ether, hydrogen peroxide, benzene and toluene, but also the non-volatile poisons, such as arsenious oxide and some metallic poisons,

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[1] Moritz and Scherpe, Cent. Bakt. 2 te., 13, 573.

[2] Heinze (1907), *ibid.*, 18, 56.

when applied to the soil, acted in the same way.[1] These must disappear from the soil before a crop is grown, and this occurs, either by the evaporation of the volatile disinfectant, by fixation of the metallic oxides, or by the decomposition of the benzene-ring compounds, which in the presence of lime and soda, act as sources of carbon for the soil bacteria. The volatile disinfectants, which contain no sulphur, act in a manner similar to carbon disulphide, and so the oxidation of the sulphur to sulphuric acid cannot be the chief cause of the increase of crop.

The action of mustard, either as a crop or as green manuring, in preserving the soil nitrogen, for it cannot fix nitrogen like the leguminous plants, is believed to be due to the action of the mustard-oil in the soil. The product of fermentation, allyl isothiocyanate, is supposed to act like the volatile disinfectants, and thus a reason has been advanced for the beneficial effect which has long been known to follow the growth of mustard.

The Limiting Factor.

In 1909, Russell and Hutchinson[2] published a very comprehensive paper upon the effect of sterilisation by heat and by toluene upon soils. Although, like Hiltner and Störmer, these authors found a difference in the types of bacteria in the toluened as compared with the raw soil, they did not consider that any change in type was responsible for the increased activity which follows the treatment. The increase in the numbers of bacteria was alone believed to be of significance. They considered the behaviour of the soils from a new standpoint. Instead of looking at the

[1] Recent work upon the stimulating effect of the metallic poisons is included in an admirable address by F. B. Guthrie, read before the Australasian Association for the Advancement of Science in 1913. The address includes an appendix by L. A. Musso in which the bibliography is noted and briefly summarised.

[2] Journ. Agr. Sci., 3, 111.

numbers of the bacteria in the raw soil as a standard, and the numbers obtained following treatment with heat or volatile antiseptics as an increase, they reversed the point of view and considered the numbers in the raw soil as being anomalous. The irregularity was caused by something which limited the natural increase, and in casting about for a clue to this limiting factor, they noted from various experiments which they made, that it was put out of action by volatile antiseptics sufficiently potent to kill the nitrifying organisms, and by heat above 55°. If the soils were kept free from reinfection, the factor did not reappear, even although the conditions were made very favourable for the growth of bacteria. A lower degree of heat put it only temporarily out of action, and if the soil was kept under favourable conditions it soon reappeared. It could be reintroduced into a treated soil by adding a small quantity of a raw soil. It developed more slowly than bacteria, for the effect was not seen for some time, and yet it appeared to be biological, for the conditions that favoured its activity were precisely those which favoured living organisms. It did not appear to be bacterial nor of the nature of a toxin, nor due to any adverse physical or chemical state of any of the soil constituents; indeed, there was no escape from the conclusion that it was a living organism, and the only organisms that appeared to agree with the observed facts, were the protozoa.

The phagocytic tendency of the protozoa, such as the larger ciliates, especially *Colpoda cucullus* and the amœbæ, was considered to be the reason for the numbers of bacteria being kept down to a comparatively low level. Although in their first paper, Russell and Hutchinson say that the protozoa are only one reason for the limitation of the bacteria, yet later papers give the impression that they consider the protozoa to be the one and only reason. Indeed in his latest paper,[1] a reply to Goodey's claim that the protozoa are not responsible for the limiting factor, Russell says that the protozoa are the only organisms fulfilling the conditions that fit the limiting factor, and that there is the closest possible relation between the extinction of the protozoa and of the limiting factor.

They considered that the limiting factor could not be a toxin, for if it were, it would be sure to affect the more sensitive nitrifying bacteria rather than the sturdy ammonifying bacteria. In raw soils, nitrates may accumulate but ammonia never does, and, as there can be nothing toxic to the nitrifiers, it was very unlikely that there could be anything toxic to the ammonifiers. Again, as no difference was seen in the growth of barley seedlings grown in extracts of raw or toluened soils, there could be no toxic substance in the raw soil, or the effect would have been shown upon the seedlings. The fact that treatment short of partial sterilisation brought about a certain but slow limitation of the bacteria, appeared to be an objection to any toxin hypothesis, because one could not conceive a partially destroyed toxin revivifying itself.

It apparently did not occur to them that toxins may be secreted by bacteria and moulds, and that almost complete destruction of a particular toxin-producing species or group, might account for the slow revivification of toxin.

Among all the experiments bearing upon the protozoal hypothesis, the most important are those in which it has been shown that the limiting factor could not be introduced into partially sterilised soils in any other manner than as raw soil. Pure cultures of certain prominent bacteria were without effect, and the so-called pure cultures of protozoa were likewise inoperative. This is very important, as

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[1] Proc. Roy. Soc., (1915) B. 89, 76.

bacteriologically the proof must be made with pure cultures. There are so very many organisms of all kinds in raw soil and any one of them might produce the limiting factor. It would be a long and tedious process to test all the micro-organisms of the soil, and it is therefore probable that the organisms that were tested, did not include the active organism. Indeed this was recognised by Russell and Hutchinson in their first paper, for there the protozoa were only provisionally identified with the detrimental agent, and even the term "protozoa" was not rigidly interpreted. In other words the limiting factor was considered to be only probably protozoal.

Although Russell and Hutchinson carefully safeguarded themselves, the head of the Rothamsted Experimental Station, in which the work was carried out, said in a presidential address before the British Association, that the phagocytic action of the protozoa in limiting the growth of the soil bacteria, was the greatest discovery in soil bacteriology since Hellreigel and Willfarth's historical paper upon the nodule bacteria.

The addition of raw soil to toluened soil brings about a curious result with regard to the flora. A toluened soil, capable of supporting some 43 millions per gram of dry soil and no more, when treated with raw soil, became capable of supporting another 30 millions of bacteria. This does not augur very well for the activity of the introduced protozoa. It rather indicates some condition regarding the balance of the bacterial groups, that, according to the kinds of bacteria, there is a certain normal number supportable by the soil.

The Bacteriotoxins in the Soil.

Upon reading Russell and Hutchinson's paper, I was struck by the many divergences from a common law, by the strenuous pushing forward of the protozoal hypothesis, and, at the same time, the safeguarding of the conclusion, in case the hypothesis should prove to be faulty. I was also impressed with the fact that the hypothesis was based upon the supposed absence of toxins in the soil. I could not believe that toxins really were absent, for it is a well-known fact in bacteriology, that bacteria growing in a nutritive medium, and the soil moisture must be considered as such, give rise to waste- or by-products, and unless these are removed or destroyed, they increase to an extent which ultimately poisons, checks or inhibits further growth. Some bacteria may produce lysins, which dissolve the formed cells, others may give rise to acids, others to poisons and so on. It is impossible to obtain a culture of bacteria in a medium in which all the nutriment has been converted into bacterial protoplasm, that is to say, the growth of the bacteria increases to a maximum, when it is slowed down by the action of the accumulated by-products, and these in time weaken and eventually kill off the cells, and the culture becomes dead. The word "toxin" is a general name for an injurious product, but Russell and his colleagues, while denying the presence of "toxins" in soils, still admit that there may be "inhibiting substances." I cannot see why there should be any discrimination until the nature of the toxins or inhibiting substances is determined.

To argue that because the delicate nitrate bacteria can grow in soil, there can be no toxins present or they would be destroyed, appeared to be wrong, and I set about to prove, that the general bacteriological knowledge regarding the presence of injurious bacterial by-products in a nutritive medium, such as the soil moisture, was not at fault. This I succeeded in doing by the use of porcelain-filtered extracts of the soil. The extract, after being filtered through porcelain, was seeded with known numbers of bacteria which after a time were counted. A loss showed a toxic effect.

I clearly showed that the extracts could be toxic to a bacterium such as *Bac. prodigiosus*, and that so far as the soil bacteria were concerned, the toxic extracts, while not actually destroying them, yet decidedly hindered their multiplication.[1] In the soil-extract there is, as it were, a contest between the nutrients and the toxins, and the ultimate victory will depend upon the preponderance of the one or the other.

The nutrients are probably fairly constant in amount, while, on account of their instability, the toxins are variable. It is therefore not to be expected that the extracts will always be directly toxic. An indirect toxic action, however, can, as a rule, be shown by heating the extract and comparing it with an unheated portion. The heated extract usually gives an enhanced growth of bacteria. I showed that the toxins are rapidly decomposed by heat, by storage in aqueous solution and by the action of sunlight.[2] They are soluble in water and are easily washed out of the soil by rain,[3] and, on this account, direct evidence of toxicity may be difficult to obtain in some soils, especially in those of moist climates.

The Agricere of the Soil.

It is not at all probable that any one reason will explain the cause of the enhanced fertility of soils that have been treated with volatile disinfectants. Russell and Hutchinson showed that there was an instantaneous production of a small quantity of ammonia upon the soil being toluened. I have shown that the disinfectant, acting as a fat-solvent, dissolved the soil-wax or fat (agricere), and instead of depositing it again in the original position on the evaporation of the solvent, it is carried with the liquid disinfectant and deposited near the surface of the soil.[4] It is deposited on

[1] Proc. Linn. Soc. New South Wales, 1910, 814. [2] *Ibid.*, 1910, 822. [3] *Ibid*, 1911, 685. [4] *Ibid.*, 1910, 817; 1911, 699.

the points of the soil particles, and although the vapours of the disinfectants may not transport the agricere, the condensed vapour on the surfaces of the particles will cause a segregation. Instead of uniformly coating the particles, the agricere is deposited on the raised angles of the soil fragments. The agricere is the remainder of the ether-soluble material of the organic matter of the soil, and as such must be concentrated in the decomposing organic matter, saturating it, as it were, and hindering its rapid decomposition by bacteria. With its removal, the organic matter should be more easily decomposed and the fertility increased. There is the probability that it is the agricere which prevents the too rapid decomposition of the organic matter of sandy soils, that it prevents the soil from becoming a raw sand.

My experiments with organic matter artificially covered with paraffin, did not show the benefit expected from an ether or chloroform treatment, but that was undoubtedly caused by the dried blood or casein, used for the purpose, swelling upon being moistened, and so breaking the paraffin covering.[1] The direct influence of the agricere is therefore difficult to prove, and so it may be taken that its segregation, caused by the volatile disinfectants, plays a certain though perhaps a small part in the increased fertility.

The Possible Nature of the Limiting Factor.

Among the various possibilities which may ultimately explain the nature of the factor that limits the increase of the bacteria in soil, we cannot imagine that it is a physical condition, for such a state could not propagate itself. A colloidal condition of the humus or the clay, if destroyed by disinfectants or by air-drying, could not be restored by the addition of 5% of untreated soil as Russell and Hutchinson has shown. These authors say that it must be

[1] Proc. Linn. Soc. New South Wales, 1913, 740.

biological and of this there can be no doubt. Russell and Hutchinson's experiment, showing that the so-called pure cultures of protozoa, when introduced into sterilised soil, did not limit the growth of bacteria, was confirmed by me and has since been proved by Goodey,[1] who in testing soils, which had been stored in bottles for many years, found that only those soils which had not been air-dried contained the limiting factor. A soil which contained amœbæ and flagellates, upon being moistened, behaved as if the limiting factor were absent. He showed that the presence of 10,000 amœbæ per gram of soil was not enough to reduce the bacterial content to the level of a similar soil containing no protozoa, and he therefore concluded that the protozoa cannot functionate as the limiting factor. I have shown that air-drying, combined with antiseptic treatment, does not vitally affect the typical soil protozoa.[2]

The factor may be an obscure member of the protozoa, just as it may be a filterable micro-organism, but at this stage of progress in the matter such a contingency cannot be entertained. We are therefore driven to consider the bacteria and moulds as being the probable agents. The conditions that destroy the limiting factor destroy some of the bacteria and moulds. The bacteria affected include the nitrifying organisms and the sulphur-oxidising bacteria and many other delicate forms. The net result is the temporary establishment of a new flora, and it appears to be only when the old and natural flora is re-established that the limiting factor returns. It would be hopeless to consider the matter as pertaining to the whole flora, because this would lead us to nowhere. It is to the single members or the single classes that we must turn our attention. Hiltner and Störmer early showed that the denitrifiers and the streptothrix varieties were almost completely destroyed

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[1] Proc. Roy. Soc., B. 606 (88) p. 437.

[2] Proc. Linn. Soc. New South Wales, 1914, 839.

while Russell and Hutchinson noted certain alterations in the flora but denied the destruction of the streptothrix forms.

Be this as it may, since the protozoa are out of the question, it is to the classes of micro-organisms and especially to their by-products that we must look for the elucidation of what constitutes the limiting factor.

The Stimulation of Bacteria by Poisons.

Although the action of the poisons and disinfectants in stimulating the growth of yeasts and moulds has been known for forty years, I believe Hüne[1] in 1909 was the first to investigate the action of volatile disinfectants upon bacteria. He tested the action of fluorine, copper sulphate, thymol, ether and formalin, upon the growth of *Bac. coli* suspended in dilute bouillon. They all stimulated growth, but there was a certain maximum concentration or dilution, below and above which growth was diminished. The point of maximum stimulation varied with the disinfectant. It ranged from one part in a hundred for ether to one part in ten millions for formalin. Fred[2] followed the same line of investigation using copper sulphate, ether, carbon bisulphide potassium bichromate and salvarsan, with all of which he obtained a stimulation, when the disinfectants were employed in appropriate dilutions. The ammonifying bacteria were more easily stimulated than the nitrogen-fixing and the denitrifying groups of bacteria. The two latter groups, however, require organic matter to enable their activities to be made manifest, and as this is so small in ordinary soil, he concluded that the action of the disinfectants upon nitrogen-fixation and denitrification in soil must be negligible.

As the result of experiments upon plants growing in disinfected soils, he concluded that the plants were stimulated directly, and at the same time an indirect stimulation was

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[1] Cent. Bakt., 1 te, 48, 135. [2] Cent. Bakt., 2 te, 31, 185.

given through the stimulation of the soil bacteria. This appears to be the first suggestion of a direct and indirect plant stimulation by disinfectants.

I do not think that a direct stimulation of a growing plant by a volatile disinfectant has been proved, although the stimulation of germinating seeds has been known for some time. The action of ether in hastening germination was described to me when in Copenhagen in 1897. Koch[1] records the stimulation of weed seeds by carbon disulphide, and Hamburger[2] says that chloroform in the proportion of one to one hundred thousand parts stimulates the germination of seeds, while with one to one thousand parts the germination is impaired.

The effect upon the seed is probably caused by an increased permeability of the cell-walls of the tissue by the action of the disinfectant, and the consequent easier migration of the enzymes to the glucosides.[3]

With regard to the stimulation of the bacteria by disinfectants, both Hüne and Fred employed bouillon for growing the organisms, and in concluding that a bacterial stimulation occurred in the soil, Fred must have taken it for granted that some of the disinfectant remained in the soil in order that it might exert its effect. If the disinfectant has entirely volatilised when its presence cannot be detected by the senses, all stimulating action must cease. A sustained stimulation necessitates the continued action of a stimulant. Heinze detected traces of carbon disulphide in the soil a month after treatment, and recently I have shown that traces of chloroform remain in the soil for at least six months. At the same time I showed that small amounts of chloroform stimulate the multiplication of bacteria in soil extract. Soil extracts may be nutritive or

[1] Cent. Bakt., 2 te, 31, 175. [2] Nature, 96, (1915), 19.
[3] The Armstrongs, Proc. Roy. Soc., B. 84, 226.

toxic. If they are nutritive, traces of chloroform enhance the nutritive effect, while, if the extracts are toxic, they increase the toxicity.[1] Chloroform therefore acts in a manner similar to the soil toxins, or to reverse the point of view and to generalise, the toxins behave like the volatile disinfectants so far as their stimulating and toxic powers are concerned. This is what we should expect, for, toxins are really poisons and should behave like the disinfectants, and the mineral poisons such as arsenious oxide, copper sulphate and the like. It follows that the bacterio-toxins are the natural soil stimulants, and if kept under control, so that the amount never becomes excessive, they will conduce to increase the soil fertility.

The Action of Lime.

The action of quicklime upon the bacteria of the soil appears to have been first investigated by H. Fischer,[2] who found that it acted much as a volatile disinfectant, in first depressing then augmenting the bacterial numbers. With 0·7%, the bacteria rose in 16 weeks to 420 millions per gram.

Hutchinson[3] showed that the action of caustic lime was intermediate between that of the volatile disinfectants and that of a high temperature. Many bacteria are killed, the larger protozoa are destroyed and there is a decomposition of organic matter.[4] The bacteria remain depressed until the excess of calcium oxide is converted to carbonate when there is an active bacterial multiplication. In a later paper, in conjunction with MacLennan,[5] he showed that

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[1] Proc. Linn. Soc. New South Wales, 1915, 724.

[2] Cent. Bakt., 2 te, 26, 263. [3] Journ. Agr. Sci., 5, 320.

[4] It is claimed that the decomposed organic matter exercises a "feeding effect" by which is meant that the bacteria quickly rise to enormous numbers, but these are not sustained. This is generally noted with soils that have been sterilised by heat and sometimes by disinfectants. It is open to question whether it is due to an increased amount of available nutriment or to the destruction of toxins or to a combination of the two.

[5] *Ibid.*, 6, 302.

the action of lime depended upon the character of the soil, each soil absorbing a definite and variable amount before the so-called partial sterilisation effect became evident. This critical CaO point can be determined chemically, as it is the point at which there is no more absorption of lime. Above this point the lime remains as free alkali, and it is the free alkali that functionates as a disinfectant.

The Soil Protozoa.

Our knowledge of the soil fauna is at present very scanty. The economic value of the protozoa is undoubtedly to decompose organic matter, for they feed upon it, and therefore, if the effect of digestion is similar to that of the higher animals, the bulk of the food is soon resolved into simpler substances. We are not quite sure what protozoa are vegetating in the soil. All forms that are present must surely have vegetated under some conditions, but that they do not always lead an active life appears from the work of several observers.

Goodey[1] concluded that the large *Colpodæ* exist in the encysted condition, for he noted that when the soil was shaken up with culture media, the first cells to be observed did not have the granular structure of vegetating forms. In culture media infected with soil, the protozoa are found to run in cycles; some forms predominate at one time, and others at another, and Martin and Lewis[2] think it possible that this also occurs in soils, and that two soils with similar water content, may show a different fauna according to the point of the cycle at which the soil had arrived. The cycle may be explained by the protozoa secreting substances which are toxic to themselves, as has been shown by Woodruff in the case of *Paramecium aurelia*. Sun confirmed this, and pointed out that heating the fluids destroyed the

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[1] Proc. Roy. Soc., 1911, B. 84, 165.

[2] Journn. Agr. Sci., 7, 106.

toxins.[1] Even the toxins secreted by bacteria may have an effect upon the fauna, for Cropper and Drew[2] believe that the amœbæ encyst in order to protect themselves from the toxic products secreted by bacteria in the medium.

In the soil, one must distinguish an active, a resting and a cultural micro-fauna. Martin and Lewis believe the active fauna to consist chiefly of small flagellates and amœbæ.

It is doubtful whether the active protozoa have much effect in reducing the numbers of soil bacteria. My observations point to the bacteria being ingested accidentally. *Colpoda cucullus* is very fond of bulky organic matter; I have seen several feeding voraciously upon the slime extruding from encysting Colpodæ, like sharks feeding upon the carcase of a horse. The soil amœbæ do not appear to find bacteria very attractive, for I have seen bacteria passing over the amœba surface and being left behind. This occurred in culture media, and it may be that, in such a nutritive fluid, the phagocytic tendency is at a minimum. There does not appear to be any reason for the ingestion of bacteria if enough soluble and suitable nourishment can be obtained by diffusion, a conclusion that Wolff arrived at from experimental work in 1909.[3] The englobing of bacteria may be quite an accidental phenomenon, for amœbæ free from bacteria, have been found by Musgrave and Clegg[4] in sterile liver abcesses. They, probably to a slight extent, do diminish the numbers of bacteria in the soil, but the by-products of digestion, secreted by amœbæ and other protozoa, are sure to contain auxetics and soluble nitrogenous matter which must enable the surviving bacteria to multiply to some extent which may even counterbalance any diminution through phagocytosis. Indeed it has been

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[1] Through Bull. Inst. Past., XIII, 515. [2] *Ibid.*, XIII, 521,

[3] Cent. Bakt., 2 te, 24, 465, [4] Walker, Cent. Bakt. 1 te, Ref. 50, 583.

shown[1] that the maximum activity of the protozoa and of the bacteria correspond very closely.

Cunningham,[2] by sterilising soils with formalin and decomposing the residual disinfectant with lime, claims to have shown that the introduction of protozoa does cause a diminution in the bacterial counts after 25 days. We do not know how the bacteria, introduced with the protozoa, increased during the first 25 days, but it is probable that there was an enormous increase followed by a decrease by the twenty-fifth day. I was not alone in showing that the direct introduction of so-called pure cultures of protozoa into disinfected soil did not result in a diminution of bacteria, for Russell and Hutchinson had previously obtained similar results, while Lipman[3] found that it made no difference in the bacterial counts whether one added suspensions of soil, freed from protozoa by filtration, or unfiltered suspensions to an already sterilised soil. This has also been recently confirmed by Goodey[4] who worked with a soil that had been stored for seventy years, and was quite free from protozoa and contained few bacteria. The addition of fresh or foreign bacteria caused at first an enormous increase, which was followed by a decrease when the numbers remained at a level below that of the moistened soil. It is a general rule that, when a foreign flora is added to a soil, the numbers of bacteria increase greatly within the first twenty days and then decrease. The same phenomenon occurs with a soil sterilised by heat and simply moistened. On the other hand, a soil sterilised by a volatile disinfectant shows a gradual rise to a new bacterial level.[5] This makes one believe that the action of heat is largely to destroy

[1] Cunningham and Löhnis, Cent. Bakt. 2 te, 39, 596.
[2] Journ. Agric. Sci., 7, 49.
[3] Bull. N. J. Expt. Stn. No. 248.
[4] Proc. Roy. Soc., B 606, 88, 437.
[5] Proc. Linn. Soc. New South Wales, 1913, 671.

bacteriotoxins, while that of the disinfectant is to liberate nutrients. Goodey furthermore found that the addition of a *Vorticella sp.* showed a bacterial curve akin to that of the untreated soil, and that the addition of *Colpoda sp.*, of amœbæ and of flagellates, gave numbers always higher than the untreated soil, from which he naturally concluded that the addition of protozoa, with the inevitable bacterial impurity, did not bring about a diminution of the soil bacteria.

Russell and his colleagues believe that 1% of toluene destroys all protozoa, and, although this is the case generally, many of their experiments show that the treatment had not eliminated the protozoa. Gainey found that toluene depressed the soil bacteria more than the protozoa, and from his experiments he could not account for Russell and Hutchinson's results. Very early in my experiments, I found that even 20% of disinfectant did not destroy the microfauna, and, in work undertaken to discover the reason, I found that much depended upon the moisture content of the soil. When soils are prepared for experimental work, it is usual to partly dry them to enable them to be thoroughly mixed, and to furnish a representative sample. If the drying is allowed to proceed so far as to bring the moisture below one-twentieth of the water-holding capacity of the soil, the protozoa are not destroyed by the volatile disinfectants.[1] Yet in such soils the protozoa do not appear to have any influence in reducing the bacteria. In the research, I showed that the toluening of moist soils not only destroyed the protozoa, but also destroyed the sulphur-oxidising bacteria, with the result that in certain culture media, traces of sulphuretted hydrogen are produced which prevent the growth of protozoa. This is a point that should not be lost sight of when proving the absence or presence of protozoa in treated soils.

[1] Proc. Linn. Soc. New South Wales, 1914, 839.

The claims that have been made regarding the functions of the protozoa, have led investigators to endeavour to count their number in the soil. With one exception, Remy's method has been adopted of shaking the soil with water, and diluting the suspensions until there is reached a limit beyond which no protozoa develop. The method is useful for the enumeration of bacteria or vegetating protozoa, but the principle is useless for counting the encysted protozoa. It does not appear to have been observed that when certain protozoa, such as the ciliates and amœbæ, encyst, they extrude a quantity of slime by which they attach themselves to solid particles or surfaces. They occasionally appear to aggregate together, but this may be due to some inequality of the surface. However, I am convinced from my observations, that any method of enumerating protozoa by means of aqueous suspensions is doomed to failure. This has been the experience of an investigator, the reference to whose paper has been mislaid. He found that fairly concordant results could be obtained in no other way than by adding definite weights of soil, even to fractions of a milligram, directly to nutritive fluids.

The function of the Protozoa.

Since the evidence shows that the protozoa do not destroy the actual numbers of bacteria in the soil, they must have another function to perform. This is probably the destruction of certain forms of organic matter. In experimenting with irrigated soils, Wolff found that as soon as the air-spaces of the soil were filled up with water, the protozoa grew with a new intensity. He suggested that their function was to take up and destroy moulds, algæ and bacteria, to withdraw important substances from the soil water, and to preserve them by assimilation before they sank into the subsoil, and to exert a solvent action through the acid products of metabolism. We have no evidence regarding the destruction of the moulds and algæ, and it is quite possible that this may be their function. We do know that the actual numbers of bacteria are not influenced, but we do not know if some bacteria are absorbed by the amœbæ and others ignored. The selective action upon the soil bacteria is a point that requires elucidation. We know that certain amœbæ select certain nutrients, as for example, *A. nitrophylla*, and it may be that they select or refuse certain kinds of bacteria, just as do the phagocytic leucocytes of the animal body. They will certainly withdraw nutrients from the soil water, and by converting them into organised proteid, will prevent them passing into the subsoil. But the by-products of digestion will be extruded, and may, as Wolff suggests, by reason of their acidity, exert a solvent action upon mineral fragments. By reason of their simpler and more diffusible nature, they will assist the growth of the soil micro-flora and of plants.

Sewage-sick Soils.

It has been claimed by Russell and Golding[1] that the sickness of sewage soils is due to the activity of protozoa, because treatment with volatile disinfectants brings about a cure. I have shown that the protozoa are not destroyed by the treatment, possibly because the soil was air-dried in order to obtain a uniform condition. Russell and Petherbridge say that partial sterilisation may fail in the case of soils rich in organic matter, and it is under this category that sewage soils must be classed. Personally I believe[2] that the sickness is caused by the slime that accumulates in such soils, and any substance or treatment that destroys the slime will cure the trouble. The soils are akin to a slimy bath-sponge, which may be able to be used if the water is hard, for lime salts coagulate the bacterial slime.

[1] Jour. Soc. Chem. Ind., 30, 471.

[2] Proc. Linn. Soc. New South Wales, 1912, 238.

Air-drying and liming coagulate the slime of the sewage-sick soil, and possible also destroy the causative bacteria. The surviving bacteria doubtless attack the coagulated slime, and the sickness disappears. On this account, volatile disinfectants by disturbing the original flora may eliminate the sickness.

The effect of Air-drying the Soil.

With regard to the simple air-drying of soils, there appears to be no doubt that the chemical and bacteriological activities are considerably increased. Heinze[1] found that air-dried soil was about 20% more active than moist. It formed 20% more acid from glucose, 20% more gas was evolved in the presence of carbonate of lime, and in solutions of peptone and urea, 20% more ammonia was formed. The fermentation, as shown by Ritter,[1] was quicker and more intensive, but the difference became obliterated later on. Rahn[2] showed that the acid production was greatest during the first twelve days, but was quite evident on the sixtieth day. Buhlert and Fickenday[1] found that even a slight drying increased the nitrate reaction. It has been found that a slowly dried soil is more active than one which has been rapidly dried. The activity appears to rapidly disappear upon again moistening the soil, for in twenty-four hours the greater part has gone. The bacteria are greatly decreased in numbers; I found that air-drying reduced the bacteria from 14 millions to 3·6 millions.[3]

The reason for the increased activity is difficult to explain. It cannot be due to a physical difference in the structure, for a dry soil is more difficult to wet than a moist one, and even if so, the small quantity of soil added to a comparatively large quantity of culture fluid would annul any physical difference. It may be that the mineral

[1] Cent. Bakt. 2 te, 33, 116. [2] *Ibid.*, 20, 38.
[3] Proc. Linn. Soc. New South Wales, 1915, 638.

and nitrogenous substances go quicker into solution from the dry than from the wet soil, as in the case of a soil treated with a volatile disinfectant, but it is more likely that the drying brings about an increased oxidation through the water being displaced by air, some of which may be adsorbed. This was brought forward by Fischer,[1] and certainly the loss of activity upon moistening and storing the soil appears to favour the idea.

König, Hasenbaumen and Glenk[2] came to a different conclusion. They found that all soils, with the exception of clays, show a small but demonstrable increase of dialysable materials when heated under diminished pressure. They concluded that this results from an alteration of the colloidal condition of the soil, which causes the adsorbed materials to become soluble. Even air-drying of the soil, under natural conditions, causes a partial destruction of the colloidal state, and therefore an increase in the solubility of the colloid-bound nutrients. They investigated the crops grown upon various heated soils, and found that the dry matter of the crops varied in the order of the quantity of the dialysable substance of the soils. They considered that this explained the value of repeated drying and wetting in increasing plant growth.

Buddin[3] showed that there was a certain relation between the simple air-drying of soil and the treatment with volatile disinfectants and with heat. It is possible to trace a certain graduated intensity of effect between disinfectants, from the strongest, such as formaldehyde, through the more or less potent, down to the simple air-drying of the soil in a thin layer. This suggests that the alteration in the bacterial flora may be the chief reason for the increased activity following the air-drying of the soil.

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[1] Cent. Bakt. 2 te, 36, 346. [2] *Ibid.*, 39, 184.
[3] Journ. Agric. Sci., 6, 417.

The Influence of Season.

The fertility of a natural soil is largely influenced by the moisture content and by the temperature. The bacterial activities, as indicated by the fluctuations in the bacterial numbers, in the carbon dioxide content and in the amount of nitrates, rise and fall generally with the seasons.[1] There may be slight influences brought about by the effect of manuring and cropping, but the general rise and fall of the biochemical activity, as indicated by these co-related factors, varies with the season. It is at a maximum in late spring or early summer, at a minimum in summer, a maximum in late autumn and a minimum in winter. Although we cannot alter these general changes very much, we can, by soil treatment, make certain differences which render the soil more fertile. We endeavour to do so by manuring. Practice has proved that certain fertilisers have a decided effect upon the growth of plants, and the wonder is, that although there may be an abundance of fertilising material already in the soil, the addition of a few hundredweights per acre of a fertiliser has a profound effect upon the crop. The reason has been ascribed to the greater availability of the added fertiliser, but Whitney and others, have suggested that the fertiliser acts more by reason of its power to neutralise soil toxins than by its nutritive capacity.

This has been rebutted by certain Rothamsted investigators,[2] who upon growing plants in the extracts of various soils, found that the growth was proportional to the manurial history, the previous cropping, and the composition of the soil solution.

Raw Organic Matter in Soil.

Experience has shown that it is not good agricultural practice to add raw, that is, unfermented organic matter

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[1] Russell and Appleyard, Journ. Agri. Sci., 7, 1.

[2] Hall, Brenchley, and Underwood, *Ibid.*, 6, 278.

to soil. The farmer rarely puts raw manure into the soil, and if green manuring is employed, time is given for it to ferment before the crop begins to grow. What holds for complex manures, also holds for simple carbohydrates such as starch. Unless time is given for this to decay, the crop is injured. The injurious effect of adding sugar to soil has been noted by several investigators,[1] by some of whom it is ascribed to the loss of combined nitrogen by denitrification, although Lipman[2] has shown that the addition of glucose, or other organic matter, depresses the crop even in the presence of an excess of fertilising material containing nitrate. Indeed nitrates were found in the tissues of the impoverished plants. Some reason other than denitrification must therefore be found to account for the crop depression.

The addition of an excess of bulky fertiliser, such as farmyard manure, has been found to diminish the crop and at the same time to lessen the bacterial counts.[3] The reason for this is obscure, although some light is thrown upon the matter by the work of Temple,[4] who showed that the sterilisation of raw manure increases the bacteria in the soil, as well as the general fermentable activity. The work points to the destruction by heat of depressing substances or toxins in the raw manure.

From what has been done, the inference appears to be that, easily fermentable organic matter in the soil gives rise to an undesirable fermentation, with the production of depressing or toxic substances, and time must be allowed for these to decay or the crop will suffer.

Bacteria, while growing in soil bring about the decay of the organic matter, and in doing so cause the liberation

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[1] Münter and Robson, Cent. Bakt. 2 te, 39, 419.
[2] N. J. Ag. Expt. Stn. Rept. 257.
[3] Brown, Cent. Bakt. 2 te, 39, 523.
[4] *Ibid.*, 34, 204.

of the nutrients bound up with it. The by-products of the bacterial decomposition are many, and have various chemical and physiological activities. Acids there are undoubtedly, and these will attack the mineral fragments, liberating available mineral nutrients. But there are other substances, some of which are injurious to the bacteria themselves, to other micro-organisms and to plants, while some are beneficial and act as accelerators. A better name for what we have previously called toxins might be retarders, while the accelerators have been named auxetics and auximones.

Schreiner and his colleagues[1] have isolated from soils a number of definite chemical bodies, some of which are injurious, while others are beneficial to plants. In certain unproductive soils the injurious compounds predominate. They are all derived from the organic matter of the soil by the agency of bacteria, and include arginine, guanine, dihydroxystearic acid, coumarin and aldehydes, such as vanillin and benzoic aldehyde. The toxicity of some of these are overcome by certain fertilising substances, for example, the objectionable activity of vanillin is annulled by nitrates, coumarin by phosphates, and that of p-benzoquinone by potassium salts.[2]

Auximones.

Recently Bothamley[3] has discovered that, when peat is fermented with certain ærobic, ammonia-producing soil bacteria, the liquid contains substances which stimulate plant growth. They are related to the vitamines of Funk, but appear to be more closely allied to the growth-producing bodies of Hopkins, which, in exceedingly small amount, are necessary for the growth and well-being of animals.

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[1] Through Journ. Chem. Soc., 1914, I, 1195.
[2] Chem. Soc. Rept., 1913.
[3] Proc. Roy. Soc., B 602, (88) 237.

These plant stimulants or auximones are soluble in water and in alcohol, and are not destroyed when boiled with water for a short time. Like the vitamines, they form insoluble silver and phosphotungstic acid compounds, which enables them to be partially purified.

Auximones are formed during the formation of humus from organic matter, and occur in fresh and rotted farmyard manure.[1] There is a greater amount in the rotted than in the fresh manure. They have also been found in the nodules upon the roots of leguminous plants. They are apparently developed, along with certain vitamines, during the germination of seeds. Bothamley claims to have obtained marvellous results with the auximones, so much so that they appear to pertain to the nature of the nutrient written about by Wells in "The Food of the Gods." Under the name of "Humogen," a preparation of the auximones is about to be placed upon the market for agricultural and horticultural purposes.

Toxins.

Certain plants, and probably this applies to all plants, appear either to secrete or cause the formation of toxins which are injurious, not only to other plants, but even to the plants themselves. A direct secretion of toxin is possible, but an indirect action through a secretion influencing the activity of certain groups of soil micro-organisms is probable. A possible direct action has been instanced by Fletcher in the case of maize and *Sesamum indicum* growing in alternate rows. The latter were injured by the maize, and Fletcher considered that the toxicity may have been due to the secretion of dihydroxystearic acid by the maize roots.

The indirect formation of toxins is probably seen in the case of soil sickness, which we have reason to believe is due to the activity of certain micro-organisms.

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[1] Through Journ. Soc. Chem. Ind., 34, 881.

A probable indirect production of toxicity has been shown to occur in the case of the leachings of soil which has been growing plants. The Duke of Norfolk and Pickering,[1] after noting that grass under growing fruit-trees caused the trees to grow badly, found that the leachings from soil growing grass were injurious to growing trees and other plants. Similarly the leachings from clover soils were injurious to tobacco, tomatoes and mustard, and to clover itself. Indeed it appears that the leachings from soil growing any kind of plant is toxic to the plant itself and to all other plants. They did not believe that the toxic substances were secreted directly by the growing plants, but that they were derived from the decay of the plant débris. Thus the soil bacteria, or at any rate the soil micro-organisms, which produce the decay of the vegetable matter, are inferentially considered to be the active agents in the formation of the plant toxins.

There can be little doubt that the life in the soil is interrelated. The plant has an influence on the bacterial flora and upon other plants; the bacteria influence the growth of plants, of other bacteria, of moulds, and of protozoa, and this is entirely caused by the secretion or excretion of various bodies of an acid, a nutritive, a toxic or an enzymic nature. The amount of each of these relative to the others and the alterability of one to the other is of importance. The nutritive quality of the soil is naturally of paramount importance, for the food of the bacteria, protozoa or of plants, depends upon this factor, and doubtless it is also responsible for the nature of the bacterial flora and protozoa fauna. But behind all this there is the action of the growing plant, for we see from the occurrence of soil sickness that the crop influences the balance of the bacterial flora. The bacteria again are influenced in their activities by the

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[1] Journ. Agri. Sci., 6, 136.

seasonal conditions, which by alternately wetting and drying the soil, disturbs the relative numbers in the various groups. Not only this, but the temperature has considerable effect upon the activity of certain forms. The bacterial products are thus continually altering, as the one bacterial group or the other preponderates. This alteration of bacterial products will naturally influence the plant. Thus the fertility may be as much a factor of the plant, as of the soil or the bacterial or the protozoal life.

When considering fertility, however, we are chiefly concerned with an increased growth of crop, and for this to occur we must naturally enquire into how best to annul the effects of anything which will hinder growth, whether it be a lack of nutriment, or an adverse condition, or an excess of some poison or toxin. The working of the soil and its consequent exposure to the oxidising action of the air and antitoxic action of the sun, is without doubt the natural method of destroying toxins, and favouring the activity of the beneficial micro-organisms, and possibly also of altering the condition of the soil colloids. In a dry climate such as we have, the high temperature and comparative dryness of the soil is probably adverse to the accumulation of toxins, while in a wet climate, the rain washes them out of a well-drained soil. Still they are continually being formed, and when they are allowed to exist, only as traces, they act not as toxins, but as stimulants, and while they do so they increase the fertility of the soil.

A curious feature of these soil toxins is that they can only be detected directly when a certain quantity of water relative to the soil is used in extracting them. This quantity is generally one of water to one of soil.[1] By using a smaller quantity of water the extract is found to be

[1] Proc. Linn. Soc. New South Wales, 1913, 725; 1915, 633.

nutritive, and this effect is at a maximum when the ratio of soil to water is about two to one, that is when the soil is little more than saturated.

With regard to the toxicity of the leachings of grassed soils, Miller[1] remarked that it was strange that they should be toxic, while the same water in contact with the soil in a pot should be nutritive. It is strange, but the fact remains that when the soil is watered, a toxicity does not make itself palpably evident. If the same soil is leached, the toxicity can be clearly shown. It is the same with the action of the soil extracts upon the growth of bacteria, no palpable or direct evidence can be shown until the soil-water ratio is the same as would be used in leaching a soil. There is thus a parallel between my results with bacteriotoxins and those of the Duke of Bedford and Pickering with plant toxins. There may be more than a parallel, for as the authors consider that the plant toxins are derived from the decay of root débris by bacteria, there is the probability that the bacteriotoxins and plant toxins are one and the same.

Toxins only act as poisons when they are in solution in sufficient concentration to enable their toxic character to become evident. In smaller amount their action is reversed, and they act as stimulants. This applies to metallic poisons and to disinfectants, and I have shown that it also applies to the bacteriotoxins.[2] When they are diluted by a half or even more, the solution instead of being toxic becomes nutritive, in some cases extremely so. Considerable dilution however weakens the concentration of the nutrients in the extract, and the bacterial increase due to stimulation by the weakened toxin becomes non-evident.

The soil toxins may be chemical entities, but they are different from such toxic substances as coumarin, vanillin,

[1] Chem. Soc. Ann. Rept., 1914, 232.

[2] Proc. Linn. Soc. New South Wales, 1913, 725.

etc., which are not affected by heat. They may be of the nature of the hop-constituents, which when boiled with water are changed from being petroleum-soluble and preservative to petroleum-insoluble and non-preservative.[1] They are probably changed into stimulants, for while heat makes a toxic extract nutritive, the nutritive effect is frequently far greater than would be expected from the mere destruction of the toxins.

The soil toxins have alone been considered, but there is a toxin in the subsoil which differs from that of the soil in remaining toxic upon prolonged boiling.[2]

It is quite within the bounds of possibility that Bothamley's auximones are altered toxins, for we should expect his process of fermenting organic matter to result in the production of toxins, and the subsequent procedure of evaporating, storing, etc., would be sufficient to alter the toxin into a stimulant. The actual proof that toxins are converted into stimulants by heat however is still lacking. They are undoubtedly weakened, and a stimulating effect is shown which is progressive with the extent of the heating.[3] But whether the stimulation is due to a weakened toxin or to a conversion of the toxin into an auximone is not at present known. The proof will probably be furnished indirectly by showing that a solution of Bothamley's auximones is toxic before treatment, or that its nutritive or stimulating effect is altered by heat.

The Commercial Use of Partial Sterilisation.[4]

The partial sterilisation of soils has been used on a commercial scale in England for glass-house work in which the soils consist of compost, virgin loam, straw-manure or

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[1] Chapman, Proc. Chem. Soc., 29 (417) 182.

[2] Proc. Linn. Soc., New South Wales, 1913, 725. [3] *Ibid.*, 1910, 808.

[4] Russell and Petherbridge, Journ. Board Agric., 18, 809; 19, 809. Russell, *ibid.*, 21, 97.

other rich mixtures of manure and organic matter. Under the conditions of growth, moisture and comparatively high temperature, the soils soon become unfitted to grow the desired plants, and in this condition are termed "sick." A cucumber soil is generally good for a year, when it is rejected, and a fresh virgin loam is used. A tomato soil is generally useless after five years. There is always enough manurial matter in the spent soils, in some cases they are even richer than stable manure, but they are so full of disease germs, eel-worms, plant-lice and fungi, that the plants cannot compete and a poor growth is obtained.

Various methods of disinfection have been tried in the commercial nurseries. the most successful being high pressure steam, low pressure steam and baking. The use of disinfectants is still in the experimental stage, but considerable promise has been obtained with formaldehyde at five pence per pound, and carbolic acid at three half-pence per pound. The general application is from a half to one pound per square yard, which is equivalent to two to four pounds per ton. The practical objections to most liquid disinfectants are the price, and the fact that they do not reach all parts of the soil, but are retained near the surface. Baking or steaming works out at from sixpence to one shilling per ton, but much depends upon the resources available.

Tomato soils which are steamed when not absolutely "sick," cause a better growth at first, but the advantage gained disappears when the plants are fed with manure, as the fruit begins to swell. The backward plants in the untreated soil come forward and overtake those in the steamed soil. It is probably unnecessary to use much nitrogenous manure in steamed soils, as the treatment produces the equivalent of a nitrogenous manuring. The differences, however, are shown in the roots and in the fruit.

The roots of the plants in the steamed soil are much more fibrous, and the fruit is generally greater in quantity and better in quality. A mechanical trouble arises in steaming cucumber and chrysanthemum soils, for after the steaming the fibrous nature of the soil is lost, and a judicious mixture with a new soil is advisable. Still the rejuvenated soil is as good as new soil, and generally the cost of steaming is less than the cost of new soil.

In "sick" soils the effect of steaming or baking, or of disinfectants, is very marked as the sickness is cured and the plants grow in a healthy manner and with luxuriant foliage.

Partial sterilisation has not and probably never will be attempted in the field, as to be effective the cost would be prohibitive. It is true that carbon disulphide has been used to combat the soil-sickness and phylloxera of the vine, but for ordinary crops the treatment would not be economical. Lime has been used, and especially the old fashioned gas-lime, rich in calcium sulphide and polysulphides, in checking the ravages of finger-and-toe disease of cruciferous root-crops. Lime is used in ordinary farming practice, more to counteract soil acidity and to favour the growth of clover, than to partially sterilise the soil. Possibly if partial sterilisation ever is attempted with our crops, it will be with potatoes, and the agent may possibly be a lime and sulphur compound, for it gives most promise of being purchasable at a low price.

In Australia, the tropical and subtropical sun is continually subjecting the soil to a process of partial sterilisation, not only by the high daily temperatures, but also by the repeated and extensive drying or desiccation. So much is this the case, that probably the action of the limiting factor is at a minimum for the greater part of the year. During my experimental work, I have found that it is hopeless to expect to find the direct evidence of toxin in soils at any other time than during the cool winter months.

Conclusion.

In concluding, I have endeavoured to show that a new stimulus was given to the study of certain aspects of the microbiology of the soil by the work of Russell and Hutchinson, and although their deductions have not been generally accepted, yet they have done much to advance the study of the protozoa and of other factors in soil fertility. It has not been proved that the protozoa play any part in restricting the gross numbers of the soil bacteria. They do not constitute the limiting factor, and with their claims out of the way, attention can be paid to the work of the other micro-organisms. These are non-phagocytic, and must exercise their activity by the secretion of certain bodies which, being destructive, are called toxins. At present the nature of these toxic bodies is a matter of indifference. Their characters will naturally be determined when we isolate the causative micro-organisms. This may involve a considerable amount of research work, but I believe that the elucidation of the problem is not far distant. So far as we can judge at present, our policy should not be directed to preventing the total formation of the toxic products of micro-organisms, even if it could be done, but to regulating their amount, so that they are present in the soil in the proportion in which they act as microbic and possibly as plant stimulants.

SOME AMPHIPODA AND ISOPODA FROM BARRINGTON TOPS (4600 ft. alt.) N.S.W.

By CHAS. CHILTON, M.A., D.Sc., M.B., C.M., LL.D., F.L.S., C.M.Z.S.,
Professor of Biology, Canterbury College, New Zealand.

(Communicated by C. HEDLEY.)

With Twenty-two Text-figures.

[*Read before the Royal Society of N. S. Wales, June 7, 1916.*]

IN January, 1916, I received from the authorities of the Australian Museum, a small collection of Amphipoda and Isopoda that had been gathered a short time previously by Mr. C. Hedley, on Barrington Tops near Dungog, New South Wales, at an altitude of 4,600 feet above sea-level.[1] On examination the collection proved to consist of four species, two *Isopoda* and two *Amphipoda*, there being one terrestrial and one fresh water representative of each group. The species are:—

Isopoda— Terrestrial, *Cubaris helmsianus* sp. nov.
Fresh water, *Phreatoicus shephardi* Sayce.

Amphipoda—Terrestrial, *Talitrus sylvaticus* Haswell.
Fresh water, *Gammarus barringtonensis*, sp. nov.

Two of these species are new, all of them present points of individual interest, their geographical distribution is important, and a brief account of them is therefore desirable.

[1] Just before the New England Plateau dips into the trench of the Hunter valley, it rises at Barrington Tops to a height of five thousand feet. Here the climate proper to such an altitude nourishes a subalpine fauna and flora on an island, as it were, set in a subtropical sea. So inaccessible is this spot that it has hitherto escaped scientific examination. Under the auspices of the West Maitland Scientific Society, an excursion to it (described in the *Sydney Morning Herald*, 1/4/16) was arranged by our member, Mr. J. W. Enright, for the Christmas holidays of 1915. A botanist, a geologist, and several zoologists joined this party and accomplished useful work. The present communication, which will, it is hoped, be followed by several others, was preceded by articles on the Coleoptera by Messrs. Sloane and Carter, Proc. Linn. Soc. N.S.W., XLI., 1916, pp. 196–214, and a note on a Moss by W. W. Watts, *op. cit.*, p. 385.—C.H.

TALITRUS SYLVATICUS Haswell (figs. 1 to 3).

Talitrus sylvaticus Haswell, 1879, Proc. Linn. Soc. N.S.W., vol. iv, p. 246, pl. vii, fig. 1.

Talitrus sylvaticus Haswell in Sayce, 1909, Proc. Roy. Soc., Victoria, vol. xxii, p. 30, pl. xi (with synonymy).

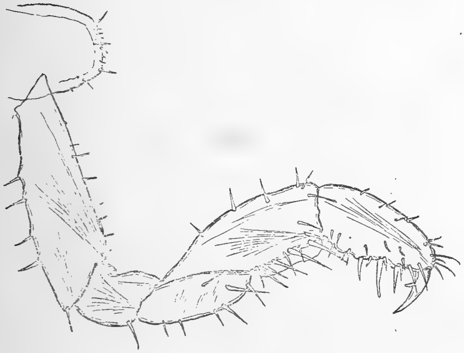

Fig. 1. *Talitrus sylvaticus*, first gnathopod.

Of this species there was only a single representative which was included in the tube containing the *Gammarus barringtonensis*. *Talitrus sylvaticus* is strictly a terrestrial form found under decaying leaves, etc., but may be occasionally taken in damper places, as appears to be the case in this instance. There has been some confusion in connection with the description of the species, and as Dr. Calman[1] has pointed out, it is possible that more than one species has been included under this name by different authors. The species was redescribed by the late Mr. Sayce in 1909, and at the same time was distinguished from a second species, *Talitrus kershawi*, found associated with it at a number of localities in Victoria.

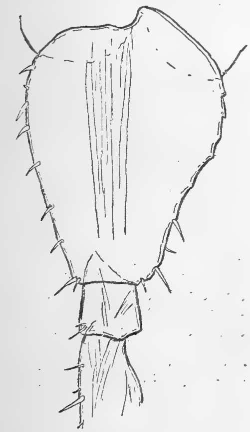

Fig. 2. *Talitrus sylvaticus*, basal portion of third peraeopod.

The single specimen from Barrington Tops agrees very closely with Sayce's description of *T. sylvaticus*,

[1] Calman, *Ann. and Mag. Nat. Hist.*, Ser. 8, vol. 10, p. 135.

Fig. 3. *Talitrus sylvaticus*, maxilliped.

and I have been able to compare it with specimens collected many years ago by the late R. Helms near the top of Mount Kosciusko, and find that it also agrees precisely with these specimens. The general external appearance of these terrestrial Amphipoda is very much the same in species found in widely separated lands, and it is not always easy to get definite points of distinction that can be readily examined. Sayce has pointed out that the species in question is a genuine species of *Talitrus*, since the gnathopoda of the males and females are almost identical in structure; it is thus clearly marked off from species of *Parorchestia*, in which the males have the second gnathopoda developed into powerful subchelate organs. In species of *Parorchestia*, however, the males are often very rare, and the same thing may be the case with *Talitrus*, so that it is not always easy to apply this sexual difference. In the present case, fortunately, *Talitrus sylvaticus* can apparently be pretty readily recognised by the three following points:—

(1) *The first gnathopod.*—In this, the side-plate distinctly narrows distally, the carpus expands distally, is much longer than the propod, and has on the under or posterior side, a small sub-pellucid area marked off from the rest of the joint by a fairly regular row of spinules; the propod narrows towards the dactyl, there is no appreciable palm, but the posterior margin is armed with spines of varying sizes, (see fig. 1).

(2) *The third peraeopod* has the basal joint distinctly narrowing distally, the posterior margin being irregularly serrate and provided with a few spinules chiefly on the lower part, (see fig. 2).

(3) In *the maxillipeds* there are also distinctive features, the chief of which is that the outer lobe narrows towards the apex, so that this is distinctly subacute. It is tipped with a few fine setae, and the inner margin bears a few stouter setae somewhat widely separated, (see fig. 3). In *T. kershawi*, the outer lobe has the apex "rather broader, distinctly indented, and clothed with two tufts of setae, separated by the indentation."[1] In *Parorchestia sylvicola* Dana, the terrestrial land-hopper common throughout New Zealand, the maxillipeds are considerably different, and, in particular, have the outer lobe well rounded and fringed with numerous spinules.

Talitrus sylvaticus appears to be very common in Tasmania, and is also found along the coastal and mountainous regions of Victoria and New South Wales. Sayce records that it is very common throughout Victoria at all elevations, and that he has taken it under dead sea-weed just above tide-level at several places along the coast. The other species, *T. kershawi*, was found by Sayce at a considerable number of localities in Victoria, but has not yet been observed elsewhere. No species of *Talitrus* has, as yet, been recorded from New Zealand, where the genus appears to be represented by the common and widely distributed land-hopper, *Parorchestia sylvicola* Dana. At the Seychelles and Madagascar, however, there is a closely allied species, *Talitrus alluaudi* Chevreux, which appears to be closely related to *T. sylvaticus;* it has also been recorded from hothouses in France, to which it had doubtless been accidentally conveyed from its original habitat. In 1912, Dr. Calman[2] described another terrestrial species, *T. hortulanus* from specimens obtained in the gardens of Kew; it appears to be pretty close to the three species already mentioned,

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[1] Sayce, 1909, p. 33

[2] Calman, *Ann. and Mag. Nat, Hist.*, Ser. 8, vol. 1), p. 132.

but may be distinguished by the points given by Calman. In it the outer lobe of the maxilliped is broadly rounded.

Calman[1] has pointed out that there is some discrepancy in the published accounts of the pleopoda of *T. sylvaticus*. G. M. Thomson and Sayce state that they are unable to find the third pair, while Chevreux, who examined specimens from Mount Kosciusko sent to him by myself, states that it resembles the first two pairs in being biramous, although of smaller size, and this is confirmed by Calman by the examination of two specimens received from the Australian Museum. I have not been able to examine the pleopoda in the single specimen from Barrington Tops. It would not be surprising if there are considerable individual differences in the development of these pleopoda, since they are to be looked upon as functionless vestigial organs in a species that is characteristically terrestrial.

GAMMARUS BARRINGTONENSIS, sp. nov. (figs. 4 to 12).

In the collection were a few specimens of varying sizes of a Gammarid which it is not easy to identify with any of the somewhat numerous species of this group already described from Australia. In general appearance, in the structure of the antennae, gnathopods, peraeopods and telson, it presents very considerable resemblances to *Gammarus australis* Sayce,[2] found in different localities in Victoria, though the long setae on the appendages appear to be much less numerous. It is, however, clearly marked off from this species and from the allied species, *Gammarus haasei* Sayce,[3] also found in Victoria, by the structure of the third uropod which has the inner ramus quite small and vestigial, as in the genera *Niphargus* and *Neoniphargus*. In this character and also in the gnathopods, antennae, etc.,

[1] Calman, *loc. cit.*, p. 135.
[2] Sayce, *Proc. Roy. Soc. Victoria*, vol. 13, (new series) p. 233.
[3] Sayce, *loc. cit.*, vol. 15, p. 53.

the Barrington Tops specimen comes pretty close to *Niphargus mortoni* G. M. Thomson,[1] from Mount Wellington in Tasmania, and I am almost inclined to look upon it as a variety of this species. However, as there are several other nearly allied species, with none of which our specimens exactly agree, it will be safer to describe it in the meantime as a new species. *Niphargus mortoni* was placed under the genus *Niphargus* by Mr. G. M. Thomson with considerable hesitation, for, as he pointed out, it differs from that genus in several points, though Stebbing[2] in 1910, leaves it under this genus. I agree with Mr. Geoffrey W. Smith[3] that this species, as well as the others described by him, are perhaps better placed under the genus *Gammarus*, since, except in the minute inner joint of the uropod, they very closely agree with the species *G. australis* Sayce and *G. haasei* Sayce, which certainly appear to be rightly referred to *Gammarus*.

The species now under consideration, on the whole seems nearest to *G. australis* Sayce, but differs chiefly in being less abundantly supplied with long setae. The following description therefore will be sufficient.

Specific Diagnosis.—Female.—Segments of the urus with a few long setae on the dorsal surface, one or two small ones being also found on the last two segments of the pleon; on the last segment of urus there is a small spine in addition to the long setae. Eyes small, oval. First four sideplates deeper than their segments, nearly twice as deep as broad, the inferior margin with a few short setae widely separated; in the first sideplate these extend along a portion of the anterior margin. Segments of pleon as in *G. australis.* Upper antennae (fig. 4) about half the length of the body;

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[1] Thomson, *Proc. Roy. Soc., Tasmania* for 1892, p. 24 (of separate copy).
[2] Stebbing, *Australian Museum, Mem.* 4, p. 641.
[3] G. W. Smith, *Trans. Linn. Soc., Zool.*, vol. 11, p. 76.

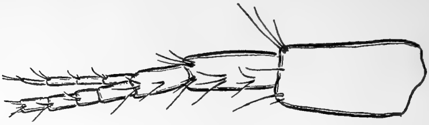

Fig. 4. *Gammarus barringtonensis,* first antenna.

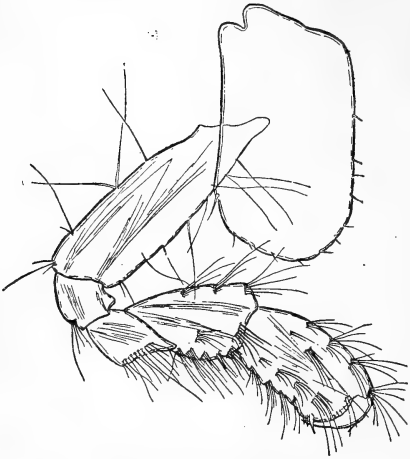

Fig. 5. *Gammarus barringtonensis,* first gnathopod of female.

Fig. 6. *Gammarus barringtonensis,* second gnathopod of female.

the first joint of peduncle stout with a few spinules at distal extremity, second joint much more slender and a little shorter third segment rather more than half as long as the second; secondary flagellum usually with four joints, primary flagellum with about forty. Lower antennae about half as long as the upper; peduncle and flagellum with numerous long setae. Mouth parts the same as in *G. australis.* First gnathopod (fig. 5) with propod about as long as the carpus, both with numerous tufts of long setae; palm slightly oblique, straight, finger narrowing somewhat abruptly about the middle and ending acutely. Second gnathopod (fig. 6) longer and more slender than the first; propod slightly narrower than the carpus, palm rather more oblique than in the

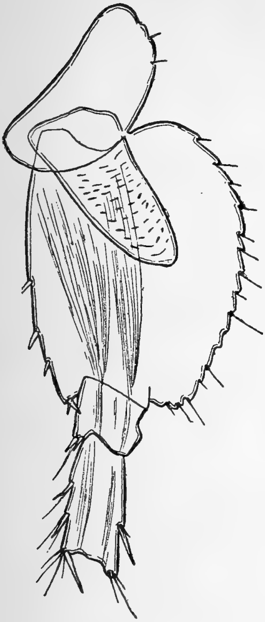

Fig. 7. *Gammarus barringtonensis,* basal portion of fifth peraeopod.

first. Third, fourth and fifth (fig. 7) peraeopoda with the basal joint moderately expanded, posterior margin serrate. Terminal uropoda (fig. 11) projecting beyond the others, basal joint stout and short, with several spines and long setae at the extremity, outer ramus about three times as long as peduncle, with about five groups of spines and slender setae; second joint very short; inner ramus very small, triangular, and bearing one small seta. Telson (fig. 12) cleft to the base, each lobe with extremity rounded and bearing on the outer and posterior margins four or five long slender setae, two or three other setae arising from the upper surface.

The description given above applies to the female. I have only a few specimens and have not been able to work out the sexual differences fully.

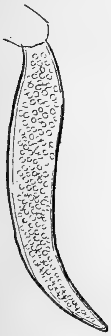

Fig. 8. *Gammarus barringtonensis,* "accessory branchia."

Fig. 9. *Gammarus barringtonensis,* first uropod.

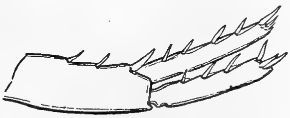

Fig. 10. *Gammarus barringtonensis,* second uropod.

Fig. 11. *Gammarus barringtonensis,* third uropod.

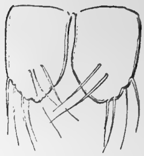

Fig. 12. *Gammarus barringtonensis,* telson.

Colour (in spirit) nearly white.

Length of largest specimen. 11 mm.

Locality, Barrington Tops, 4,600 ft., N.S.W. (*C. Hedley*).

Remarks.—On some of the segments of the peraeon there are finger-like appendages which appear to be of the same nature as the "simple accessory branchiae" described in *Hyalella jelskii* Wrzesn, and *H. dybowskii* Wrzesn. These are present on the last three segments of the peraeon and possibly also on the two segments anterior to these and appear to arise from the sternum of the segment internal to the branchia, but I cannot determine their exact occurrence and attachment without sacrificing too many of the few somewhat imperfect specimens at my disposal. They (fig. 8) are cylindrical, curved, tapering towards the subacute apex and have the interior closely filled with round refractive bodies looking like oil globules. I doubt if they are branchial in function, but, whatever their nature, it is interesting to note that they are found in species of two different genera in localities high above the sea-level, viz. *Gammarus* in Australia at a height of 4,600 feet, and *Hyalella* on the Cordilleras in America, at a height of about 7,000 feet. Appendages, apparently similar, are found in *Waldeckia zschauii* Pfeffer and other Antarctic Amphipoda.[1]

The fresh water Gammarids of Australia and Tasmania described by Thomson, Sayce and G. W. Smith are already

[1] Chilton, Amphipoda of "Scotia" Expedition, *Trans. Roy. Soc., Edinburgh,* vol. 48. p. 472.

fairly numerous, and, just as in Europe and North America, they include surface forms with eyes and blind subterranean forms, both being sometimes found together in surface streams. The difficulty of classifying these forms is already considerable and will probably be greater when other specimens from intermediate localities are examined, though when a sufficient number of these are accurately known, it will doubtless be possible to trace out the lines upon which development has taken place. It seems likely that they have arisen from a form that could be rightly included in the genus *Gammarus*, and that is perhaps still represented by *G. australis* Sayce. From this, there have arisen forms resembling the genus *Niphargus* of Europe, but it is clear that the development of these in Australia has been independent of that in Europe, and that, as G. W. Smith[1] has pointed out, we have here a case of convergence that is well worthy of attentive study. The fresh water Amphipoda of Australia have differentiated into genera and species simulating those of Europe, much in the same way as the marsupial mammals have differentiated into groups parallel to those of the true mammals.

PHREATOICUS SHEPHARDI Sayce (figs. 13 to 17).

Phreatoicus shephardi Sayce, Proc. Roy. Soc. Victoria, vol. 13, p. 26, pl. 3.

Of this species there were numerous specimens in the collection. Mr. Hedley has been kind enough to give me the following particulars as to the locality and circumstances under which they were taken. He says that they came from a height of nearly 5,000 feet, at the source of the river Manning, N.S.W., in South Latitude 32°, much further north, therefore, than previous records of the species. The surroundings were quite subalpine, near by was a *Fagus* forest; indeed, the spot is a subalpine island in a subtropical area. The broad, shallow valleys of the

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[1] G. W. Smith, *loc. cit.*, p. 77.

highest part of the plateau originate in large swamps that are almost peat bogs. Characteristic of such swamps is a large moss forming cushions a yard across, and the *Phreatoicus* lives in this moss. Mr. Hedley says they were quite abundant, three or four being found in each handful of moss, sometimes among the stems, but more often among the muddy roots.

These specimens clearly belong to the species named above, and on the whole agree well with the description given by Sayce, although naturally the numbers of spines found on the different parts of the body and appendages are not always precisely the same as those given in his description, which was drawn up from a single male specimen. The lower antenna (which was lost in Sayce's specimen) is as long as the head and first four segments of the peraeon, and agrees in general structure with that of *P. australis*.

I have numerous female specimens, and am, therefore, able to add the description of the female. Sayce's specimen was a male, but possibly not fully mature. The male specimens have the peraeon more slender than in the female, and somewhat longer in proportion to the pleon. Sayce stated that in *P. shephardi* the pleon is relatively longer than in *P. australis* Chilton; this appears to be true to some extent for the females, but in the males, the proportions of those specimens that I have measured are almost the same as in *P. australis*.

Fig. 13. *Phreatoicus shephardi*, first peraeopod (gnathopod) of male.

Fig. 14. *Phreatoicus shephardi*, fourth peraeopod of male.

The first leg or gnathopod in the fully developed male (fig. 13) has the propod very greatly enlarged, its anterior margin being extremely convex, the palm oblique, nearly straight, and with irregular serrations which are most marked towards the base of the dactyl. The fourth pair of legs (fig. 14) is also modified in the male somewhat in the same way as it is in *P. australis*. The merus, carpus and propod are all short, subequal, the propod has the anterior margin very convex, the posterior is produced at the articulation of the dactyl into a prominent stout tooth, and the rest of this margin forms a short palm defined by three strong spines, against which the strongly curved dactyl closely impinges, the whole constituting a powerful subchelate appendage. The relative proportions of the joints and the setae on them will be readily seen from the figure, and need not be described in detail.

Fig. 15. *Phreatoicus shephardi*, first peraeopod (gnathopod) of female.

In the female the gnathopod (fig. 15) is of the same general shape as in the male, but is much smaller, the propod being only slightly enlarged, the palm straight and without evident serrations. The fourth pair of legs is not specially modified, but is similar to the second which is shown in fig.

Fig. 16. *Phreatoicus shephardi,* second gnathopod of female.

16; the second, third and fourth pairs of legs are subequal, and all somewhat longer and more powerful than the gnathopod; the fifth, sixth and seventh increase regularly in length; the seventh is shown in fig. 17.

Some of the females bear eggs in the brood pouch which is formed of plates corresponding apparently to the first, second, third and fourth appendages of the peraeon; in one specimen examined there were about a dozen eggs.

Fig. 17. *Phreatoicus shephardi,* seventh peraeopod.

This species, as already pointed out by Sayce, is pretty nearly allied to *P. australis*, but differs in the absence of eyes, in the character of the spines on the uropods, and in a few details of the mouth parts. Other species of the genus occur in Australia, Tasmania and New Zealand, and another, *P. capensis* Barnard,[1] has recently been described from Cape Colony, South Africa.

[1] K. H. Barnard, *Annals South African Museum,* vol. 10, p. 231.

CUBARIS HELMSIANUS sp. nov. (figs. 18 to 22).

Specific diagnosis.—Body (fig. 18) oblong oval, fairly convex, the side portions of the segments wide, projecting slightly outwards. Whole surface minutely squamate. Dorsal surface of head uneven, with a slight groove parallel to the hind margin, and the portions between it and the eyes slightly raised. Segments of peraeon usually with indistinct tubercles, about six or seven on each side of median line but sometimes fewer on the posterior segments, median portion of each segment sometimes free from tubercles.

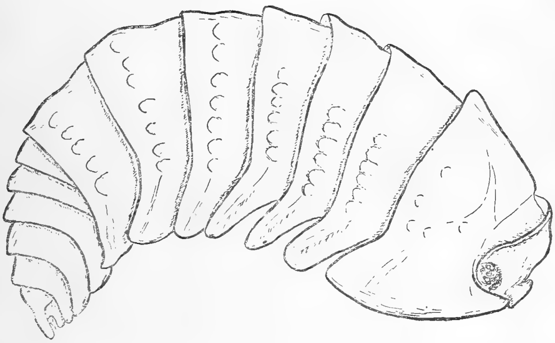

Fig. 18. *Cubaris helmsianus*, side view of animal.

Head (fig. 19) rather more than twice as broad as long. Epistome (fig. 20) with upper margin reaching in advance of the front, and with a deep triangular depression and notch in the middle.

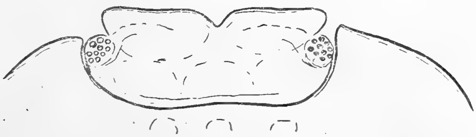

Fig. 19. *Cubaris helmsianus*, head seen from above.

Eyes of moderate size, convex, projecting beyond the lateral margin of the head.

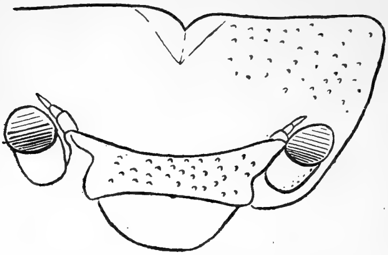

Fig. 20. *Cubaris helmsianus*, ventral view of anterior part of head showing epistome, first antenna and upper lip.

First segment of peraeon longer than the others, its side-plate produced anteriorly beyond the eyes and nearly to the level of the anterior margin of the head, this portion recurved so as to be nearly horizontal, posteriorly it extends in a triangular lobe with rounded apex nearly to the level of the posterior margin of the second segment. Side plates of the first and second segments with margins thin, inner surface with a slight ridge ending in a small tooth. Second, third, and fourth sideplates rather narrow, each with an oblique ridge running downwards and backwards on the outer surface, fifth, sixth and seventh sideplates progressively broader and with the ridge less distinct.

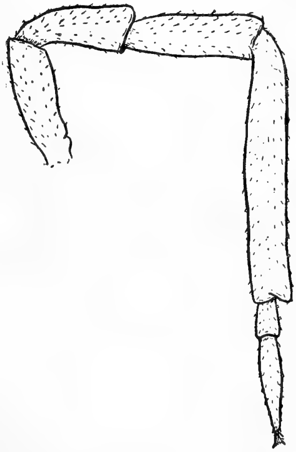

Fig. 21. *Cubaris helmsianus*, second antenna.

Sideplates of the third, fourth, and fifth segments of pleon well developed, broad, rectangular. Terminal segment (fig. 22) longer than broad, constricted near the middle, posterior margin

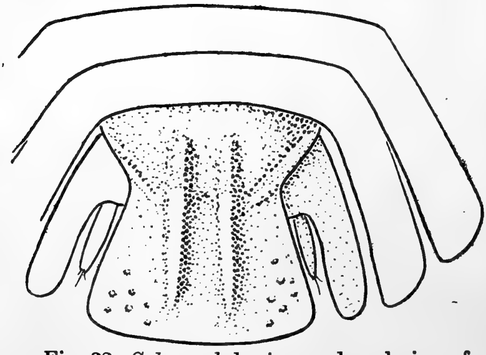

Fig. 22. *Cubarus helmsianus*, dorsal view of posterior portion of pleon and uropoda.

straight or very slightly convex, its upper surface bearing two longitudinal ridges with a shallow between them.

Antenna (fig. 21) with last joint of peduncle longer than the two preceding together, flagellum as long as penultimate joint of peduncle, its first joint about one-third the length of the second.

Peduncle of uropoda much longer than broad, extremity rounded, outer ramus small, not reaching to the end of peduncle, inner ramus reaching nearly to the end of the anal segment.

Length 11 mm. *Breadth* 5·5 mm. *Height* about 2·5 mm.

Colour brown or dark brown, with marblings of a lighter colour.

Localities. Barrington Tops, (4,600 feet), N.S.W. (C. Hedley); Mount Kosciusko, (R. Helms).

This species appears to belong to Section VI in Budde-Lund's Revision[1] of the genus *Cubaris* (which he called *Spherillo*), the type of the section being *Cubaris ambitiosus* (Budde-Lund), a species very common throughout the greater part of New Zealand. It differs from that species, however, in being less convex, and in having the sideplates broader and projecting slightly outwards; this is particularly noticeable in the anterior part of the first side-plate. It is also distinguished from *C. ambitiosus* by the notch in the upper margin of the epistome, and by the two longitudinal ridges on the terminal segments.

The species also appears to be fairly close to *C. cinctutus* (Kinahan), a species which has been recorded from the Loyalty Islands by Stebbing,[2] and from New Caledonia by Budde-Lund. In that species, however, the epistome is produced to a much greater extent in advance of the head,

[1] G. Budde-Lund, Revision Crustacea Isopoda Terrestria, Copenhagen 1904, p. 52.
[2] T. R. R. Stebbing, Willey's Zoological Results, p. 651.

and in place of the triangular notch has a median fissure; on the terminal segment there is a faint longitudinal sulcus or stria, but there are no evident ridges, as in *C. helmsianus.*

From Barrington Tops, I have three specimens, the largest, which has the dimensions given above, is much lighter in colour than the other two, being of a reddish brown, while the others are dark brown or almost black; in all there are marblings of lighter colour. The longitudinal ridges on the terminal segment also seem to vary in development; in the two darker specimens they are evident, particularly in one of them, while in the lighter-coloured specimen a faint longitudinal sulcus can be made out, but hardly any trace of the ridges.

In addition to the Barrington Tops specimens, I have three specimens collected on Mount Kosciusko many years ago by the late Mr. R. Helms, and forwarded to me by the Australian Museum, but hitherto undescribed. These are all rather lighter in colour than the Barrington Tops specimens, but agree in the notch in the epistome, the ridges on the terminal segments, etc. Some of them still bear the antennae which I am therefore able to figure and describe; they have been broken off in all the specimens from Barrington Tops.

In all these specimens the surface of the segments is somewhat uneven, generally forming a transverse row of indistinct tubercles, a little anterior to the posterior margin of the segment. These tubercles vary in number and in prominence; usually there appear to be six or seven on each side of the median line with rather fewer on the posterior segments, and they are sometimes less distinct near the median line. I have one specimen from Grafton, N.S.W., sent me by R. Helms in 1894, which I think belongs to *C. helmsianus*, and in that the tubercles on the segments of the peraeon and the ridges on the terminal segment of the pleon are much more distinctly marked.

THE ANALYSIS OF TOLUENE AND BENZENE IN COAL TAR OILS.

By George Harker, D.Sc.,
Assistant Lecturer and Demonstrator in Organic Chemistry (Pure and Applied) in the University of Sydney.

[*Read before the Royal Society of N. S. Wales, June 7, 1916.*]

At the outset of certain munition work dealing with toluene, which had been undertaken on behalf of the Federal Munitions Committee, it became necessary to find a reliable method for the estimation of toluene and incidentally of benzene in coal tar oil. Reference was made to standard works of analysis, and several papers on the subject which had appeared in recent chemical literature were consulted. It was found that while the methods employed were similar in general principle they differed very considerably in detail. In most cases after a preliminary distillation of the coal tar oil to a temperature of 150° to 170°, followed generally by a purification of the oil so obtained with sulphuric acid and soda, resort is had to a distillation test which varies greatly as given by different authors. In this distillation test, which must be carried out under rigid conditions, the volume of distillate at certain fixed temperatures is noted, and by reference to a table the percentage of toluene is estimated. The range of any of these tables correlating volumes of fractions collected up to and between certain temperatures with benzene and toluene content is more or less limited, *e.g.*, the table may only hold good for samples containing between 50 and 75 per cent. of toluene, in which case other samples must be mixed with benzene, toluene, or xylene before distillation.[1] James on the other hand,[2] employs three preliminary distillations to separate the oil into three fractions, No. 1

[1] H. G. Coldman, *Journ. Soc. Chem. Ind.*, vol. 34, p. 163. [2] *Ib.*, vol. 35, pp. 236 - 240.

below 110·6°, No. 2 from 110·6 to 140°, No. 3 above 140°. A distillation test is then applied to Nos. 1 and 2, and a table for each is provided whereby the percentage of toluene is estimated.

From the divergence of the methods described, and in view of the more or less limited range covered by any of the distillation tables correlating volumes of fractions collected up to and between certain temperatures with benzene and toluene content, it was not considered advisable to proceed with the analysis of any samples of coal tar oil before making a series of blank experiments in which pure benzene and toluene in known quantity could be used. This was done in the first instance, to determine the reliability of the distillation test under observed conditions. As it was found that consistent results could be obtained from two or more distillations of any given mixture of benzene, toluene and xylene, provided the conditions were kept constant, the blank test method, as will be explained later, was used for the final determination of the benzene and toluene content of the coal tar oil samples, it being considered that this method was as quick and reliable as any that could be used. Fortunately for the purpose of the blank tests Kahlbaum's pure chemicals were available. The benzene and toluene boiled constantly at 80·2° C. and 110·5° C. respectively, and a sample of Kahlbaum's xylene (containing evidently the isomers of xylene) which was also used, distilled over between 134° and 139°, but mostly between 136° and 138°.

A Young and Thomas still-head of five sections was employed to assist fractionation, as giving greater definition than an ordinary distillation flask, and the rate of distillation was kept at one drop per second. The same still-head and rate of distillation were maintained throughout the analytical work on all samples and blank tests.

When mixtures of benzene and toluene were distilled, in which benzene was in the proportion of 3 : 1 or 4 : 1 to the toluene, it was found that under the conditions of experiment outlined above, the number of c.c. equal to the volume of benzene present distilled over when the temperature reached 90° C. or thereabout. When the benzene and toluene were in equal proportions, as for example, when distilling a mixture of 50 c.c. benzene and 50 c.c. toluene, the first 50 c.c. came over slightly above 95° C. Additions of xylene meant that the temperature of the mixture had to be raised still higher before the volume of distillate corresponding to the benzene fraction came over. These results were to be expected, and experiments were then made on mixtures of benzene, toluene and xylene in order to obtain some idea of the limits of temperature for the toluene fraction as well as for the benzene fraction with varying mixtures. The tests were useful in giving data for the approximate estimation of the benzene and toluene content of the samples examined later. Thus a mixture containing benzene and toluene in nearly equal proportions (the benzene preponderating), with a small proportion of xylene, had to be distilled to about 95° C. to give the volume of distillate equivalent to the amount of benzene contained in it, while the toluene figure was given by the volume of distillate collected between 95° and about 130° C. This kind of mixture was met with frequently in analysing the coal tar oil samples. The actual content of benzene and toluene present in the samples was obtained by carrying out a blank test after each distillation of the sample oil. In this blank test to the residue left in the flask, quantities of benzene (Kahlbaum's) toluene and xylene were added in accordance with the approximate estimation. The mixture was again distilled, whereby any error in the first estimation was corrected.

An actual analysis of tar oil for benzene and toluene will now be described.

A preliminary distillation of the oil up to 170° C. was first made in an ordinary distillation flask (without still-head) in order, while retaining all benzene and toluene, to separate a great portion of the higher boiling substances. The oil thus obtained was washed with sulphuric acid and caustic soda according to the method of Davis, as given in Lunge and Keane, vol. 2, part ii, p. 767. The washed oil, after standing overnight in order to complete the separation of water, was then distilled under the conditions outlined at the beginning, using the same round-bottomed flask and still-head as for the preliminary tests.

The paraffins present in the sample of coal tar oil were estimated either in the benzene or toluene fractions separately, or in the combined fraction. Generally speaking, the proportion of paraffins in the benzene or toluene fractions was about the same. The estimation was carried out with anhydrous sulphuric acid.[1]

Blank tests were first carried out with pure benzene and toluene, using 10 c.c. of anhydrous sulphuric acid and 5 c.c. hydrocarbon. In both cases the hydrocarbon was rapidly sulphonated and dissolved. The method was then tested on a sample of light ligroin distilled up to 100° C., and on mixtures of this with benzene and toluene, and found to be quite reliable. In carrying out an actual determination after sulphonation in a 100 c.c. cylinder, the liquid was poured into a small measuring cylinder whereby the volume of oil floating on top of the sulphonated liquid could be more accurately estimated.

Estimation of benzene and toluene in samples of coal tar oil, marked I, II and III, from the Sydney Municipal Council (Wattle Street Depôt).

Sp. gr. at 17° C. 0·928, 0·98, 1·012.

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[1] Lunge and Keane, vol. 2, pp. 799, and Allen, 4th Ed. vol. 3, p. 241.

Preliminary distillation of 250 c.c. in an ordinary distillation flask at 170° C.

Distillation Temp.	I. C.C.	II. C.C.	III. C.C.
100°	18	10	5 (including 2·5 c.c. water)
130°	100	17	
150°	135	40	6 (including 3·0 c.c. water)
170°	163	70	10
Left after washing with conc. H_2SO_4 and NaOH	136	53	benzene and toluene present in very small amounts. Not further exam.

The next step consists in the distillation of the washed oil from samples I and II in a round bottomed flask provided with still-head, the distillation being carried out as nearly as possible at the rate of one drop per second. After completing the distillation and measuring the residue, the latter is put back into the distillation flask and the estimated quantities of pure benzene, toluene, and xylene added. The blank test is then performed.

No. I. Sample.

68 c.c. of washed oil.		Blank consisting of 20 c.c. benzene, 22 c.c. toluene, 3 c.c. xylene, and 23 c.c. residue.	Remarks.
73°	first drop	80°	The blank would have been nearer the sample if 20 c.c. toluene and 5 c.c. xylene had been used.
80	1 c.c.		
85	3·5 c.c.	4 c.c.	
90	12	14	
95	18	18	
100	19	20	
105	21	22	
110	23	26	
117	31	36	
130	39	41	
140	44	44	
Residue	24		
	68 c.c.		

In distilling the sample oil, the residue is always measured in order to provide a check against possible losses in distillation. It sometimes occurs that the distillation loss exceeds 2 or 3 c.c., in this case the distillation must be repeated.

A comparison of the distillation figures for the sample and blank leads to the conclusion that 19 c.c. of benzene and 20 c.c. of toluene were present in the 68 c.c. washed oil, or 15·2 per cent. of benzene and 16·0 per cent. of toluene in the original No. I oil. The paraffins etc., contained in the benzene and toluene were estimated by sulphonating 5 c.c. of the mixed benzene and toluene distillate; 0·2 c.c. of oil was left equivalent to 4 per cent. of paraffins. This proportion of impurities of uncertain boiling point is too small to effect to any extent the comparison of the distillation figures of the sample and blank.

No. II. Sample.

53 c.c. of washed oil.		Blank consisting of 3 c.c. benzene, 12 c.c. toluene, 8 c.c. xylene, and 30 c.c. residue.	Remarks.
71° first drop		87° first drop	Proportions for blank test badly estimated owing to large ratio of higher boiling constituents to the lower boiling.
80	0·5 c.c.		
85	1·0		
90	2·0		
95	3·0	2·0 c.c.	
100			
105	5·0	3·0	
110	6·0	3·5	
117	11·0	5·5	
130	18·0	11·0	
140	23·0	16·0	
Residue	30·0		

It is clear that the benzene in the sample must have been between 4 and 4·5 c.c., and since 15 c.c. (equal to volume of the 3 c.c. benzene and 12 c.c. toluene added) were distilled over from the blank between 130° and 140°, it is estimated that 17 c.c. of toluene were present in the sample, *i.e.*, 21 c.c. of benzene and toluene together. This gives 1·6 per cent. benzene and 6·8 per cent. toluene in oil No. II. It is quite exceptional for the first approximation to differ so much from the true content as shewn by the blank test, and in order to confirm the figures a second blank test should have been performed. The paraffins were present to the extent of 4 per cent.

NOTES ON AUSTRALIAN FUNGI, No. III.

NIDULARIACEÆ AND LYCOPERDACEÆ.

BY

J. BURTON CLELAND, M.D.,

Principal Microbiologist, Department of Public Health,

AND

EDWIN CHEEL,

Botanical Assistant, Botanic Gardens, Sydney.

[*Read before the Royal Society of N. S. Wales, June 7, 1916.*]

THROUGH the works of C. G. Lloyd of Cincinnati on the Nidulariaceæ and the Australian Lycoperdaceæ, and through his kindness in identifying specimens for us, we have been able to review the specimens belonging to these two families in our own collections and in that of the National Herbarium, Sydney. The following paper is the outcome of our labours in this connection. Of the 121 species of Australian Lycoperdaceæ recorded by Cooke, 22 were Geasters. The remaining 99 species can now be reduced to 75 with 4 varieties.

NIDULARIACEÆ.

CYATHUS (Bird's-nest Fungus).

(1.) *C. stercoreus*, Detoni, Cheel, Report of the Botanic Gardens, Sydney, 1911 (1912), 12. Syn. *C. fimetarius*, Cooke, Handb. Aust. Fungi, No. 1213; Grant, Rep. Bot. Gard. Sydney, 1901 (1902), 10; Cheel, Proc. Linn. Soc. N.S.W., xxxii (1907), 204.

Specimens of this species have been identified by Lloyd (Nidulariaceæ, 1906, 20, and Letter No. 19, 1908), who includes as synonyms *C. Baileyi*, Mass., Grev., Vol. 23, (1892), 3, and in Bailey's Bot. Bull. No. viii (1893), 109. We have also specimens in the National Herbarium, Sydney, labelled *C. plumbagineus*, McAlp., which clearly belong to this species.

This species is very common on cow-dung and horse-dung in meadow land and on manure in plantations throughout the State, a very fine series of specimens being represented in our collections and in the National Herbarium from the following localities:—Sydney district, numerous collections (Jan., Feb., March, June, August, Nov.); Hawkesbury River (J. B. Cleland, Feb., 1911); Meryula, 25 miles east of Cobar and Mount Boppy, near Cobar (L. Abrahams); Hill Top (E. Cheel, May, 1913); Cobbity (J. H. Maiden, November, 1914); Seaham (S. A. Hanscombe, July, 1915).

The spores in Milson Island specimens, which were kindly identified for us by Lloyd, were pear-shaped ($35 \times 20{\cdot}5\mu$), oval ($26 \times 22{\cdot}5\mu$), or spherical (27 to 30μ) and in Penshurst specimens oval ($29 \times 23\mu$).

Some specimens from Barber's Creek, collected by J. H. Maiden, and from Delegate, collected by W. Forsyth, appear to belong to this species, but in both collections the peridioles are absent.

(2.) *C. vernicosus*, Tul.

This species has previously been recorded for Queensland, Victoria and Western Australia by Cooke (Handb., p. 218) and for Australia by Lloyd (Nidulariaceæ, 1906, p. 24).

At Goulburn, N.S.W. some specimens were collected by E. J. Rutherford, in July, 1911, and recorded by one of us (E. C., Rep. Bot. Gard., Sydney, 1911 (1912), 12), and we have also some specimens collected by the other of us (J.B.C.) near Adelaide, S.A., (spores 12 × 8·5μ) and at Bibbenluke, N.S.W., in March, 1913, attached to stems of grass (mouldy smell on crushing; spores 12 to 13·8 × 8·5μ).

(3.) *C. striatus*, (Huds.) Hoffm., Cheel, Rep. Bot. Gard., Sydney, 1912 (1913).

Jellore Creek, near Mount Jellore (E. Cheel, 1912).

Crucibulum.

(4.) *C. vulgare*, Tul.

Specimens of this species were collected on the ground near dung at Orange by one of us (J. B. C.) in November, 1915, and have been identified for us by Lloyd, who adds that there is only one species of *Crucibulum* (Cooke gives *C. vulgare* and *C. simile* for Australia). Spores of these specimens are 8·5 to 10·4 × 3·4 to 4·8μ. We have also specimens of this species collected at Ohakune, New Zealand, in March, 1909, by one of us (E.C.), which are on dead wood.

LYCOPERDACEÆ.

Tribe Podaxineæ.

Podaxon.

(1.) *P. ægyptiacus*, Mont. Syn. *Podaxis indica*, L., in Cooke's Handb. Aust. Fungi, p. 223.

Previous records are:—Near Bourke by Baker (Proc. Linn. Soc. N.S.W., Vol. xxxi, (1906), 721), from Wittagoona, near Cobar, and Girilambone by one of us (E.C.) in Rep.

Bot. Gard., Sydney, 1910 (1911), 11. We have also additional specimens to record from Nyngan, collected by E. Mackinnon in February, 1911, and E. Breakwell, in May, 1914. It is recorded for Australia by Lloyd (Lycoperdaceæ (1905), 5, pl. 25, figs. 1, 2 and 3), who says that "at Kew, England, there is a poor specimen from Suttor River, on which the record of *P. indica*, Spreng. in Cooke's Handbook is based." The spores in our specimens are sub-globose, 12 × 9μ.

Tribe Tylostomeæ.

TYLOSTOMA.

(2.) *T. McAlpinianum*, Lloyd, Tylostomeæ, p. 15, (1906), pl. 78, and Letter No. 31.

Specimens collected in Meadow-land at Penshurst in June, 1907, were recorded by one of us (E.C.) in Proc. Linn. Soc. N.S.W., xxxii, (1907), 840, under the name *T. mammosum*, Fr. Duplicates were sent to Mr. Lloyd who has determined them as the above. Specimens collected at Reynella near Adelaide in July, 1914 (J.B.C.), have been identified by Lloyd also as this species. Spores of this latter collection are pale yellow, finely warted, 5·2 to 5·5μ in size. Another collection made at Dubbo, N.S.W., in July, 1915, has likewise been identified by Lloyd as *T. McAlpinianum*. In these specimens, however, there is a thick, warty yellow-brown epispore which is elliptical (12 × 10·4μ) or spherical (10·4 to 12μ) surrounding a spherical spore of 7 to 8·5μ in size. The capillitium is hyaline, 2·5μ thick. In addition to the above we have other specimens which appear to belong to this species from the following localities:—Goulburn (E. Cheel, April, 1908); South Head near Sydney (W. Craigie, August); Botanic Gardens, under pine-tree (E. Cheel, June); Nyngan (E. Mackinnon, August 1913).

(3.) *T. albicans.*

A *Tylostoma* with a very marked tubular mouth obtained near Morgan, S.A., in November, differs apparently from our specimens of *T. McAlpinianum* identified by Lloyd, and is, we think, this species which Lloyd records for Australia (S.A.). The tubular mouth is longer than the latter species —spores tuberculosely warty, 6 to 8·5μ.

(4.) *T. poculatum.*

Lloyd has identified as *T. poculatum* specimens collected on a sandy hillock near Forbes in August, 1915. The spores were flatly verrucose or almost polyhedral, yellow-brown, 7 to (occasionally) 8·5 × 5·2μ. (Lloyd's measurements of them were 5 to 6μ). Another single specimen, collected at the same place, and probably the same species though the mouth is less fibrillose, has rough spores 5 × 3·4μ.

CHLAMYDOPUS.

(5.) *C. Meyenianus*, Berk. (*Tylostoma maxima*, Cooke and Massee).

In the National Herbarium there are specimens of this species collected at Wittagoona near Cobar by Mr. L. Abrahams in September, 1910. Mr. Abrahams states that the specimens were found on "wind swept surface of hard clay."

The specimens collected by Mr. Abrahams are of special interest as previous to this collection, the only solitary specimen in existence from Australia was at Kew, England. It was originally collected on the Gascoyne River, W.A., by Mrs. Gribble, and according to Lloyd[1] there is "but one species known, originally from Peru, but found also in Western United States." Our specimens may be briefly described as follows :—Volva about 3 cm. long, with rather

[1] Mycol. Notes, p. 134, pl. 10, and Lycoperdaceæ of Australia, etc., p. 9 (1905).

laciniate lobes. Stipe 7 cm. long, 13 mm. thick, tapering downwards to 7 mm. Peridium 3 cm. in diameter, breaking up at the apex when mature irregularly, in similar manner to the Calvatias. Spores minutely warted, 7μ diam.

PHELLORINA.

(6.) *P. Delastrei.*

A specimen collected in December, 1913, by one of us (J.B.C.) either at Alawoona in the Murray Desert or at Overland Corner on the Murray River, both in South Australia, has been identified as this species by Lloyd. We have also two fine specimens collected at Nyngan, in red soil scrub-lands on Miowera Station, by Mr. W. W. Froggatt, in November, 1911, which seem to us to belong to this species.

Only one Australian specimen of this species was previously known, which according to Lloyd (Lycoperdaceæ, p. 10, 1905) is at Kew and was collected at Stewart's Range, Central Australia, by Charles Winnecke. Our Nyngan specimens may be described briefly as follows:—Peridium 4 – 5 cm. across, breaking up into scales and exposing the rusty coloured gleba and spores, the base forming a shallow socket. Stem solid, woody, more or less broken up into scales or shreds, up to 22 cm. long, 2 cm. thick at the base, gradually increasing in thickness up to 3½ cm. in the upper part. Volva incomplete, but the remnants are about 2 cm. long. Spores granular, 6μ diameter.

BATTARREA.

Four "species" of this genus are recorded for Australia by Cooke (Nos. 1242 – 1245), none of which are given for New South Wales. *B. Muelleri*, Kalchb. and *B. Tepperiana*, Ludw. are both referred by Lloyd[1] as forms of *B. phalloides*.

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[1] Lycoperdaceæ of Australia, p. 11, (1905).

(7.) *B. phalloides*, Dicks. (pl. 28, Lloyd) and *B. phalloides* var. *Stevenii.*

Lloyd, in his "Lycoperdaceæ of Australia," etc., points out that *B. Stevenii*, which has been recorded from Australia, is unquestionably only a form of *B. phalloides*, showing a more robust growth and thick lacerated scales on the stipe. This view is supported by our finding, growing together in the same locality (Alawoona, S.A., December, 1913) what appear to be the two forms. The smaller, more slender form, with a stem tapering downwards and covered with longer slender fibrillose scales, Lloyd identified as *B. phalloides*. The spores were smooth, 5·2 to 6·8μ in diameter. The characteristic "annulate cells" were 5·2μ in thickness. The more robust form, with heads nearly two inches in diameter, had much broader lacerated scales. The spherical spores of these plants were 2·5 to 5·5μ in size, minutely rough (oil immersion lens). One "plant" has two volvas and stems inserted into what appears to be one cap, though a slight line of demarcation seems to indicate the union of the original two caps, with nevertheless an apparently single circumscissile top. The following notes were made in the field and refer particularly to the latter form:—"Volva sometimes on the surface of the ground, sometimes buried several inches, 1½ in. in diameter, greyish-brown. Stem 4½ ins. high, elongating to 9 ins., yellowish-brown, fibrously scaly, the scales imbricated downwards, solid, white internally. Cap convex, 2 to 2½ ins. in diameter, 1 in. high, cover double, the inner one soft and white, on the outside adherent greyish-brown remains of the volva. The cover on falling off leaves a thick mass (half inch deep) of cinnamon-coloured spores supported on a thin smooth convex white stratum, seen in the fresh state as a smooth white under surface."

We have also specimens of this species in our collections from Gular near Coonamble (J. B. Cleland, November, 1911) which are perfect, not having shed their spores. The whole plant is pallid-white before the shedding of the spores takes place.

Previous records are Murchison River and Lake Albacutya (Cooke); Tumby Bay on the west coast of Spencer's Gulf, South Australia, Lloyd ("Two Rare Plants from Australia") and Port Lincoln, S.A., Lloyd (18). There are also according to Lloyd (Lycoperdaceæ p. 11, 1905), specimens at Kew, England, from Israelite Bay, W.A. F. M. Bailey records specimens from Gladfield, Queensland. *B. Stevenii* is recorded by Cooke for Western Australia, and Froggatt collected specimens in N. S. Wales (Lloyd, Letter No. 53, p. 4). Duplicates of the latter, from Brewarrina, September, 1911, are in the National Herbarium collection.

Two remnants of a *Battarrea* are recorded for Victoria by Lloyd (Mycol. Notes, No. 21, p. 245, 1906).

POLYSACCUM (PISOLITHUS).

Lloyd considers that the Australian forms are but varieties of one species, *P. pisocarpium*, though it is convenient to designate three extreme departures from the more typical forms as *crassipes*, *tuberosum* and *confusum*.

Intermediate forms connect these extremes with each other. Cooke's nine species are thus reduced to one with three varieties. We have met with the following :—

(8) *P. pisocarpium*, Fr., Cooke's Handb., p. 243; Baker, Proc. Linn. Soc. N.S.W., xxxi, p. 720 (1906); Cheel in Rep. Bot. Gard., Sydney, 1909 (1910), 10, and 1910 (1911), 12.

We have specimens approaching the typical form, being sub-globose with a short rooting stem, from the following localities :—Governor's Domain, Sydney (E. Cheel, May, 1907, spores granulated 8 to 12μ); Centennial Park (A. A. Hamilton, February, 1911); Gladesville (M. Flockton, February, 1911); Neutral Bay, Sydney (J. B. Cleland, June, 1913, spores 8·5 to 10·3μ); Kurrajong Heights (J. B. Cleland, August, 1912, spores warty, 7 to 8·5μ); Flinders Island, Bass Straits (J. B. Cleland, November, 1912, in sandy soil, spores finely warty, 5 to 6·5μ, perhaps var. *confusum*); Mount Lofty, S.A. (J. B. Cleland, July, 1914, spores tuberculate, 10·4 to 12μ); Overland Corner, S.A. (J. B. Cleland, November, 1913, spores very rough, 8·5μ); Western Australia (Dr. F. Tidswell, June, 1909); Strelley River, N.W. of W.A. (J. B. Cleland, approaching var. *crassipes*.)

P. pisocarpium var. *crassipes*.

Peridium tapering into a strong thick rooting base.

Specimens of this form have already been recorded from New South Wales (collected by A. G. Hamilton and J. L. Boorman) by Lloyd in Letters No. 8 (1905), 17 (1907), and 23 (1908). In addition to the above we have a very fine series of specimens as follows:—Sydney district, numerous collections (Jan., April to August, Oct.. Dec.); Kingwell, near Gosford (Rev. W. W. Watts, May, 1909); Jellore Creek (E. Cheel, April, 1912); Hill Top (E. Cheel, April, 1913); Bent's Basin (J. H. Maiden, June, 1915); Lawson (D. Wiles, June, 1910); Weston (V. Davis); Mount Lofty, S.A. (J.B.C., May, 1910).

P. pisocarpium var. *tuberosum*.

Globose with scarcely any stem.

(A. G. Hamilton, Lloyd's Letter No. 17, p. 3, 1907). We have a specimen from New South Wales, spores rough, 7 to 8·5μ).

P. pisocarpium var. *confusum*.

A form almost smooth, with very thin walls to the peridioles, and small spores.

North Shore, Sydney, April, 1914 (spores smooth or perhaps slightly rough, 5·2μ); New South Wales (spores very finely rough under oil-immersion lens, 5·2 to 7μ). We have also specimens from East Hills (E. C., September, 1908) and Richmond (J. Staer, May, 1910), which are globose and stemless, smooth and pallid or whitish, which probably are identical with *P. album* (Cooke and Massee, Grev. xx, p. 30 and Cooke, Handb. Aust. Fungi, p. 245), specimens of which we have not seen.

SCLERODERMA.

Lloyd recognises six species of this genus, transferring one of Cooke's eight species, *S. umbrina*, to *Polysaccum* as being really *P. pisocarpium.*

(9.) *S. geaster*, Fries.

Lloyd has identified as an unopened specimen of this species, a plant found at the base of an old tree-trunk on burnt ground at Narrabeen in April, 1915, spores 7 to 8·5μ, shaggy. We have also specimens from Goulburn collected by one of us (E.C.) in April, 1908, and from the Centennial Park, Sydney, collected by A. A. Hamilton in May, 1910, which seem to belong to this species.

(10.) *S. flavidum*, Ellis. Lloyd, Letters Nos. 5, 7, 19 and 38; Lycoperdaceæ of Australia, New Zealand etc. (1905), p. 14, pl. 30, figs. 4, 5, and 6; Cheel, Rep. Bot. Gard., Sydney, 1909 (1910), 10, and 1910 (1911), 12.

This is very common in this State as well as in Victoria and South Australia. We have a very fine series of specimens in all stages of development from the following localities :—Sydney district, numerous collections (April to July); Sydney (J. B. C., spores 7·5 to 10·4 in some collections and 10·5 to 15μ in others); Jenolan Caves (J. H. Maiden, June, 1899); Blackheath and Mount Victoria (J. H. Maiden, April, 1906); Waterfall (A. A. Hamilton, May, 1908); Kingwell, near Wyong (Rev. W. W. Watts, April, 1909); Hawkesbury River (J. B. C., May, 1910, and July, 1912); Moss Vale (E. C., April, 1910); Hill Top (E. C., March, 1911, specimens very strobilate); The Oaks (J.B.C., June, spores 7·5 to 10·4μ, shaggy); Leura (T. Steel, February 1911); Lake Illawarra (E.C., April, 1912); Cronulla (E. Breakwell, May); Jellore Creek, foot of Mount Jellore (E. C., April); Terrigal (J.B.C., June, spores 7·5 to 10·4μ, shaggy); Austinmer (W. M. Carne, April, 1914); Mount Wilson (A. G. Hamilton, April, 1912); Mount Lofty, S.A. (J. B. C., May, 1910 and June, 1914), one of these plants had burst into four lobes, spores dark purple, densely echinulate, 10·4 to 12μ; Mount Lofty, S.A. (J.B.C., spores 10·4 to 15μ); Murray River, S.A. (J.B.C., spores 10·4 to 15μ); Western Australia (Dr. F. Tidswell, June, 1909).

(11.) *S. cepa*, Persoon.

This species has been collected by Messrs. W. W. Froggatt, A. G. Hamilton, R. T. Baker and Miss M. Flockton, and recorded for this State by Lloyd in Letters Nos. 8 (1905) 17 (1907) and 23 (1908), and Lycoperdaceæ (1905), p. 14. The specimens collected by Mr. Baker are figured on Lloyd's plate 31, fig. 1, with a suggestion that they may be unexpanded specimens of *S. flavidum*. We have also specimens collected in the Botanic Gardens, Sydney (E. C., March, 1908); Kingwell near Wyong (Rev. W. W. Watts, May, 1909); Lilyvale (A. A. Hamilton, April, 1912); Taronga Park, Mosman (L. Abrahams, May, 1913); Neutral Bay (J. B. C., July, 1915); Mount Irvine (J. B. C., June, 1915). The spores of the latter specimens are 8·5μ in size, very rough.

(12.) *S. vulgare*, Fr. (*S. aurantium*, Pers.)

We have specimens collected in the Botanic Gardens by Mr. M. McGovern in May, 1899, and by E. C. in February, 1907 and March, 1908, which we refer to this species. The specimens are rarely found fully developed owing to being crushed under foot by the traffic on the lawns.

It has previously been recorded for this State under the name *S. aurantiacum*, Bull., by Mr. R. T. Baker, in Proc. Linn. Soc. N.S.W., xxxi, (1906), 720.

(13.) *S. vertucosum.*

This species is also common in the Sydney district. The spores are shaggy, 8·5 to 11·5μ. We have the following collections:—Sydney (J. B. C.); Hawkesbury River (J.B.C., June); Bulli Pass (J. B. C., April); Mount Lofty, S.A. (J. B. C., July).

GEASTER.

The Geasters have been dealt with in No. II of this series of papers.[1]

MYCENASTRUM.

(14.) *M. corium* (Guersent), Desv. Syn. *M. olivaceum; M. phœotrichum.*

Lloyd points out (Lycoperdaceæ, p. 24) that the two synonyms above, given to Australian specimens, are based on the colour of the gleba which depends on the stage at which the plant is collected. In Cooke's Handbook, p. 241, it is recorded for Victoria and Queensland only, but one of us (E.C.) has recorded it for this State in Rep. Bot. Gard. Syd., 1908 (1909), 12, and 1909 (1910), 10. Specimens have also been identified by Lloyd in Letters No. 17, p. 2, and No. 31, p. 1, as this species, from specimens collected in this State by one of us (E.C.) and by Mr. W. W. Froggatt.

We have also additional specimens from the following localities:—Sydney district, several collections (Jan. and May); Goulburn (E. Cheel, April, 1908); Susan Island, Clarence River (T. McDonough, June, 1909); Wollongong (A. A. Hamilton, October, 1909); Wittagoona near Cobar (L. Abrahams, September, 1910, spores globose, warty, 8–11μ diam., capillitium 5–10μ thick, spiny at the tips);

[1] This Journal, Vol. XLIX, p. 199, 1915.

Hawkesbury River (J.B.C., June, 1912, spores rough, 10·3μ, capillitium thorny, 8·3μ in diameter); Bibbenluke (J. B. C., March, 1913, spores rough, 10·3μ, capillitium thorny, 8·5 to 12μ in diameter); Wagga, July, 1914, spores rough, 10·4μ); near Adelaide, S.A. (J.B.C., 1898).

Catastoma.

(15.) *C. anomalum*, Lloyd, Lycoperdaceæ, p. 27, 1905; Cheel, Rep. Bot. Gard., Syd., 1908 (1909), 13. *Bovista anomala*, Cooke and Massee, Grev. xviii, p. 6 (1889); Cooke's Handb., p. 234.

We have collected a number of perfect specimens of this species characterised by its protruding mouth, from various localities in the Port Jackson district and from Milson Island, Hawkesbury River (July). Mr. C. G. Lloyd (Letter No. 31, 1911) has kindly confirmed the identification.

The plants grow with their mouths upwards; spores spherical, warty, 5·2μ in diameter, capillitium threads 3μ in diameter. Specimens, also identified by Lloyd, found at Forbes in August, show protruding mouths when young, but these are less evident when old; spores bright yellow-brown, tuberculosely warty, 5·2 to 6μ, capillitium threads yellow-brown, branched, 3·5μ in diameter.

(16.) *C. abnormalis?*

Specimens collected in New South Wales by A. Green have been doubtfully referred to this species by Lloyd in Letter No. 19 (1908).

Bovistella.

Lloyd places Lycoperdons with pedicellate spores in the genus *Bovistella*. He records seven species for Australia. We have met with the following:—

(17.) *B. aspera*, Lloyd, Letter No. 8 (1915), Lycoperdaceæ, p. 28 (1905) and (Mycol. Notes, No. 21, p. 247, 1906); Cheel, Proc. Linn. Soc. N.S.W., xxxix, p. 255 (1914).

The specimens recorded by Lloyd *(l.c.)* were collected in the Sydney district by the Rev. W. W. Watts. We have also specimens of this species collected at Como in February and Dubbo in August, 1908; Penshurst in May 1907 and February, 1911; Milson Island, Hawkesbury River, on cow-dung (spores smooth, 4·2 to 5μ, pedicels 14μ); N.S.W. (spores usually spherical, 5·5μ, sometimes oval, 8·9 $\times$ 7μ). According to Lloyd there are specimens of this species at Kew, collected by Mueller at Haidinger Range in 1861.

The plant was originally described from Chile *(Bovista aspera*, Ann. Sci. Nat. 3-5-162). Lloyd further states that comparison of the specimens received from W. W. Watts with the types from Chile in the Museum at Paris shews some slight differences. The cortex of the Australian plant is not so strongly developed. The colour of the gleba is olive, while in the type it is brown. The pedicels of the spores of the Australian plant are longer.

(18.) *B. scabra*, Lloyd, Mycol. Notes No. 21, p. 248 (1906) and Letter No. 31 (1911).

Specimens of this species were collected at Penshurst (spores 5μ, pedicels 4 – 7μ), by one of us (E.C.), in March 1909, and were kindly identified by Lloyd as this species, who states that the plant has the general size, appearance and structure of *B. australiana*, and differs only in its cortex. It has also been recorded for Casterton, Victoria, and Norwood, South Australia, by Lloyd in Letter No. 8 (1905), and from other parts of Australia without specifying the particular State (but probably Victoria) in Letters No. 13 (1906) and No. 17.

(19.) *B. australiana*, Lloyd, Lycoperdaceæ, p. 28, (1905), Mycol. Notes, No. 21, p. 247 (1906), Plate 33, f. 1 – 5) and Letters No. 23, p. 3 (1908), and No. 38, p. 4 (1911).

The specimens recorded by Lloyd *(l.c.)* from Australia were collected by Mr. A. G. Hamilton, and Miss M. Flockton. See also Letters No. 8 (1905), and No. 17 (1907) for other Australian records. We have the following specimens: Manly, April, 1915 (identified by Lloyd—covered with minute mealy warts, well-marked sterile base, black branching roots, spores smooth 5·2 × 4·4μ, with pedicels 8·5μ long which are very hard to differentiate in a watery medium); Sydney, January, 1915 (spores 5μ, pedicels 8·5μ ; locality not noted (spores 3·4 to 4μ, pedicels 5 to 12μ); Sydney, April (spores yellow-brown, spherical, 4μ, pedicels 8·5μ); Mosman (spores 3·4μ, pedicels up to 17μ); Milson Island, November (spores 3·4 to 4μ, smooth, pedicels 7μ).

(20.) *B. Gunnii*, Lloyd, Letter No. 8 (1905), Lycoperdaceæ, p. 29 (1905), and Mycol. Notes, No. 21, p. 247, (1906), pl. 70. Syn. *Lycoperdon Gunnii*, Berk., Hooker's Fl. Tasm. ii, p. 264.

Grange near Adelaide, July, 1914 (spores yellow-brown, tuberculate, 5μ in size, pedicels up to 14μ—specimens identified by Lloyd who says:—"I call the spores 'smooth' although they are slightly rough under a high power. All *Lycoperdon* spores are 'rough,' but we call those smooth that are not strongly rough under a ¼ in. objective"); New South Wales specimens have spores 4·2 to 5μ, pedicels up to 10μ in length (Milson Island, November, and other localities).

(21.) *B. bovistoides*, Lloyd, Mycol. Notes, No. 21, p. 247 (1906), and Letters No. 8 (1905), No. 13 (1908), No. 38 (1911). Syn. *Mycenastrum bovistoides*, . . . *Grevillea*, Vol. 16, p. 26.

Specimens from Australia collected by Mr. A. G. Hamilton (probably in N.S.W.) have been identified by Lloyd.

(22.) *B. rosea*, Lloyd, Mycol. Notes, No. 21, p. 248 (1906) and Letter No. 23 (1908).

Specimens of this species have been collected by Miss M. Flockton and identified by Lloyd.

(23.) *B. glabrescens*, Lloyd, Lycoperdaceæ, p. 28 (1905). Syn. *Lycoperdon glabrescens*, Berk., Fl. Tasm., ii, p. 264.

LYCOPERDON.

(24.) *L. polymorphum*, Vitt., Lloyd, Lycoperdaceæ (1905) 29.

(25.) *L. cepæforme*, Kalchb., Lloyd, Lycoperdaceæ (1905), Mycol. Notes, No. 21 (1906), 246, and Letters No. 8 (1905), No. 13 (1906), No. 17 (1907), No. 23 (1908), No. 35.

Specimens of this species have been forwarded by R. T. Baker, Rev. W. W. Watts, W. W. Froggatt and Miss Flockton, to C. G. Lloyd, and determined by him.

Atypical forms:—Hawkesbury River, November, 1914 (J.B.C.). Of this specimen Lloyd says "I should class this as *cepæforme*, although it has no sterile base, and strictly should be called large *L. pusillum*. This large form devoid of sterile base does not occur in Europe." Our notes of these fresh specimens shew that there was then evident a very slight basal layer and a definite root with branching mycelium. Spores smooth, 4·2 to 5μ, stumps of pedicels. Another collection, described in the same terms by Lloyd, has spores 4·4 to 4·8μ, no pedicels. We have the following additional collections:—Orange, October, spores 3·8 to 4μ; Adelaide, July, spores smooth, 3·5μ.

Lloyd says of specimens with oval, finely warted spores, 5 × 3·7μ in size, collected at Milson Island in June 1912, "has not been separated from *cepæforme*, although the decidedly rough spores, slightly pyriform, and absence of sterile base should separate it. It has no name I believe."

(26.) *L. pusillum*, Fr., Syst. Myc. iii, f. 33; Batsch ? see Kalchb., Grev. iv, 74, 1875; Cooke, Handb., p. 239; Lloyd, Lycoperdaceæ (1905) 30, pl. 65, f. 8, and Letter No. 19 (1908); Wakefield, Kew Bull. (1915), 374.

We have specimens of what appears to belong to this species collected at Penshurst in May, 1907, Dubbo in August, 1908 (spores $4\frac{1}{2}\mu$ with very minute stumps of pedicels present), and Forbes in August, 1915, with well-developed roots (spores smooth or very slightly rough, 5μ, sometimes rather oval, stumps of pedicels $1{\cdot}8\mu$ long). Specimens of this species have been recorded by Lloyd (*l.c.*) collected in Australia by A. G. Hamilton—these were probably collected in New South Wales.

(27.) *L. nigrum*, Lloyd, Lycoperdaceæ (1905) 30.

We have specimens of what appears to be this species collected at Major Bay, Concord—spores 3μ.

(28.) *L. subincarnatum*, Peck. Syn. *L. purpureum*, Lloyd, Letter No. 31 (1911).

Lloyd has kindly identified specimens for us. He says: "This is a peculiar species characterised by the little pits on the peridium like those of a thimble, and its hyaline, septate capillitium. It is rather rare in the United States and (excepting the common *L. pyriforme*) the only puff-ball we have that habitually grows on logs. We collected it in Samoa, and we believe that the scanty material representing *Lycoperdon purpureum* at Kew from Bonin Island is the same plant, but the 'type' is too poor to consider." On decaying logs, Otford (J. L. Boorman, March, 1901); Bulli (E. Cheel, April, 1910); Lilyvale (A. A. Hamilton, June, 1910); Mount Irvine, Blue Mountains, (J. B. Cleland, June, 1915—spores smooth, $3{\cdot}5\mu$).

(29.) *L. pratense*. Lloyd, Lycoperdaceæ (1905) 31, pls. 34 and 71, fig. 1, 2), and Mycol. Notes No. 21 (1906), 249. Syn. *L. furfuraceum*, McAlp. *non* Schaeff., Rep. Dept. of Agriculture, Victoria, May 14th, (1898), and Proc. Linn. Soc. N.S.W., xxv, (1900) 702, pl. xlvii.

There are specimens of this in the National Herbarium from Melbourne, collected by McAlpine in July, 1900. We have also specimens from Flinders Island, Bass Straits, November (spores smooth or under oil-immersion lens slightly rough, 3·5 to 4μ); Adelaide (spores smooth, 3·5μ, small pedicels).

(30.) *L. gemmatum*, Batch, Lloyd, Lycoperdaceæ (1905) 32, and Mycol. Notes, No. 21 (1906) 249.

We have fine clusters of this species taken by one of us (J.B.C.), growing in red clay at Lismore, N.S.W., in October 1913, and others from Port Hacking (E.C.) in August, 1915. The spores of the Lismore specimens are spherical, 3·5 to 4μ, appearing as very finely warted under an oil immersion lens. The spines have fallen off and the surface is minutely pitted. We also refer, to this species, specimens collected at Wilson's Creek, Helensburgh, W. Craigie, August, 1909; Dorrigo, J. L. Boorman, May, 1909; St. Mary's A. A. Hamilton, August, 1910; Leura, B. Carney, 1915. The spores of these collections are practically identical, being globose, smooth or very faintly warted, 3 – 4μ diam.

(31.) *L. pyriforme*, Schaeff., Lloyd, Lycoperdaceæ (1905) 33, and Mycol. Notes, No. 25 (1907) 318, and Letter No. 13 (1906); R. T. Baker, Proc. Linn. Soc. (1906) 720.

This species was found to be common at Mount Wilson, Blue Mountains, in June, 1915, growing on fallen rotten logs, spores smooth, 3·8μ. The shape of the plant is rather pyriform. The peridium is dark brown from fine spines, becoming brownish-white and slightly areolate as these fall off. We have also specimens collected in the Botanic Gardens. *L. pyriforme* (spelt *piriforme*) var. *flavum*. Lloyd, Letter No. 60, pp. 4 and 11 (1915). Type probably from Botanic Gardens, Sydney.

CALVATIA.

(32.) *C. lilacina*, Lloyd, Lycoperdaceæ (1905) 35, pl. 35, f. 1, and Letters No. 8 (1905), No. 23 (1908) and No. 31 (1911). Syn. *Lycoperdon lilacinum*, Berk. in Cooke's Handb.; *Bovista lilacina*, Mont. et Berk. in Hooker's London Journ. Bot. (1845) 64.

We have examined a fine series of specimens of this species in the National Herbarium, and in our own collections. The plants are very variable and comprise the following:—Pear-shaped with a short stalk, 1½ in. high, 1¼ in. in diameter, capillitium threads purplish 3·5μ in diameter, spores purplish, warty, 5·2μ in diameter, smaller ones of 3·5μ size being smoother, Hawkesbury River, April; young specimens, similar to the preceding, capillitium threads brown, 3·4μ in diameter, spores smooth, 5·2μ to 6·8μ, Lisarow, April; Sydney district, several collections (Feb., May to July, Aug., Nov.); State Nursery, Campbelltown (A. Grant, March, 1904); Penshurst (E. C., August, 1906, and May, 1907, spores 4μ); Mortdale (E.C., March, 1909); Brownsville near Dapto (E.C. April, 1912); Tuggerah (Mrs. F. Moore, 1916); Lucindale, S.A. (J. B. C., August, 1898). According to Berkeley and Broome (Ceylon Fungi, Journ. Linn. Soc. Bot., xiv, p. 78, 1873), this species is sold at Rangoon in the bazaars when young as an esculent.

(33.) *C. Gardneri*, Berk.

One of us (J.B.C.), has collected a specimen (the locality has unfortunately not been noted and it is probably not a New South Wales specimen, but from South Australia or perhaps Flinders Island in Bass Straits) which C. G. Lloyd has identified as *C. Gardneri*. He says it is the first specimen he has had from Australia, though he has it from Japan, India, etc., and that it originally came from Ceylon. "Your specimen is more turbinate than other collections but with same gleba, spores, etc., I think same species."

We have another specimen collected in December in South Australia, between Morgan and Renmark on the river Murray. Our specimens are pear-shaped, 3½ to 4 in. tall by 3 to 3½ ins. broad. The cortex is thin, brownish to pallid, breaking away in flakes. The gleba of the specimen Lloyd has seen is a pale café-au-lait brown, the spores are 4·4 to 5μ, very finely warted, the capillitium 3 to 3·5μ in diameter, and there is no apparent sterile base. In the other specimen, which is otherwise almost identical, the gleba is of a distinct yellowish-brown—though not far removed in tint from the former specimen—the spores are 4·8 to 5μ, smooth and the capillitium 2μ in diameter.

(34.) *C. rubro-flava*, Craigin, Lloyd, Mycol. Notes, No. 15, p. 149 (1903), No. 22, p. 11, No. 27 (1907) 347. Syn. *Lycoperdon australe, forma major*, Massee in letter to Cheel, Proc. Linn. Soc. N.S.W., xxxii (1907) 202.

According to Lloyd (*l.c.*) this species has a fairly wide range, specimens having been found in Brazil, Argentine and the United States of America. It appears to be found chiefly in cultivated plantations. It was originally found in this State by A. Grant, in April, 1899, at Wentworth Park. It has since been found abundantly in the Botanic Gardens, Sydney, by various collectors, and in the Centennial Park by one of us (E.C.), in March, 1901. The latter specimens were determined by Massee at the Royal Gardens, Kew, as *Lycoperdon australe, f. major*. Specimens collected in the Botanic Gardens, which appear to be identical with the Centennial Park specimens, were forwarded to Lloyd, who has determined them as *Calvatia rubro-flava*. Spores of the Botanic Gardens specimens are 4 to 5μ, smooth or perhaps slightly rough under a high power. We have specimens also from Neutral Bay, Sydney, growing under *Lantana* (March, 1916).

(35.) *C. candida.* Lloyd, Letter No. 13 (1906) N.S.W., W. W. Watts.

(36.) *C. olivacea* ?. Lloyd, Letter 13 (1906), N.S.W., W. W. Watts. Syn. *Bovista olivacea*, Cooke and Massee. See also Bailey in Queensl. Agric. Journ., May, (1912), 358, 359.

MITREMYCES.

(37.) *M. fuscus*, Lloyd, Lycoperdaceæ (1905) 41; Letters Nos. 7 and 8 (1905). Syn. *Calostoma fusca*, Berk., Cooke, Handb., p. 227; Baker, Proc. Linn. Soc. N.S.W. xxii, (1897) 239, and probably *Calostoma sp.* of R. T. Baker, *ibid.*, (1900) 14, and *Calostoma fusca*, Moss, of R. T. Baker, *ibid.*, (1906) 720.

The specimens recorded by Baker are from Hornsby, Dorrigo, Wentworth Falls and Katoomba. We have some fine specimens of this species from Conjola, collected by W. Heron, in May, 1890.

I. List of Australian Lycoperdaceæ recorded by Cooke with the identifications as made by C. G. Lloyd :—

1218 *Secotium acuminatum.* Its occurrence doubtful if based on the fragments seen by Lloyd.

1219 „ *coarctatum* = *S. coarctatum.*

1220 „ *melanosporum* = *S. melanosporum.*

1221 „ *erythrocephalum* = *S. erythrocephalum.*

1222 „ *Gunnii.* Based on a fragment, probably *S. coarctatum*, but spores a little larger.

1223 „ *scabrosum* = *S. scabrosum.*

1224 *Chainoderma (Secotium) Drummondii.*

1225 *Cyloderma platyspora.* Erroneous (Lloyd).

1226 *Mesophellia arenaria* = *M. arenaria.*

1227 „ *inpatissima.* Type apparently lost.

1228 „ *scleroderma*, N. Zealand = *Gallacea scleroderma.*

1229 *Podaxis carcinomalis* = *P. carcinomalis*, prob. var. *elatior.*

1230 „ *indica (P. pistillaris)* = *P. pistillaris* (in this case probably *P. ægyptiacus*).

1231 *Podaxis axata (P. calyptratus)* = *P. Muelleri.*
1232 *Gymnoglossum stipitatum* = *G. stipitatum.*
1233 *Protoglossum luteum.* Probably a *Hymenogaster.* Cooke's figure is a different plant (Lloyd).
1234 *Tylostoma mammosum* = *T. mammosum.*
1235 „ *leprosum* = *T. mammosum* with its veil, probably.
1236 „ *Wightii* = *T. Wightii* (no Australian specimen seen by Lloyd).
1237 „ *maximum* = *Chlamydopus Meyenianus.*
1238 „ *fimbriatum* = *T. granulosum.*
1239 „ *brachypus (T. granulosum)* = *T. granulosum.*
1240 „ *album* = *T. album.*
1241 „ *pulchellum* = *T. pulchellum.*
1242 *Battarrea phalloides* = *B. phalloides.*
1243 „ *Stevenii* = *B. Stevenii.*
1244 „ *Muelleri* = *B. Stevenii.*
1245 „ *Tepperiana* = *B. Stevenii.*
1246 *Calostoma lurida* = *Mitremyces luridus.*
1247 „ *fusca* = „ *fuscus.*
1248 „ *viridis* = „ *fuscus.*
1249 „ *æruginosa* = „ *fuscus.*
1250 – 1271 *Geaster.* These have been dealt with in our second paper.
1272 *Diploderma glaucum* = *Mesophellia arenaria,* probably.
1273 „ *suberosum.* Erroneous.
1274 „ *pachythrix* = *Mesophellia pachythrix.*
1275 „ *alba.* Erroneous.
1276 „ *fumosa.* „
1277 „ *melasperma.* „
1278 *Bovista brunnea* = *B. brunnea.*
1279 „ *Mulleri* = *Catastoma Muelleri.*
1280 „ *hyalothrix* = „ *hyalothrix.*
1281 „ *hypogaea* = „ *hypogaeum.*
1282 „ *anomala* = „ *anomalum.*
1283 „ *olivacea* = *Calvatia olivacea.*
1284 „ *cervina* = *Catastoma.*

1285 *Lycoperdon lilacina*, = *Calvatia lilacina*.

1286 „ *violascens*. Belongs to 'atro-purpureum section,' specimens seen by Lloyd too old for specific identification.

1287 „ *bovistoides* = *L. bovistoides*, illustration resembles *Catastoma* but with a sterile base.

1288 „ *natalense* = *L. pratense*.

1289 „ *gemmatum* = *L. gemmatum*.

1290 „ *colensoi*, New Zealand = *L. gemmatum*.

1291 „ *pyriforme* = *L. pyriforme*.

1292 „ *glabrescens* = *Bovistella glabrescens*.

1293 „ *bovista (L. giganteum)* = *Calvatia gigantea*.

1294 „ *Fontanesii*, New Zealand = *Calvatia Fontanesii*.

1295 „ *cœlatum* = *Calvatia cœlata*.

1296 „ *Cookei* = *Bovistella*, probably.

1297 „ *Sinclairi*, New Zealand = *Calvatia Sinclairii*.

1298 „ *australe* = *L. pusillum*.

1299 „ *stellatum* = *L. stellatum*.

1300 „ *substellatum*. Type apparently non-existent or insufficient (Lloyd).

1301 „ *coprophilum* = *L. coprophilum*.

1302 „ *microspermum* = *L. pusillum*, apparently.

1303 „ *dermoxanthum* = *L. dermozanthum*.

1304 „ *reticulatum*. Type apparently non-existent or insufficient (Lloyd).

1305 „ *tephrum* = *L. tephrum*.

1306 „ *pusillum* = *L. pusillum*.

1307 „ *mundula*. Type apparently non-existent or insufficient (Lloyd).

1308 „ *novœ zelandiœ* = *Calvatia lilacina*.

1309 „ *Gunnii* = *Bovistella Gunnii*.

1310 *Scleroderma geaster* = *S. geaster*.

1311 „ *bovista* = *S. texense*, probably.

1312 „ *vulgare* = *S. aurantiacum* and *S. cepa*.

1313 „ *verrucosum* = *S. verrucosum*.

1314 „ *pandanaceum*. No type found at Kew (Lloyd).

1315 *Sclerodeama aurea.* No type found at Kew (Lloyd).
1316 „ *australe.* „ „ „
1317 „ *umbrina* = *Polysaccum pisocarpium.*
1318 „ *(Areolaria) strobilina* = *Phellorina strobilina.*
1319 *Mycenastrium corium* = *M. corium.*
1320 „ *phæotrichum* = „
1321 „ *olivaceum* = „
1322 *Castoreum radicatum* = *C. radicatum.*
1323 *Xylopodium australe* = *Phellorhina australis.*
1324 „ *ochroleucum* = „ *strobilina.*
1325 *Favillea argilacea* = *P. pisocarpium*, probably.
1326 *Polysaccum pisocarpium* = „
„ „ var. *acaule.*
1327 „ *microcarpum* = *P. pisocarpium.*
1328 „ *crassipes* = „ var. *crassipes.*
1329 „ *turgidum* = „ „
1330 „ *tuberosum* = „ var. *tuberosum.*
1331 „ *marmoratum* = „ var. *crassipes.*
1332 „ *confusum* = „ var. *confusum.*
1333 „ *australe* = „
1334 „ *album.*
1335 „ (?) *degenerans.*
1336 *Arachnion Drummondi* = *Arachnion Drummondii.*
1337 *Paurocotylis pila*, New Zealand. Belongs to the Tuberaceæ.
1338 „ *echinosperma.*

II. Corrected List of Australian Lycoperdaceæ based on Lloyd's works.

1 *Podaxon ægyptiacus*
2 „ *Muelleri*
3 „ *carcinamalis*, var. *elatior.*
4 „ *pistillaris* (pobably *P. ægyptiacus*
5 *Gynoglossnm stipitatum*
6 *Secotium erythrocephalum*
7 „ *coarctatum*
8 „ *melanosporum*
9 „ *acuminatum* (?)
10 „ *Rodwayi.*
11 *Tylostoma albicans*
12 „ *McAlpinianum*

13 *Tylostoma mammosum*
14 ,, *purpusii*
15 ,, *Wightii* (?)
16 ,, *australianum*
17 ,, *album*
18 ,, *Readeri*
19 ,, *egranulosum*
20 ,, *poculatum*
21 ,, *subfuscum*
22 ,, *granulosum*
23 ,, *exasperatum* (?)
24 ,, *pulchellum* (?)
25 *Chlamydopus meyenianus*
26 *Phellorina delastrei*
27 ,, *strobilina*
28 *Phellorina australis*
29 *Battarrea phalloides*
29*a* ,, ,, var. *Stevenii*
30 *Polysaccum pisocarpium*
30*a* ,, ,, var. *crassipes*
30*b* ,, ,, ,, *tuberosum*
30*c* ,, ,, ,, *confusum*
31 ,, *degenerans* (?)
32 *Scleroderma geaster*
33 ,, *flavidum*
34 ,, *cepa*
35 ,, *texense*
36 ,, *aurantiacum*
37 ,, *verrucosum*

Geaster.—A list of these has been given in No. 2 of this series.

38 *Bovista brunnea*
39 *Catastoma hypogæum*
40 ,, *anomalum*
41 ,, *Muelleri*
42 ,, *hyalothrix*
43 ,, *abnormalis* (?)
44 *Bovistella aspera*
45 ,, *australiana*
46 ,, *glabreoscens*
47 ,, *Gunnii*
48 ,, *scabra*
49 ,, *bovistoides*
50 ,, *rosea*
51 *Lycoperdon polymorphum*
52 ,, *nigrum*
53 ,, *cepæforme*
54 ,, *pusillum*
55 ,, *dermozanthum*
56 ,, *pratense*
57 *Lycoperdon stellatum*
58 ,, *gemmatum*
59 ,, *pyriforme*
60 ,, *coprophilum*
61 ,, *tephrum*
62 ,, *subincarnatum*
63 *Calvatia lilacina*
64 ,, *cœlata*
65 ,, *Gardneri*
66 ,, *candida*
67 ,, *olivacea*
68 ,, *rubroflava*
69 *Castoreum radicatum*
70 *Arachnion Drummondii*
71 *Mesophellia arenaria*
72 ,, *pachythrix*
73 *Mitremyces fuscus*
74 ,, *luridus*
75 *Paurocotylis echinosperma* (?)

NAPIER'S LOGARITHMS: THE DEVELOPMENT OF HIS THEORY.

By H. S. Carslaw, Sc. D.

[*Read before the Royal Society of N. S. Wales, August 2, 1916.*]

Introductory.

§ 1. This paper deals with Napier's idea of a logarithm.[1] In my view there are three distinct stages in the development of this idea in his work. In the first he is concerned with a one-one correspondence between the terms of a Geometrical Progression and the terms of an Arithmetical Progression. There are traces of this in the *Constructio*[2] in his use of the series

$$10^7,\ 10^7\left(1-\frac{1}{10^7}\right),\ 10^7\left(1-\frac{1}{10^7}\right)^2, \text{ etc.,}$$

and in the word logarithm itself, derived from λόγος ἀριθμός, and generally taken to mean "the number of the ratios." In the second he has passed from this correspondence, and his logarithms are given by the well known kinematical definition, which forms the foundation of the theory of the *Constructio*. In the third, referred to in the Appendix to the *Constructio*, he has reached the idea of a logarithm as *defined* by the property:—

[1] In a previous paper in these Proceedings:—The Discovery of Logarithms by Napier of Merchiston—Vol. 48, pp. 42–72, 1914—the question of the construction of the logarithms of the *Canon* has been discussed.

[2] The *Mirifici Logarithmorum Canonis Constructio* was published in 1619, two years after Napier's death, but had been written several years before his *Mirifici Logarithmorum Canonis Descriptio*, published in 1614. I shall refer to these works as the *Constructio* and the *Descriptio*. The *Descriptio* was translated into English by Wright (1616), and Filipowski (1857), the *Constructio* by Macdonald (1889). The former is a rare book, both in the original and in translation. Several of the more important pages are reproduced in the *Napier Tercentenary Memorial Volume*, Plates I–VI, (London, 1915).

The logarithms of proportional numbers have equal differences, with the additional condition that the logarithms of two numbers are given.

In the second and third stages he has obtained what we would now call a function of the independent variable—the number—, but the function of the third stage is more general than that of the second, which it includes as a special case.

If this view is correct, the statement that "Napier's *theory* rests on the establishment of a one-one correspondence between the terms of a geometric series and the terms of an arithmetic series"[1] should not be taken too literally. Further the custom of employing the term "Napier's logarithms" to describe only the logarithms of his *Canon* is unfortunate. It will be seen in the course of this paper that logarithms to the base 10—as we know them—are Napier's logarithms just as much as the logarithms of his *Canon*.

The First Stage.

§ 2. The idea that multiplication and division could be reduced to addition and subtraction by the correlation of a geometrical series and an arithmetical series was not a new one. Aristotle was familiar with it, and since his time many mathematicians had returned to it. If we take the series

1, 2, 3, 4, 5, 6, 7, 8, ... 15, ...
2, 4, 8, 16, 32, 64, 128, 256,.........32768,......

the product of 128 and 256 in the geometrical series can be read off as 32768, which corresponds to 15, the sum of 7 and 8 in the arithmetical series.

[1] Cajori, Napier's Logarithmic Concept: A Reply. *American Mathematical Monthly*, Vol, 23, p. 71, (1915).

The Swiss Bürgi in his *Arithmetische and Geometrische Progress Tabulen,*[1] constructed some time between 1603 and 1611, but first published in 1620, used the series

$$\begin{array}{llll} 10 \times 0, & 10 \times 1, & 10 \times 2, & \ldots 10 \times n, \ldots\ldots \\ 10^8, & 10^8\left(1+\frac{1}{10^4}\right), & 10^8\left(1+\frac{1}{10^4}\right)^2, & \ldots 10^8\left(1+\frac{1}{10^4}\right)^n, \ldots \end{array}$$

His tables cover the range 10^8 to 10^9, and for all practical purposes are as satisfactory as Napier's Table of Logarithms of 1614. If Napier had simply used the idea of the correspondence between the terms of a geometrical series and the terms of an arithmetical series, his work could not be regarded as so great an advance upon Bürgi's as it really is.

But it is clear that at the beginning of his labours, which extended over a period of twenty years, Napier's mind was working on the same lines as Bürgi's, and that at this stage he used the series

$$\begin{array}{llll} 0, & 1, & 2, & \ldots\ldots \\ 10^7, & 10^7\left(1-\frac{1}{10^7}\right), & 10^7\left(1-\frac{1}{10^7}\right)^2, & \ldots\ldots \end{array}$$

in a similar way. This geometrical series occurs in the *Constructio.* He employed it in the calculation of his logarithms, but neither then, nor later, are his logarithms the terms of the corresponding arithmetical series. His word logarithm, (See §1), is evidently a survival of the first stage of his work.

Napier meant his tables to be used in calculations involving the trigonometrical ratios. In his time, the sine, cosine, etc., were lines—or, more exactly, the measures of lines—in a circle of given radius. Napier took the radius

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[1] A facsimile of the title page of Bürgi's work and of one of the pages of the Tables will be found in the *Napier Tercentenary Memorial Volume* (Plates XII and XIII). Comparison with the references in Cantor's *Geschichte der Mathematik,* Tropfke's *Geschichte der Elementar-Mathematik,* and Braunmühl's *Geschichte der Trigonometrie* will show that in none of these works is the title quoted correctly.

as 10^7. It may be that Bürgi chose 10^8 in his tables for a similar reason. With our notation Napier's sines would correspond to 7-Figure Tables of Natural Sines, etc. If greater accuracy were required, the radius was taken as 10^{10}, and sometimes even a higher power of 10 was used. These sines, etc., following Glaisher,[1] we shall refer to as line-sines, etc.

The Second Stage.

§ 3. Napier opened out entirely fresh ground, when he passed to his kinematical definition of the logarithm of a sine or number. By this definition he associated with the sine, as it continually diminished from 10^7 for 90° to zero for 0°, a number which he called its logarithm; and the logarithm continually increased from 0, for the sine of 90°, to infinity, for the sine of 0°.

The fundamental proposition in Napier's theory in the *Descriptio* (1614) and the *Constructio* (1619) is to be found in Prop. I of the *Descriptio:*

The logarithmes of proportionall numbers and quantities are equally differing.[2]

And in Section 36 of the *Constructio* it appears as *the logarithms of similarly proportioned sines are equidifferent.*

Glaisher has introduced a convenient notation $nl_r\, x$ for Napier's logarithm, in this system, when the radius is 10^r. He also uses $\text{Sin}_r\, x$ for the line-sine of the angle x, when the radius is 10^r, and he keeps the symbol $\sin x$ for the sine in the modern sense of the term. With this notation we have

$$\sin x = \frac{\text{Sin}_r x}{10^r}.$$

[1] *Quarterly Journal*, Vol. 46, p. 125 (1916). To this paper I am indebted, not only for a most convenient notation for the different systems of logarithms, but also for an account of Speidell's work, hitherto inaccessible to me.

[2] In quoting the *Descriptio* I follow Wright's version, and for the *Constructio* I adopt Macdonald's.

In this paper I follow his notation, and $\log_e x$ is used in its modern sense for the logarithm of x to the base e, the system commonly called hyperbolic logarithms.

The fundamental theorem, referred to above, can now be stated as follows:—

If $a : b = c : d$, then $nl_r a - nl_r b = nl_r c - nl_r d$.........(1)
Also we are given that $nl_r 10^r = 0$. ....(2)
Napier's *Canon* consists of a Table of Logarithms in which (1) and (2) are satisfied. His definition of the logarithm by means of the velocities of two points moving in two different lines leads to the formula

$$nl_r x = 10^r \log_e \left(\frac{10^r}{x}\right).$$

But, of course, neither this, nor the fact that his function $nl_r x$ has -1 for its differential coefficient, when $x = 10^r$, could be known in his time.

The Third Stage.

§ 4. Since $uv : u = v : 1$,
we have $nl_r(uv) - nl_r u = nl_r v - nl_r 1$.

Thus $nl_r(uv) = nl_r u + nl_r v - nl_r 1$,
and it must be remembered that $nl_r 1$ is not zero.

When $r = 7$, $nl_r 1 = 161180896{\cdot}38$ (Cf. *Constructio*, Section 53).[1]

Similarly $nl_r(u/v) = nl_r u - nl_r v + nl_r 1$.

Thus multiplication and division are changed into addition and subtraction. But the logarithms of numbers with the same figures in the same order cannot be read off from one another, since, in this system,

$$nl_r(10^m a) = nl_r a - m(nl_r 1 - nl_r 10),$$

[1] The error in Napier's Second Table affects the accuracy of his Canon and this number should be 161180956·51. The alteration can be made from the corrected result given by Macdonald in his English translation of the *Constructio* pp. 94-5, for it is not difficult to show that $nl_7 1 = 7\, nl_7 10^6$.

and $nl_7 1 - nl_7 10 = 23025842{\cdot}34$ (Cf. *Constructio*, Section 53).[1]

It is obvious that if a system of logarithms could be devised in which the logarithm of unity is zero and the logarithm of 10 is unity, the calculations would be immensely simplified, and the table curtailed; because one of the chief defects of Napier's *Canon*, as well as of Bürgi's Tables, was that, if the numbers did not come within the range covered by it, more or less awkward calculations were needed to overcome this difficulty.

Napier's *Canon* was first printed in the *Descriptio* (1614). After his death in 1617 the *Constructio* was published by the care of his son. It had been written several years before the *Descriptio*. To this work was added an Appendix, by the hand of Napier himself, "On the Construction of another and *better kind of* Logarithms, *namely* one in which the Logarithm of unity is 0." This Appendix begins with the words:—

"*Among the various improvements of Logarithms, the more important is that which adopts a cypher as the Logarithm of unity, and 10,000,000,000 as the Logarithm of either one-tenth of unity or ten times unity. Then, these being once fixed, the Logarithms of all other numbers necessarily follow.*"

It is clear from Napier's words that, when he wrote the Appendix, not only did he see the advantage of such a system, but he was in a position to draw up a Table of Logarithms in which these conditions would be satisfied. Indeed he gives three distinct methods of finding these logarithms. The kinematical definition of the logarithm was superseded, and the correspondence between the terms

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[1] This number should be $23025850{\cdot}93$, since it is easy to show that $nl_7 1 - nl_7 10 = nl_7 10^6$, and Macdonald gives the corrected logarithm of 10^6 (*loc. cit.*, pp. 94-5).

of a geometrical series and the terms of an arithmetical series was left far behind. This is the third and final stage of his work.

Briggs and Napier.

§ 5. In the change from the logarithms of the Canon to this "better kind of logarithms" Briggs was associated with Napier; but, chiefly because of the unsatisfactory account of the matter given by Hutton in his *History of Logarithms*,[1] the share of the former in the discovery has been exaggerated. The fault is not due to Briggs; and, though his reference to the question in the preface to the *Arithmetica Logarithmica* (1624) is familiar, I reproduce it again here:—

"I myself, when expounding publicly in London their doctrine to my auditors in Gresham College, remarked that it would be much more convenient that 0 should stand for the logarithm of the whole sine, as in the Canon Mirificus, but that the logarithm of the tenth part of the whole sine, that is to say, 5 degrees 44 minutes 21 seconds, should be 10,000,000,000. Concerning that matter I wrote immediately to the author himself; and as soon as the season of the year and the vacation time of my public duties of instruction permitted, I took journey to Edinburgh, where, being most hospitably received by him, I lingered for a whole month. But as we held discourse concerning this change in the system of logarithms, he said that for a long time he had been sensible of the same thing, and had been anxious to accomplish it, but that he had published those he had already prepared, until he could construct tables more convenient, if other weighty matters and his frail health would permit him to do. But he conceived that the change ought to be affected in this manner, that 0 should become the logarithm of unity, and 10,000,000,000 that of the whole sine; which I could not but admit was by far the most convenient of all. So, rejecting those which I had already

[1] Hutton's *Tracts on Mathematical and Philosophical Subjects*, Vol. I, Tract 20.

prepared, I commenced, under his encouraging counsel, to ponder seriously about the calculation of these tables."

Napier also mentions his discovery of the new system in the dedication of his *Rabdologia* (1617) in a passage quoted in my previous paper.[1]

It will be seen from Briggs' own words, that the modification which he suggested to Napier was to keep the logarithm of the radius as zero, but to take the logarithm of one-tenth of the radius as 10,000,000,000. His reference to the *Canon* is sufficient to show that he does not look upon the radius as unity. In the construction of the Table of Logarithms, after Napier's death, he takes it as 10^{10}, and it is for this reason that the characteristics 9, 8, etc., are to be found in the logarithms of the sines, etc.

Using the notation $bl_r x$ for the logarithm of x in the system suggested by Briggs when the radius is 10^r, we have

$$bl_r\, a - bl_r\, b = bl_r\, c - bl_r\, d,$$

when $a : b = c : d$.

Also $bl_r 10^r = 0$, and $bl_r 10^{r-1} = 10^{10}$.

In this system we have

$$bl_r(uv) = bl_r u + bl_r v - bl_r 1,$$
$$bl_r(u/v) = bl_r u - bl_r v + bl_r 1.$$

$$\text{Also } bl_{10} 10^{10} = 10\, bl_{10} 10 - 9\, bl_{10} 1 = 0$$
$$bl_{10} 10^9 = 9\, bl_{10} 10 - 8\, bl_{10} 1 = 10^{10}.$$

Thus $bl_{10} 10 = 9 \times 10^{10}$ and $bl_{10} 1 = 10 \times 10^{10}$.

The advantage of the new system consists in the fact that the logarithms of numbers with the same figures in the same order could be read off from each other, since we have $$bl_r(10^m a) = bl_r a - m \times 10^{10}.$$

§ 6. The change upon which Napier had resolved, previous to Briggs' visit, was a much more important one. He "conceived that the change ought to be affected in this

[1] See also Macdonald's English translation of the *Constructio*, p. 88.

manner, that 0 should become the logarithm of unity, and 10,000,000,000 that of the whole sine." And finally in the Appendix we see that he often passes from logarithms of sines, and now drops all reference to the radius.

In the new system, logarithms were to be *defined* by the relations:—

$$\text{If } a : b = c : d, \text{ then } nl\,a - nl\,b = nl\,c - nl\,d,$$
$$\text{with } nl\,1 = 0 \text{ and } nl\,10 = 10^{10}.$$

It need hardly be added that 10^{10} was taken for the logarithm of 10 instead of unity, for the same reason that 10^7 (or 10^{10}) was taken for the radius in dealing with the trigonometrical ratios.

Later Briggs takes the logarithm of 10 as unity, and introduces the notation of decimal fractions in his Tables, a notation employed, probably for the first time, by Napier himself.

If this account of the growth of the idea of a logarithm in Napier's work is correct,[1] it seems unfortunate that the term Napier's logarithms is usually confined to the logarithms of his *Canon.* His "better kind of logarithms" actually consists of the logarithms now in daily use—the logarithms which we call logarithms to the base 10. In some textbooks they receive the awkward name Briggsian logarithms. Certainly Briggs calculated them, and the rapidity and industry with which he performed this immense work in computation will always be the admiration of mathematicians. But the discovery of the system was Napier's, and the logarithms are as much Napier's logarithms as those of his *Canon.*

Speidell's New Logarithmes (1619).

§ 7. In most accounts of the discovery of logarithms reference is made to Speidell's *New Logarithmes* (London,

[1] See also Gibson's paper in the *Napier Tercentenary Memorial Volume,* pp. 111–137.

1619), and it is stated that they contain the first table of logarithms to the base e.[1] Attention is also usually called to the fact that, while logarithms to the base e are frequently spoken of as Napierean logarithms, they are quite different from the logarithms of Napier's *Canon;* and it is pointed out that the place of the number e in the theory of logarithms and the possibility of defining logarithms as exponents were discoveries of a much later day. These two statements, at first sight, seem inconsistent. A word or two regarding Speidell's system will make the matter clearer, and will also confirm the view I have taken above as to Napier's final conception of the logarithm.

Speidell's *New Logarithmes*, like Napier's *Canon*, refer to the trigonometrical ratios. Using Glaisher's notation $sl_r x$ for Speidell's logarithm of x when the radius is 10^r, we have

$$sl_r x = 10^{r+1} - nl_r x.$$

It follows that

$$sl_r(uv) = sl_r u + sl_r v - sl_r 1,$$
$$sl_r(uv) = sl_r u - sl_r v + sl_r 1,$$

and $sl_r 1$ is not zero.

The sole advantages of this system was that it avoided the use of negative quantities in calculation with logarithms. Such quantities were then outside the range of the "vulgar and common arithmetic."

Since $nl_r x = 10^r \log_e \left(\frac{10^r}{x}\right)$,

we have $sl_r x = 10^{r+1} + 10^r \log_e \left(\frac{x}{10^r}\right)$.

$$\text{Thus } sl_r \operatorname{Sin}_r x = 10^{r+1} + 10^r \log_e \left(\frac{\operatorname{Sin}_r x}{10^r}\right)$$
$$= 10^r (10 + \log_e \sin x).$$

[1] In Glaisher's paper already referred to, he published the interesting discovery that an Appendix (1618) to Wright's English translation of the *Descriptio* contains a table of hyperbolic logarithms by an anonymous author, whom he identifies with Oughtred.

In a sense Speidell's *New Logarithmes* may be said to be hyperbolic logarithms, but the sense is the same as that in which the logarithms of Napier's *Canon* are sometimes said to be logarithms to the base e^{-1}. However this is a misuse of the term.[1] Still Speidell's logarithms of sines, from the accident that the sine is now used in a different sense, have actually the same figures as our hyperbolic logarithms of sines.

In the *New Logarithmes* (1619) he takes the radius as 10^5, so that these tables give

$$sl_5 \text{ Sin}_5 x = 10^5 (10 + \log_e \sin x).$$

§ 8. But subsequently Speidell *did* publish a table of hyperbolic logarithms of numbers, which gives the values of $10^6 \log_e x$ for numbers 1 to 1,000. This table probably appeared either separately, or attached to an impression of the *New Logarithmes*, in 1622 or 1623. In this system he takes

$$sl_r x = nl_r 1 - nl_r x.$$

It follows that

$$sl_r (uv) = sl_r u + sl_r v,$$
$$sl_r (u/v) = sl_r u - sl_r v;$$

and since

$$nl_r x = 10^r \log_e \left(\frac{10^r}{x}\right),$$

we have

$$sl_r x = 10^r \log_e x.$$

But it is clear that in both Speidell's systems of logarithms the connection with hyperbolic logarithms is accidental, and the same is true of the logarithms discovered by Glaisher, to which reference is made at the beginning of this section.

Like Napier and Briggs, Speidell sees that the fundamental property, that the logarithms of proportional numbers have equal differences, can be taken as the starting

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[1] *Cf.* Glaisher, *loc. cit.*, p. 146, footnote.

point of the theory; and that, if the logarithm of unity is zero, the logarithms of the product and the quotient of two numbers are, respectively, the sum and difference of their separate logarithms.

§ 9. **The Differential Equation satisfied by the logarithm of** x.

We have seen that the theory of the different systems of logarithms described in the previous pages rests upon the fundamental property:—

If $a : b = c : d$, then $\lambda(a) - \lambda(b) = \lambda(c) - \lambda(d)$, where $\lambda(x)$ stands for the logarithm of x.

The function $\lambda(x)$, therefore, satisfies the equation

$$\lambda(x+h) - \lambda(x) = \lambda\left(1 + \frac{h}{x}\right) - \lambda(1).$$

$$\therefore \quad \frac{\lambda(x+h) - \lambda(x)}{h} = \frac{1}{x}\left\{\frac{\lambda\left(1+\frac{h}{x}\right) - \lambda(1)}{\frac{h}{x}}\right\}.$$

Proceeding to the limit $h \longrightarrow 0$, of course keeping x fixed, we have

$$\lambda'(x) = \frac{A}{x}, \text{ where } A = \lambda'(1).$$

Therefore $\lambda(x) = A \log_e x + B$,
and the system is made definite by adding two other conditions.

In Napier's *Canon*, writing ρ for the radius, we have

$$nl\, x = A \log_e x + B,$$

with $\quad nl\, \rho = 0$, and $nl'\, \rho = -1$.

Therefore $nl\, x = \rho \log_e\left(\frac{\rho}{x}\right)$.

In Briggs' modification of the system, we have

$$bl\, x = A \log_e x + B,$$

with $\quad bl\, \rho = 0$ and $bl\left(\frac{\rho}{10}\right) = 10^{10}$.

$$\text{Thus } bl\, x = 10^{10}\frac{\log_e\left(\frac{\rho}{x}\right)}{\log_e 10} = 10^{10}\log_{10}\left(\frac{\rho}{x}\right).$$

And Napier's final form is, of course,

$$nl\ x = 10^{10} \log_{10} x.$$

Bürgi's *Arithmetische und Geometrische Progress Tabulen* also come under the same law. If the terms in the Arithmetical Progression are taken as the logarithms of the terms in the Geometrical Progression, and $Bl\ x$ stands for what I may call Bürgi's logarithm of x, we have

$$Bl\ x = 10 \frac{\log_e \left(\frac{x}{10^8}\right)}{\log_e \left(1+\frac{1}{10^4}\right)} = 10 \log_{1+\frac{1}{10^4}} \left(\frac{x}{10^8}\right)$$

for $x = 10^8 \left(1+\frac{1}{10^4}\right)^s$, s being any positive integer.

Finally, treating Napier's series

$$0, \quad 1, \quad 2 \ldots\ldots$$

$$10^7,\ 10^7\left(1-\frac{1}{10^7}\right),\ 10^7\left(1-\frac{1}{10^7}\right)^2, \ldots\ldots$$

in the same way, and denoting this logarithm by $Nl\ x$, we have

$$Nl\ x = \frac{\log_e \left(\frac{x}{10^7}\right)}{\log_e \left(1-\frac{1}{10^7}\right)} = \log_{1-\frac{1}{10^7}} \left(\frac{x}{10^7}\right),$$

for $x = 10^7 \left(1-\frac{1}{10^7}\right)^s$, s being any positive integer.

ACACIA SEEDLINGS, PART II.

By R. H. CAMBAGE, F.L.S.

With Plates I to IV.

[*Read before the Royal Society of N.S. Wales, August 2, 1916.*]

SYNOPSIS:

SEQUENCE IN THE DEVELOPMENT OF LEAVES.
VITALITY OF SEED IN SEA-WATER.
DESCRIPTIONS OF SEEDLINGS.

Sequence in the Development of Leaves.

It was pointed out in a previous paper (Part I), on Acacia Seedlings, read before this Society in July 1915, that in by far the greater number of about sixty Acacia species, of which seedlings had been raised, the cotyledons were succeeded by one simply-pinnate leaf, which was followed by a varying number of bipinnate leaves, but that in the case of four species it was found that an opposite pair of simply-pinnate leaves appeared next after the cotyledons. The examination of fifteen species more has revealed two further species which have an opposite pair of simply-pinnate leaves.

Further species which have only one pinnate leaf are the following :—

Acacia pumila, Maiden and Baker.
,, *trinervata*, Sieb.
,, *colletioides*, A. Cunn.
,, *oxycedrus*, Sieb.
,, *aspera*, Lindl.
,, *flexifolia*, A. Cunn.
,, *Mabellæ*, Maiden.
Acacia Flocktoniæ, Maiden.
,, *homalophylla*, A.Cunn., (with an exception).
,, *excelsa*, Benth.
,, *flavescens*, A. Cunn.
,, *doratoxylon*, A.Cunn.
,, *cincinnata*, F.v.M.

The two further species which produce an opposite pair of pinnate leaves are:—

Acacia galioides, Benth., and *A. Murrayana*, F.v.M.

A. galioides has a considerable range in tropical Australia, while *A. Murrayana* occurs in north-western New South Wales, in Queensland, and South Australia.

In the case of *A. homalophylla*, (Yarran), three seedlings produced one simply-pinnate leaf, but the fourth seedling had an opposite pair. Out of about 500 seedlings of about 70 Acacia species examined, this is the second instance where a species has been noticed to produce a single pinnate leaf and also an opposite pair next after the cotyledons. The previous case was that of *A. aneura*, (Mulga). All others have fallen wholly into one group or the other. These two species, therefore, may be regarded as being in a transition stage, more examples of which will probably be found among other species.[1]

Vitality of Seed in Sea-water.

When discussing, in Part I, the possibility of seeds being transported long distances by oceanic currents, it was mentioned that seeds of *Acacia Farnesiana* from Central Queensland had germinated after having been immersed in sea-water for 148 and 190 days respectively. Since then, a seed of this same species from the same locality, which had been in a bottle of sea-water for 405 days, and was shaken from month to month, was taken out and placed in a cup which was then filled with boiling water and allowed to remain standing for a couple of hours, after which the seed was planted. At the end of five weeks the seed had not germinated, and was taken out of the soil and found to be still perfectly sound. It was again placed in boiling water as before, and then planted. As it showed no change at the end of a further nine weeks, it was again removed

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[1] This Journal, Vol. XLIX, (1915), pp. 82 – 85.

from the soil, and after being placed in boiling water was again planted. After another five weeks, or nineteen weeks from the time the seed was taken from the sea-water, and had been three times placed in boiling water, the little seedling appeared.

The object of placing the seed in boiling water was to soften the coating, and hasten the germination by allowing the moisture to enter, which process is often performed in nature by bush fires. Had this particular seed not been so treated, it might not have germinated for years.

This experiment shows the wonderful vitality of the seed owing to it being encased in a very strong testa, and demonstrates the possibility of it retaining the power of germination for a sufficient length of time to be drifted in a piece of wood for thousands of miles.

It was mentioned in Part I,[1] that of four seeds planted after having been in sea-water for three months, two germinated.

One of the remaining seeds, after having been left in the soil twenty-three months, has recently germinated.

Descriptions of Seedlings.

CONTINUÆ.

ACACIA TRIPTERA, Benth., "Wait a While." Seeds from Howell, N. S. Wales (T. S. McCrae). (Plate I, Numbers 1 and 1*a*.)

Seeds shiny black, oblong, 3 to 3·5 mm. long, 2 mm. broad, 1·5 mm. thick.

Hypocotyl erect, terete, pale pink to greenish, 1·2 to 2·7 cm. long, ·7 to 1·5 mm. thick at base, ·5 to ·8 mm. at apex, glabrous.

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[1] This Journal, Vol. XLIX, (1915), p. 94.

Cotyledons sessile, slightly sagittate, oblong, apex rounded, 5 to 6 mm. long, 2 mm. broad, at first erect, but becoming horizontal in a few days, remaining for a few weeks; outer or underside red to pink, sometimes yellowish-brown towards base, slightly wrinkled longitudinally, upperside green, glabrous.

Stem terete in the lower portion, but becoming angular in the upper part were affected by decurrent leafstalks, green, glabrous. First internode ·5 to 1 mm.; second about 1 mm.; third 1·5 to 4 mm.; fourth 2 to 5·5 mm.; fifth 2 to 5 mm.

Leaves—No. 1. Abruptly pinnate, petiole 4 to 5 mm. long, glabrous; leaflets two pairs, the basal pair oblong acuminate, 5 mm. long, 1·5 mm. broad, not always opposite, the terminal pair obovate, 5 mm. long, 2 to 2·5 mm. broad, upperside green, underside pink; rachis 4 mm. long, green, glabrous, excurrent; stipules ·5 mm.

No. 2. Abruptly bipinnate, petiole slender, 7 mm. to 1·1 cm. long, glabrous, excurrent; leaflets two to three pairs, oblong-acuminate to obovate, mucronate, not always opposite, of irregular size, the largest being 3·5 mm. long, and 1 mm. broad, midrib fairly distinct especially on underside; the pinna usually lyrate; rachis 5 to 7 mm. long, glabrous, excurrent.

Nos. 3, 4, and 5. Abruptly bipinnate, petiole 1·3 to 2 cm. long, Nos. 4 and 5 being sometimes slightly flattened vertically to about ·5 mm. broad, and with a few parallel nerves, glabrous, excurrent; leaflets two to three pairs similar in shape, size, and arrangement to those of No. 2, with, in some cases, a few indistinct hairs on margins, midrib and secondary vein sometimes showing under pocket lens, the pinnæ not always equally pinnate; rachis 4 to 6 mm. long, glabrous, excurrent; stipules weak, or little more than scales, up to about 1 mm. long. In one case No. 5 appeared as a phyllode without any leaflets.

No. 6 and upwards. Phyllodes, the first few being linear and almost straight, the later ones becoming falcate and remarkably decurrent on the stem, all being striate with several nerves, and tapering into a pungent point. In a seedling 8 to 10 cm. high, the phyllodes reach about 1·8 cm. long, by 1 to 1·5 mm. broad.

Uninerves—Brevifoliæ.

Acacia hispidula, Willd. Seeds from Cheltenham, near Sydney. Growing on Hawkesbury Sandstone formation. (Plate I, Numbers 2 to 3*a*.)

Seeds dull black, oval-oblong, 7 mm. long, 4 mm. broad, 3 mm. thick.

Hypocotyl erect, terete, sometimes brownish just above soil, pale green in upper portion, up to 3 cm. long, 1·7 to 2·3 mm. thick at base, ·8 to 1 mm. at apex, swelling suddenly into the root, which in the case of No. 2, Plate I, reached a length of 10 cm. in a few days, glabrous.

Cotyledons sessile, sagittate, ovate, soon becoming revolute, and cylindrical, 8 mm. long, 4 to 4·5 mm. broad, outer or underside at first pale yellow, becoming pale green, with a ridge about 1 mm. wide along central portion; upperside at first pale green, becoming dark green, glabrous.

Stem terete, hispid; becoming scabrous in upper portion. First internode ·5 to 1 mm.; second 5 mm. to 2·5 cm.; third 5 mm. to 1·2 cm.; fourth 2 to 5 mm.; fifth 2 to 9 mm.; sixth 2 to 7 mm., varying in different individuals.

Leaves—No. 1. Abruptly pinnate, petiole 6 mm. to 1·4 cm. long, green, pilose; leaflets four to five pairs, oblong, acuminate, often mucronate, midrib and secondary vein usually distinct, 6 mm. to 1·1 cm. long, 2·5 to 4 mm. broad, upperside green, underside paler, glabrous; rachis 1·7 to 2·6 cm. long, green, sometimes glabrous or with a very few scattered hairs, excurrent.

No. 2. Abruptly bipinnate, petiole dilated, with a strong nerve along lower margin, 1·3 to 1·5 cm. long, 1 to 1·5 mm. broad, green, hoary, excurrent; leaflets three to four pairs, obovate-oblong, mucronate, 5 to 8 mm. long, 3 to 4 mm. broad, the basal leaflets often smaller, midrib and secondary vein distinct, upperside green, becoming brownish-red in winter months, underside paler; rachis 7 mm. to 1·3 cm. long, green, pilose, excurrent; stipules reduced to scales.

Nos. 3, 4, 5 and 6. Abruptly bipinnate, petiole dilated vertically, about the same as in No. 2, and with a similar strong lower marginal nerve extending to the base of the pinnæ, 8 mm. to 1·4 cm. long, hoary to hispid; leaflets three to four pairs, similar to those of No. 2; rachis pilose to hispid, excurrent; stipules reduced to scales about 1 mm. long.

No. 7 or 8 and upwards. Usually phyllodes.

The petiole of the first bipinnate leaf of this species shows a distinct transition stage towards the development into the subsequent phyllodes.

UNINERVES—Angustifoliæ.

ACACIA STRICTA, Willd. Seeds from Homebush, near Sydney. Growing on Wianamatta Shale formation. (Plate I, Numbers 4 to 7.)

Seeds black, oblong to oval-oblong, 3 to 4 mm. long, 2 mm. broad, 1·2 mm. thick.

Hypocotyl erect, terete, creamy, becoming pale green to pale pink, 1·4 to 2·6 cm. long, 1 to 1·5 mm. thick at base, ·5 to 1 mm. at apex, glabrous.

Cotyledons sessile, slightly sagittate, oblong, apex rounded, 5 to 6 mm. long, 2 mm. broad, remaining on the plants, in many cases, until the phyllodes appear, outer or underside pinkish-green, becoming green, upperside green, glabrous.

Stem terete, green, sometimes becoming reddish on sunny side, glabrous. First internode ·5 to 1 mm.; second 1·5 to 7 mm.; third 1 mm. to 2·7 cm.; fourth 3 mm. to 2·5 cm.; fifth 2 mm. to 1·8 cm.; sixth 6 mm. to 2 cm.; seventh 1·2 cm. to 2·1 cm.

Leaves—No. 1. Abruptly pinnate, petiole slender, from 6 mm. to 1·1 cm. long, pale green, glabrous; leaflets three pairs, oblong, acuminate, 5 to 6 mm. long, 1·5 to 2 mm. broad, the basal pair often narrower, midrib and sometimes two short veins, one on either side, showing under pocket lens, making the leaflet trinerved at the base, upperside green, underside paler; rachis 6 to 7 mm. long, glabrous, excurrent; stipules minute.

No. 2. Abruptly bipinnate, 1·1 to 2 cm. long, green, glabrous, excurrent; leaflets three to four pairs, oblong, acuminate, the terminal pair being sometimes obovate; rachis 7 mm. to 1·1 cm. long, glabrous, excurrent; stipules reduced to scales and soon falling.

No. 3. Abruptly bipinnate, petiole slender, 2 to 2·7 cm. long, glabrous, excurrent; leaflets four to five pairs, often mucronate; rachis glabrous, excurrent; stipules 1 mm. long, soon falling.

Nos. 4 and 5. Abruptly bipinnate, petiole from 1·7 to 2·5 cm. long, No. 5 being sometimes dilated and with a strong nerve along the lower margin from the stem to the base of the pinnæ; leaflets five to six pairs.

Nos. 6 and 7. Usually abruptly bipinnate, petiole vertically flattened, 2·2 to 3·3 cm. long, 2 to 3 mm. broad, No. 6 having a strong nerve along the lower margin, with the dilated lamina on the upper edge, while No. 7 may have the prominent vein slightly removed from the lower margin, and a fine vein towards the upper edge confluent with the prominent nerve at both ends. No. 7 is sometimes a phyllode.

Nos. 8, 9 and 10. Phyllodes, having a prominent nerve below the central portion of the lamina, and a fine nerve extending along the upper part. These veins are confluent at the base, but not at the apex, the upper or fine vein not extending quite to the apex of the phyllode. When the trees reach maturity this fine vein is not seen though it is very distinct in seedlings, and Bentham describes the phyllode of this species as "1-nerved."[1] This feature is suggestive of the possibility that the ancestor of this species was bi-nerved, from which a 1-nerved form has been developed. See also description of *Acacia binervata, (infra).*

UNINERVES—Racemosæ.

ACACIA FALCATA, Willd. Seeds from Homebush. Growing on Wianamatta Shale formation. (Plate II, Numbers 1 to 2*a*.)

Seeds black, oval, 4 to 4·5 mm. long, 2·5 to 3 mm. broad, 1·2 mm. thick.

Hypocotyl erect, terete, reddish-brown, 1 to 3·2 cm. long, 1 to 1·4 mm. thick at base, ·4 to ·8 mm. at apex, glabrous.

Cotyledons sessile, slightly sagittate, oblong, apex rounded, 6 mm. long, 3 mm. broad, soon becoming revolute and cylindrical, falling off in a few weeks; outer or underside brownish, becoming green, upperside green, glabrous.

Stem terete, greenish-brown, glabrous. First internode ·5 mm.; second 2 to 5 mm.; third 3 to 8 mm.; fourth 4 mm. to 1·5 cm.; fifth 5 mm. to 2·7 cm.

Leaves—No. 1. Abruptly pinnate, petiole 4 to 5 mm. long, reddish-green, glabrous; leaflets three to four pairs, oblong-lanceolate, acuminate, 6 to 9 mm. long, 2 to 2·5 mm. broad, midrib distinct, upperside green, glabrous, underside pale green; rachis 5 mm. to 1 cm. long, green, glabrous, excurrent.

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[1] B. Fl., Vol. II, p. 359.

No. 2. Abruptly bipinnate, petiole 1·2 to 2 cm. long, terete, or sometimes slightly channelled above, glabrous, excurrent; leaflets four to five pairs, midrib distinct, secondary vein showing under pocket lens.

No. 3. Abruptly bipinnate, petiole 2 to 3 cm. long, usually vertically flattened, up to 1 mm. wide, with a strong nerve along the lower margin, and a finer one bordering the upper margin; leaflets four to six pairs, the terminal pair generally obovate, and the number of leaflets on the pinnæ often unequal; rachis 1·4 to 2·5 cm., glabrous, excurrent.

No. 4. Abruptly bipinnate, petiole 2·1 to 4 cm. long, vertically flattened, up to 2·5 mm. wide, sometimes with a strong nerve along the lower margin extending to the base of the pinnæ, and confluent with a finer nerve along the upper margin, or sometimes with the strong nerve extending along just below the centre line of the lamina, the upper margin of the lamina being bordered with a fine nerve, leaflets seven to eight pairs; rachis 2·3 to 3·2 cm. long.

Nos. 5, 6 and 7. Lanceolate-falcate phyllodes with one prominent nerve extending along above the centre of the lamina, thus leaving the greater portion of the leaf-blade on the lower side, which is unusual in the early phyllodes of species of uninerved Acacias.

UNINERVES—Racemosæ.

ACACIA PENNINERVIS, Sieb. Seeds from Glen Innes, N.S.W. (J. H. Maiden). (Plate II, Numbers 3 to 4*a*.)

Seeds black, oblong-oval to ovate, 7 mm. long, 3·5 to 4 mm. broad, 2 mm. thick.

Hypocotyl erect, terete, light-red to brownish-red, becoming darker, up to 1·8 cm. long, 2 to 3 mm. thick at base, 1 to 1·5 mm. at apex, glabrous.

Cotyledons sessile, sagittate, oblong, apex rounded, 9 mm. long, about 3·7 mm. broad, at first erect, becoming horizontal in two or three days, revolute and cylindrical in a week, falling in about two weeks, outer or underside brownish-red, slightly convex, with sometimes one or two whitish glands; upperside brownish-red but paler than underside, glabrous.

Stem terete, brownish-green to reddish-green, glabrous. First internode ·5 mm.; second 3 mm. to 1·7 cm.; third 4 to 8 mm.; fourth 7 mm. to 1·3 cm.; fifth 6 mm. to 2·7 cm.; sixth 1·1 to 3·6 cm.; seventh 1·6 to 2 cm.

Leaves—No. 1. Abruptly pinnate, sometimes showing as soon as the cotyledons have left the soil, petiole 4 to 7 mm. long, reddish-brown, glabrous; leaflets four to five pairs, oblong, acuminate, often mucronate, 8 mm. to 1 cm. long, 2·5 to 3 mm. broad, midrib and secondary vein distinct, upperside green, glabrous, underside pale green; rachis 1·3 to 1·7 cm. long, green, glabrous, excurrent.

No. 2. Abruptly bipinnate, petiole 7 mm. to 1·3 cm. long, sometimes with very small gland about 3 to 5 mm. from base, glabrous, excurrent; leaflets four to five pairs, pinnæ sometimes having an unequal number of leaflets.

No. 3. Abruptly bipinnate, petiole 1·5 to 2 cm. long, sometimes with very small gland on upper edge about 3 to 6 mm. from base, excurrent; leaflets five to seven pairs; stipules about 1 mm. long, pubescent.

No. 4. Abruptly bipinnate, petiole 2 to 2·4 cm. long, sometimes slightly channelled above, with a small gland about 5 mm. from base; leaflets six to eight pairs; stipules as in No. 3.

No. 5. Abruptly bipinnate, petiole 2·3 to 3·1 cm. long, with strong nerve along lower margin, channelled above, sometimes vertically flattened, and having a gland about 4 to 5 mm. from base; leaflets eight to ten pairs; rachis 2·5 to 3·6 cm. long, excurrent; stipules as in Nos. 3 and 4.

No. 6. Sometimes a phyllode, or abruptly bipinnate, with petiole similar to No. 5; leaflets nine to ten pairs; rachis 3·3 to 4 cm. long.

No. 7. Either a phyllode, or abruptly bipinnate, petiole vertically flattened to 7 mm. broad, the upper margin convex, with a strong nerve or "midrib" extending along the lower portion of the lamina, and usually a short, fine, rather insignificant vein terminating in the upper marginal gland about 5 to 7 mm. from base, the margins nerve-like, the whole blade having a system of lateral anastomosing veins; leaflets ten to eleven pairs; rachis about 4·5 cm. long.

Nos. 8 and upwards. Phyllodes.

UNINERVES—Racemosæ.

ACACIA MABELLÆ, Maiden,[1] "Black Wattle." Seeds from Milton, N.S.W. Growing on a moderately siliceous soil. (Plate II, Numbers 5 to 7).

Seeds black, oval, 4 to 5 mm. long, 3 mm. broad, 2 mm. thick.

Hypocotyl erect, terete, brownish-red, 1·8 to 3 cm. long, 1·5 to 2·4 mm. thick at base, ·5 to 1 mm. thick at apex, glabrous, often suddenly constricted just above soil.

Cotyledons sessile, sagittate, oblong, apex rounded, 5 to 6·5 mm. long, 2·5 to 3 mm. broad, at first erect, but becoming revolute and cylindrical in a few days, soon falling, outer or underside brownish-red, often with ridge along centre, upperside brownish-green, glabrous.

Stem terete in lower portion, but becoming angular where leaf-stalks are decurrent on the stem, brownish-green, glabrous, or at first with a few scattered hairs which soon

[1] This Journal, Vol. XLIX, (1915), p. 471.

disappear. First internode ·5 mm.; second 2 mm. to 1 cm.; third 2 mm. to 1·8 cm.; fourth 3 mm. to 5 cm.; fifth 3 mm. to 3·2 cm.; sixth 2 mm. to 3·1 cm.; seventh 3 mm. to 5 cm.; eighth 3 mm. to 5 cm.; varying very much in different individuals.

Leaves—No. 1. Abruptly pinnate, petiole 2 to 8 mm. long, reddish-green, becoming brownish-red, glabrous; leaflets four to five pairs, in twenty cases the leaflets were four, and in three cases there were five, oblong, acuminate, often mucronate, 6 mm. to 1·1 cm. long, 2·5 to 3·7 mm. broad, upperside green, underside often red, sometimes becoming pale green, midrib very distinct on underside, often remaining of a red colour, secondary vein showing under pocket lens; rachis 5 mm. to 1·6 cm. long, green, glabrous, excurrent.

No. 2. Abruptly bipinnate, petiole 6 mm. to 1·4 cm. long, green to brownish-red, with a few scattered hairs, and often with a very small gland about 4 mm. from base, excurrent; leaflets four to six pairs, the basal pair sometimes very small; rachis glabrous.

No. 3. Abruptly bipinnate, petiole usually slightly dilated, 1 to 3·3 cm. long, green to brownish-green, with a few scattered hairs, and a small gland about 5 mm. from base, also a strong nerve along lower margin, excurrent; leaflets four to seven pairs; stipules little more than scales.

No. 4. Abruptly bipinnate, petiole slightly dilated, 1·7 to 4·8 cm. long, with prominent nerve either along lower margin, or below centre line of lamina, and gland on upper margin; leaflets up to eleven pairs; rachis 2·2 to 4·2 cm. long; stipules as in No. 3.

Nos. 5 and 6. Abruptly bipinnate, petiole 2·5 to 5·8 cm. long, vertically flattened, with prominent nerve extending along just below centre line of lamina, and gland on upper margin about 5 mm. from base; rachis from 3 to 4 cm. long.

No. 7. Abruptly bipinnate, petiole up to 5 cm. long, vertically flattened, 2·5 mm. broad, with prominent central vein, nerve-like margins, and gland on upper margin; leaflets up to fourteen pairs; rachis up to 4 cm. long, excurrent.

No. 8. Often a phyllode up to 14 cm. long, 4 mm. broad, with prominent central nerve, and gland on upper margin about 5 mm. from base, and usually with an insignificant vein from the gland to the central nerve near the base, as in the case of *A. penninervis*, as though the upper nerve-like margin is partly deflected from the gland towards the base.

In one case all leaves up to No. 15 were abruptly bipinnate, the petiole of No. 15 being 9·5 cm. long, rachis 2·7 cm.

Uninerves—Racemosæ.

Acacia pravissima, F.v.M. Seeds from Cotter River, Federal Capital Territory, Canberra. (Plate III, Numbers 1 to 2*a*.)

Seeds black, oblong-oval, 3 to 4 mm. long, 2 to 2·5 mm. broad, 1 mm. thick.

Hypocotyl erect, terete, sometimes pink just below surface of soil, upper portion pinkish-green, about 1·7 cm. long, 1·5 mm. thick at base, 1 mm. at apex, glabrous.

Cotyledons sessile, sagittate, oblong, apex rounded, about 5 mm. long, 2 to 3 mm. broad, at first erect but becoming horizontal in about a week, and later revolute, outer or underside pale green, with sometimes a raised central nerve or ridge, upperside green, glabrous.

Stem terete, pinkish-green in lower portion, pale green above, hirsute. First internode ·5 mm.; second 2 to 3 mm.; third about 5 mm.; fourth about 6 mm.; fifth 6 to 7 mm.; sixth 5 to 6 mm.; seventh 6 to 7 mm.

Leaves—No. 1. Abruptly pinnate, petiole about 3 mm. long, glabrous; leaflets three pairs, about 5 mm. long, 2mm.

broad, oblong, acuminate, the terminal pair often obovate, light green on both sides, midrib and secondary vein showing clearly under pocket lens, especially on underside; rachis about 5 mm. long, glabrous, excurrent.

No. 2. Abruptly bipinnate, petiole 3 to 4 mm. long, pilose, excurrent; leaflets four pairs; rachis, glabrous, excurrent.

Nos. 3 and 4. Abruptly bipinnate, petiole about 4 to 6mm. long, pilose to hispid, excurrent; leaflets four to five pairs, mucronate; rachis pilose, excurrent; stipules reduced to scales.

Nos. 5 and 6. Abruptly bipinnate, petiole about 5 to 8 mm. long, slightly dilated, with nerve along lower margin, pilose to hispid, varying in degree on different plants; leaflets five to six pairs; rachis with a few scattered hairs.

Nos. 7 and 8. Abruptly bipinnate, petiole about 6 mm. to 1 cm. long, vertically flattened up to 2·5 mm. broad, with strong nerve along or near lower margin, and sometimes with a very small gland showing below middle of upper margin, while in other cases the gland is absent, pilose to hispid, excurrent; leaflets five to seven pairs; rachis glabrous or with a few scattered hairs.

Nos. 9 to 11. These, on some plants, may be phyllodes, or they may be abruptly bipinnate, and similar to Nos. 7 and 8 on others, with considerable development of lamina above the prominent nerve, and showing the secondary and lateral veins which appear in the phyllodes, margins pilose, excurrent.

Nos. 12 and upwards. Usually phyllodes, showing an abnormal development of lamina above the prominent nerve, which latter corresponds with the lower marginal nerve of the bipinnate leaves. The excurrent point of the petioles has developed into the mucronate point of the phyllodes, whose lower margins are sometimes pilose. The gland may be present on the upper margin of some of the phyllodes, but absent from others, while on the phyllodes of the mature tree from which these seedlings were raised the gland is always conspicuous.

UNINERVES—Racemosæ.

ACACIA MYRTIFOLIA, Willd. Seeds from Cheltenham, New South Wales, growing on Hawkesbury Sandstone formation, and from Aldgate, South Australia. (Plate III, Numbers 3 to 5*a*.)

Seeds shiny brown, oblong, about 3 to 3·5 mm. long, 2 mm. broad, 1·5 mm. thick.

Hypocotyl erect, terete, brownish-red, 1 to 2·2 cm. long, 1·3 to 1·8 mm. thick at base, ·6 to 1 mm. at apex, glabrous.

Cotyledons sessile, sagittate, oblong, 4 to 5 mm. long, 2 mm. broad, remaining erect until they fall, in about ten days, outer or underside brownish-red, slightly convex, upperside brownish-red but paler than underside, glabrous.

Stem terete in lower portion, angular above where affected by decurrent leaf-stalks, reddish-brown, glabrous. First internode ·5 mm.; second 2 mm. to 1·7 cm.; third 2 mm. to 1·4 cm.; fourth 3 mm. to 1·1 cm.; fifth 5 mm. to 2·2 cm.; sixth 4 mm. to 1·4 cm.; seventh 4 mm. to 2·6 cm.

Leaves—Nos. 1 and 2. Abruptly pinnate, forming an opposite pair, petiole slender, from about 3 mm. to 1 cm. long, brownish-red, glabrous; leaflets usually two pairs, rarely three, out of forty pairs of leaves counted, thirty-eight had two pairs of leaflets on each pinna, while of the other two pairs of leaves each had two pairs of leaflets on one pinna and three on the other, (Plate III, No. 5) oblong, acuminate, up to 6 mm. long, and 2·5 mm. broad, midrib and secondary vein showing under pocket lens, upperside green to pale green, sometimes tinged with red, underside reddish-green, to red; rachis 2 to 5 mm. long, glabrous, excurrent.

No. 3. Abruptly bipinnate, petiole slender, from about 6 mm. to 2·5 cm. long, green to reddish-brown, glabrous, excurrent; leaflets three to four pairs, the terminal pair usually obovate; rachis glabrous, excurrent.

Nos. 4 and 5. Abruptly bipinnate, petiole from 6 mm. to 2·6 cm. long, channelled above, small gland about the middle, glabrous, or with a few scattered hairs along edges; leaflets three to four pairs; rachis 6 mm. to 2·7 cm. long.

No. 6. Abruptly bipinnate, sometimes with two pairs of pinnæ, petiole slightly flattened vertically with strong vein along lower margin, and small gland about or below the middle on upper margin, 1·2 to 3·2 cm. long; leaflets four to five pairs; rachis 8 mm. to 2·7 cm. long.

Nos. 7 and 8. These may be phyllodes, but on some plants are abruptly bipinnate, petiole up to 2·8 cm. long, vertically flattened, with strong midrib; leaflets up to six pairs.

Some seedlings of this species flowered freely, and also set fruit, at two years and two months old.

PLURINERVES—Dimidiatæ.

ACACIA BINERVATA, DC., "Two-Veined Hickory." Seeds from Tomerong (J. C. Grant). Growing on a moderately siliceous soil. (Plate III, Numbers 6 to 8.)

Seeds black, obovate to oblong, 4 to 5 mm. long, 2·5 to 3 mm. broad, 1·5 mm. thick.

Hypocotyl erect, terete, pink to reddish-brown, 1 to 2·3 cm. long, 1·2 to 1·7 mm. thick at base, ·5 to ·8 mm. at apex, glabrous.

Cotyledons sessile, sagittate, oblong, apex rounded, 6 mm. long, 3 mm. broad, soon becoming revolute, and later cylindrical, falling in about two weeks, outer or underside, straw-coloured to pink, sometimes becoming brown, often with a central ridge, upperside green, glabrous.

Stem terete in lower portion, angular above, where affected by decurrent leaf-stalks, glabrous. First internode ·5 mm.; second 6 mm. to 2·7 cm.; third 2 to 9 mm.; fourth 3 mm. to 1·6 cm.; fifth 4 mm. to 1·2 cm.; sixth 4 to 7 mm.; seventh 5 mm. to 1·4 cm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 5 mm. long, green, becoming brown, glabrous, or with a few scattered hairs; leaflets four to five pairs, oblong-lanceolate, acuminate, often mucronate, 7 to 8 mm. long, the terminal pair shorter and sometimes obovate, upperside green, underside reddish, becoming green, margins red, midrib distinct, secondary vein showing under pocket lens; rachis 8 mm. to 1·4 cm. long, green, glabrous, excurrent, stipules reduced to scales.

No. 2. Abruptly bipinnate, petiole 6 mm. to 1·2 cm. long, green, becoming reddish, pilose, excurrent; leaflets four to five pairs. (Leaf No. 2 is missing from Number 7, Plate III).

Nos. 3 and 4. Abruptly bipinnate, petiole 7 mm. to 2 cm. long, channelled above, and sometimes dilated, with strong nerve along lower margin, faintly pilose; leaflets six to eight pairs; rachis of No. 4 1·7 to 2·4 cm. long, excurrent.

Nos. 5 and 6. Abruptly bipinnate, petiole 1·3 to 4 cm. long, vertically flattened, the upper margin being convex, the lamina of No. 6 may be 2 cm. broad, with a strong nerve a little above the lower margin and running from the plant-stem to the base of the pinnæ, above this nerve are two others extending from the base almost to the margin, the remainder of the lamina being pinnately veined; leaflets up to nine pairs.

Nos. 7 and 8. These may be abruptly bipinnate, with vertically flattened petioles from 2 to 3·3 cm. long, 2 cm. broad, and having up to eleven pairs of leaflets; or they may be phyllodes, usually triplinerved, the third or upper one scarcely reaching the margin, while the second may sometimes be confluent with the first or lower vein at both ends, but this latter feature is noticed less in the later phyllodes. The first phyllode in Number 7, Plate III, has a fourth vein above the others, extending from the base to nearly the middle of the upper margin. The small insignificant vein extending from the gland towards the base may be seen in phyllodes of this species as in those of *A. penninervis* and *A. Mabellœ.*[1]

Bentham describes the phyllodes of *A. binervata* as having two or three longitudinal nerves. The mature phyllodes are usually 2-nerved, and this fact, as in the somewhat similar case of *A. stricta*, *(supra)*, is suggestive of the possibility that, as the species developed, it reduced the number of veins in the phyllodes.

Plurinerves—Juliforæ—Falcatæ.

Acacia Maideni, F.v.M., "Sally." Seeds from Milton. Growing on a moderately siliceous soil. (Plate IV, Numbers 1 to 3.)

Seeds black, oval-oblong, 4 mm. long, 3 mm. broad, 1·5 to 2 mm. thick.

Hypocotyl erect, terete, pale green, up to 2·5 cm. long, 2 mm. thick at base, ·5 to 1 mm. thick at apex, glabrous.

Cotyledons sessile, slightly auricled, oval-oblong, about 6 mm. long, 3 mm. broad, outer or underside at first yellowish-green, becoming pale green, with one or two raised lines along centre, upperside at first yellowish-green, becoming dark green within a week, glabrous.

On one plant the cotyledons were fused along one side, and appeared as one, almost encircling the stem, the line of fusion being undiscernible.

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[1] See "The Forest Flora of N.S.W.," by J. H. Maiden, Part xxv, pl. 95.

Stem terete, green, at first faintly pilose, becoming glabrous. First internode ·5 to 1·5 mm.; second 1 mm. to 1 cm.; third 3 mm. to 1 cm.; fourth 3 to 6 mm.; fifth 2 to 4 mm.; sixth 3 to 5 mm.; seventh 3 mm. to 1 cm.; eighth 5 mm. to 1·6 cm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 7 mm. long, green, glabrous; leaflets three pairs, oblong-lanceolate, basal or largest pair up to 9 mm. long, 3 mm. broad, upper-side green, underside paler, with midrib distinct, sometimes raised, secondary vein showing under pocket lens; rachis 6 mm. to 1 cm. long, green, glabrous, excurrent.

Nos. 2 and 3. Abruptly bipinnate, petiole 7 mm. to 1·3 cm. long. No. 3 sometimes channelled above and with strong nerve along lower margin, excurrent; leaflets three to four pairs; stipules little more than scales.

Nos. 4 and 5. Abruptly bipinnate, petiole 1 to 1·5 cm. long, vertically flattened, with prominent nerve just above lower margin; leaflets four to five pairs; rachis 7 mm. to 1·5 cm., glabrous, excurrent; stipules about 1 mm. long.

Nos. 6 and 7. Abruptly bipinnate, petiole 1·7 to 4 cm. long, vertically flattened, similar to Nos. 4 and 5, but with one or two fine veins parallel to the prominent nerve; leaflets four to six pairs; rachis 1 to 2·2 cm.; stipules about 1 mm. long, pointed.

Nos. 8 and 9. Abruptly bipinnate, petiole 4 to 5·3 cm. long, vertically flattened, 3 mm. broad, with a prominent, almost central nerve from the plant-stem to the base of the pinnæ, giving the leaf, at a little distance away, the appearance of a uninerve, but with several fine parallel veins visible on closer inspection.

Nos. 10, 11 and 12. Often abruptly bipinnate, petiole up to 10 cm. long, 3·5 mm. broad, with prominent central nerve and several fine veins on each side.

In the winter months the exposed sides of the flattened petioles and young phyllodes often become purple. Tips of young phyllodes are often brownish-purple.

BIPINNATÆ—Botryocephalæ.

ACACIA PUBESCENS, R. Br. Seeds from Lidcombe, near Sydney. Growing on Wianamatta Shale formation, often among small ironstone pebbles. (Plate IV, Numbers 4 to 6.)

Seeds black, oval, 3 to 4 mm. long, 2 to 3 mm. broad, 1·5 mm. thick.

Hypocotyl erect, terete, pale pink to pale brown, up to 2·2 cm. long, 1 mm. thick at base, ·5 to ·9 mm. at apex, glabrous.

Cotyledons sessile, very slightly auricled, oblong, apex rounded, 5 to 6 mm. long, 2 to 2·5 mm. broad, becoming horizontal, revolute and cylindrical, falling in a few weeks, outer or underside brown, with central ridge, upperside reddish to green, glabrous.

Stem terete, hirsute. First internode ·5 mm.; second 1 to 5 mm.; third 3 mm. to 1·4 cm.; fourth about 5 mm.; fifth 3 mm. to 1 cm.

Leaves—No. 1. Abruptly pinnate, petiole 3 to 7 mm. long, reddish-green, glabrous or faintly pilose; leaflets three to four pairs, obovate-lanceolate 4 to 9 mm. long, 1·5 to 2·5 mm. broad, midrib showing under pocket lens, upperside green, glabrous, underside reddish, becoming reddish-green; rachis 3 mm. to 1·1 cm. long, glabrous or with a few scattered hairs, excurrent; stipules small.

Nos. 2 and 3. Abruptly bipinnate, petiole pilose to hispid, 6 mm. to 1·2 cm. long, reddish to reddish-brown, excurrent; leaflets four to seven pairs, the terminal pair opposite, the remainder often alternate, upperside green, underside pale green; rachis 4 mm. to 1·2 cm. long, pilose; stipules small.

Nos. 4, 5 and 6. Abruptly bipinnate, petiole hispid; pinnæ one to several pairs; rachis pilose to hirsute.

EXPLANATION OF PLATES.

PLATE I.

Acacia triptera, Benth.

1. Cotyledons, pinnate leaf, bipinnate leaves, and phyllodes. Howell. (T. S. McCrae.)

1a. Pod and seeds.

Acacia hispidula, Willd.

2. Cotyledons. Cheltenham.
3. Pinnate leaf, bipinnate leaves and phyllodes.

3a. Pod and seeds.

Acacia stricta, Willd.

4. Cotyledons, pinnate leaf and young bipinnate leaves. Homebush.
5. Pinnate leaf, bipinnate leaves and phyllodes.
6. Two-nerved phyllodes.
7. Pod and seeds.

PLATE II.

Acacia falcata, Willd.

1. Cotyledons, with pinnate leaf showing. Homebush.
2. Pinnate leaf, bipinnate leaves and phyllodes.

2a. Pod and seeds.

Acacia penninervis, Sieb.

3. Cotyledons, with pinnate leaf showing. Glen Innes. (J. H. Maiden.)
4. Pinnate leaf, bipinnate leaves and phyllodes.

4a. Seeds.

Acacia Mabellæ, Maiden.

5. Cotyledons, with pinnate leaf showing. Milton.
6. Pinnate leaf, bipinnate leaves and phyllodes.
7. Pod and seeds.

Plate III.

Acacia pravissima, F.v.M.

1. Cotyledons. Cotter River, Canberra.
2. Pinnate leaf, bipinnate leaves and phyllodes.

2a. Pod.

Acacia myrtifolia, Willd.

3. Cotyledons and opposite pair of pinnate leaves. Aldgate, South Australia.
4. Cotyledons and opposite pair of pinnate leaves. Cheltenham, New South Wales.
5. Opposite pair of pinnate leaves, bipinnate leaves and phyllodes. Cheltenham.

5a. Pod and seeds.

Acacia binervata, DC.

6. Cotyledons. Tomerong. (J. C. Grant).
7. Pinnate leaf, bipinnate leaves (one pinna dropped from the last bipinnate leaf), and phyllodes.
8. Pod and seeds.

Plate IV.

Acacia Maideni, F.v.M.

1. Cotyledons. Milton.
2. Pinnate leaf, bipinnate leaves and phyllodes.
3. Spirally twisted pod and seeds.

Acacia pubescens, R. Br.

4. Cotyledons and young pinnate leaf. Lidcombe.
5. Pinnate and bipinnate leaves.
6. Pod.

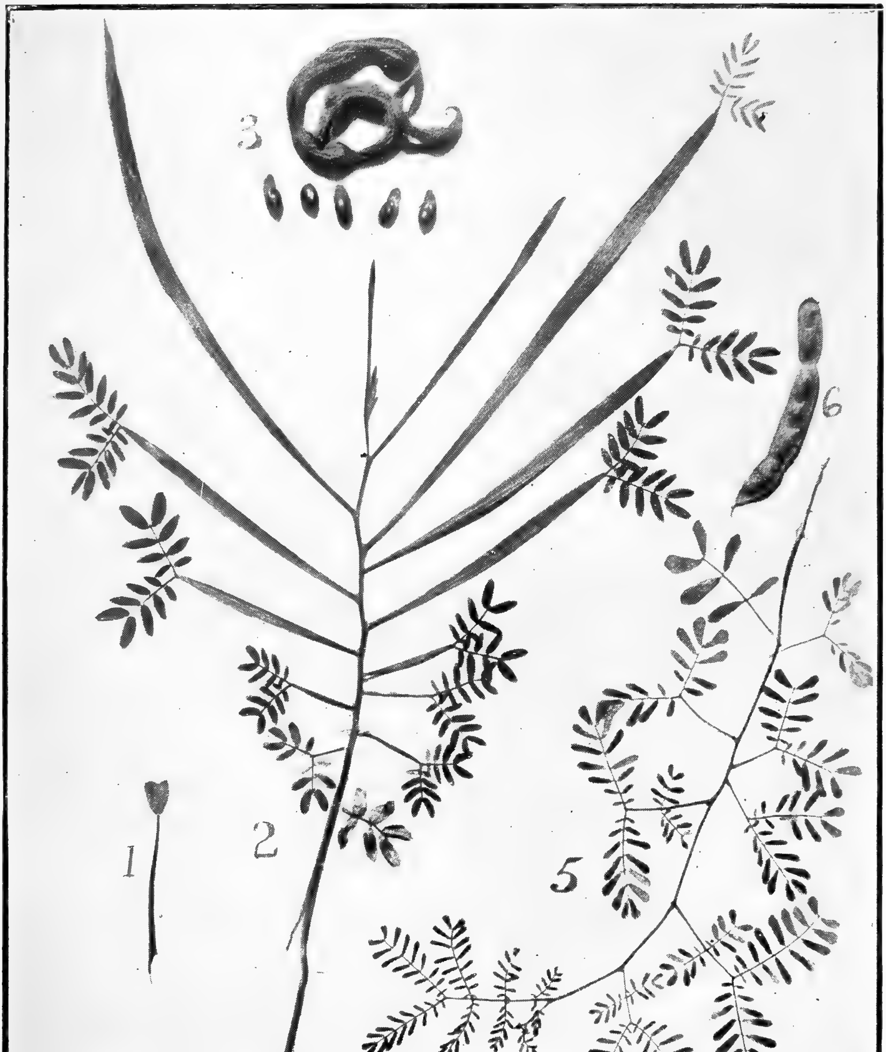
Acacia triptera (1 and 1*a*); *A. hispidula* (2 to 3*a*); *A. stricta* (4 to 7).

Slightly over two-thirds natural size.

Acacia falcata (1 to 2*a*); *A. penninervis* (3 to 4*a*); *A. Mabellæ* (5 to 7).
Slightly over half natural size.

Acacia pravissima (1 to 2*a*); *A. myrtifolia* (3 to 5*a*); *A. binervata* (6 to 8).

Three-fourths natural size.



Acacia Maideni (1 to 3); *A. pubescens* (4 to 6).

Two-thirds natural size.

SHORELINE STUDIES AT BOTANY BAY.

By E. C. Andrews, B.A., F.G.S.

With Plates V, VI.

[*Read before the Royal Society of N. S. Wales, September 6, 1916.*]

The writer has had one special shoreline under observation, namely, Lady Robinson's Beach, Sydney, New South Wales, during the past seven years, and it has seemed advisable to epitomise the main facts there noted during that period. The observations made from 1909 to 1912 inclusive, have been recorded[1] elsewhere.

The Beach—The summary of the observations over the *whole period* (1909 – 1916) may be presented here. The littoral zone under consideration is a bay, and not an ocean, type.[2] It is between four and five miles in length; its disposition is almost north and south; and it is sub-parallel to the neighbouring ocean shoreline. A line midway between Botany Heads and drawn at right angles to the general trend of the main coastline, would bisect Lady Robinson's Beach approximately. The heads are a mile apart, and they lie about six miles east of the centre of the subject beach. The bay is shallow with a greatest depth of one hundred feet approximately between the heads.

The beach terminates against George's River on the south and Cook's River on the north. In recent time these two streams discharged as one into the sea, but the lower portions of their valleys have been drowned to the amount of 200 feet, approximately, and the bay has been formed by this submergence.

[1] Andrews, E. C., Beach Formations at Botany Bay. This Journal, Vol. xlvi, 1912, pp. 158 – 185.

[2] Andrews, E. C., *op. cit.* See map accompanying paper.

The beach, as viewed from the bay, appears to be one flat curve, but viewed from any point along the beach itself it may be seen to be composed of several flat curves, which apparently have been determined by the interference of currents generated both within the bay itself and the two saltwater arms mentioned. The northernmost curve is about two and a half miles, and the one immediately adjoining it to the south is one mile in length, while the remaining mile of beach to the south is broken by three small curves. For a generation at least these small salients or cuspate forelands have been stationary, according to the testimony of old and reliable inhabitants. The earlier shoreline of the bay formed at the close of the recent submergence, lies from 1000 to 1400 yards inland of the present beach. The old cliffs of erosion are now subdued, and a creek, with swamps, drains the portion along this older shoreline. Thence to the present beach the land consists of long sand ridges and troughs the longer axes of which are subparallel to the direction of the beach while the summits of the ridges rise to accordant heights. The sand dunes immediately behind, or landward of, the beach, form accumulations on the sub-horizontal surface of the parallel sand bars.

The Winds—The prevailing winds are from the north-east quarter, but the dominant winds blow from the south to east quarter. In the winter the prevailing wind is westerly, or a land wind, causing smooth water on the beach under consideration; in summer mild to strong north-east winds cause choppy waves on the beach; local "Southerlies" affect the area after periods of warm weather, while storms blow at rare intervals from the south-east and south-west quadrants. These occur generally as south and south-east gales at a short distance off the coast and heavy waves are forced through the Botany heads on to the subject beach. The waves generated either in the bay or in the ocean do not strike Lady Robinson's Beach squarely, but reach the northern point about a minute earlier than the southern one. The small cuspate forelands which break up the otherwise simple curvature of the southern portion of the beach experience the breaking of the wave a little before those portions which lie immediately to the north. With these insignificant local exceptions, the wave, as it is traced southwards, may be said to lag behind the northern portions in a uniform manner, the rate of travel from north to south, however, of the intersections of the breaking wave with the beach being very great.

Cusps or Scallops—It was noted that during periods of strong local north-east and south-east winds, or indeed, of winds which acted along rather than at right angles to the beach, that neither beach cusps nor scallops were formed, but instead of such forms, a smooth beach was made with a ledge of erosion marking the maximum advance of the waves,[1] the position and height of the ledge depending upon the strength of the wind and the height of the high tide. The influence of a strong local wind upon a heavy ground swell was insignificant, however. While a heavy storm was at its height no scallops were seen. The heavier the storm on Lady Robinson's Beach, the flatter the beach and the higher was it piled in its central portions. Directly, however, the maximum strength of the waves had gone, the beach became scalloped with cusps, the sizes of which were approximately proportional to the heights of the waves. The larger axes of these cusps varied in direction according to the direction of approach of the storm waves and the direction of the wind, but it was always noted that the cusps were arranged in sets, and that these sets had a definite relationship to the configuration of the beach. Thus the main southern salient was only once observed to have

[1] Andrews, E. C., *Op. cit.*

been scalloped and the strand at the tiny indentation to the immediate north never appears to have been scalloped. Nevertheless, thence to the north the cusps were very prominent, but at another point almost in the central portion of the northern or main arc of the beach, a space about 150 to 200 yards in length was cuspless, whereas north and south of this length of smooth beach the cusps might be traced gradually through insignificant markings to deep and well-spaced examples.

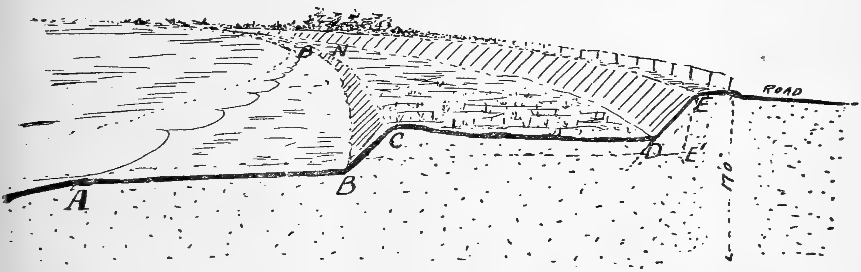
During the seven years of observation it was noted also, in periods of offshore winds, that the breaking waves or wavelets generated whole series of interfering circles or curves which travelled up the beach in geometrical patterns. These patterns were similar to those produced on a smooth pond by throwing stones into it simultaneously at regularly-spaced intervals along a line or zone. It was noted in every case that the interfering circular or curved ridges and troughs were larger and higher in proportion to the height of the breaking wave.

It was considered finally that the breaking wave might be considered as a number of unit columns of falling water, which were urged or impelled onward again by the unexpended energy of the wave portion which had not actually broken. In proportion to the height and volume of the breaking wave, so would be the energy of the interferences between the falling or cascading columns of water, and these would arrange themselves into regularly-spaced interferences of major importance as in the case of other varieties of rhythmical interference. In this particular case the major interferences bore a definite and simple relation to the strength of the fall of the unit columns or sections of the breaking and advancing wave, and these main interference figures were expressed on the beach as erosion and accumulation forms. From the salients, the sets were spaced with intermediate nodes of smooth beach.

The building of the beach behind the limit of the wave of normal weather.—The great storm of July 1912, as far as Lady Robinson's Beach was concerned, was really a series of great ground swells, these being pulsed into Botany Bay by the action of a tempest at some distance offshore. During the height of the storm, when so much damage was done to the beaches, the wind was actually offshore at the beach under consideration.

During this storm a cliff almost vertical and of height varying from five to fourteen feet was excavated by the waves in the sand dunes of the beach.

In Fig. 1 is depicted the general appearance of the southern portion of the beach in August 1916, more than four years after the great gale had gone. The cliff of erosion is subdued but it is easily the dominant form of the beach immediately seawards of the higher points of the sand dunes.



B C D = Terrace of accumulation.

Fig. 1.—Diagrammatic representation of shoreline profiles at Ramsgate, on southern end of Lady Robinson's Beach (September, 1916).

B B'N D C = Terrace formed beyond wave limit by blown sand and *Spinifex* since July 1912.

D E'E = Profile cut by 1912 storm.

Beneath the subdued cliff (Plates V, VI, figs. 1 and 3) a narrow terrace may be observed, about twelve to fifteen feet wide and four to six feet above ordinary high tide. To the casual observer this has a striking superficial similarity to a raised beach, nevertheless the writer has observed its actual growth as a terrace of accumulation during the past four years.

After the great storm of 1912 had excavated a high cliff in the sand dunes the winds began to pile up the sand under this cliff of erosion and beyond the reach of the waves of the period 1912–1916. At the same time a great sand-binder, namely, *Spinifex hirsutus*, commenced to send its long runners underneath the cliff of sand, and so helped to fix the sand. Little by little the sand was piled under the cliff, and little by little the Spinifex bound all together and maintained a surface approximately level. At the present rate of growth it would take a period of twenty to thirty years to obliterate the trace of the 1912 storm unless indeed, in the meantime, an onshore storm still greater than that of 1912, should visit the beach.

It was stated by certain local residents that the action of the *prevailing* north-easterly would hide the traces of the storm quickly, say, within a month or two of July 1912. The writer has always agreed with Dr. G. K. Gilbert[1] that the form of the beach has been determined by the great storm of the decade or the generation, or perhaps even of the century, and he has accordingly made test observations during a long period with the result that he considers Gilbert's principle may be accepted as established.

The accompanying brief notes may help to illustrate this point. Lady Robinson's Beach has been visited by several great gales during the past sixty years. The greatest of these, considered from the point of view of action in this bay, was the Dunbar Storm in 1857. The next in point of severity was the Dandenong Storm in September 1876, the

[1] Gilbert, G. K., "Topographic Features of Lake Shores." U. S. Geological Survey, Fifth Ann. Rept. 1883–1884, pp. 89, 90.

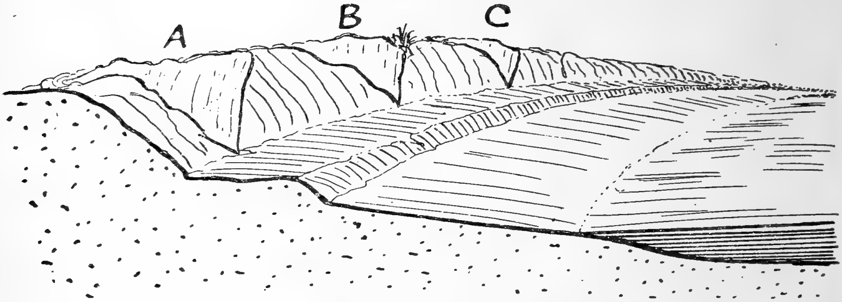
next again was the great storm of May 1889, while the storm of July 1912 was far less severe than any of those just mentioned although the waves in the bay were greater during 1912 than they had been since 1889.

The writer has only a hazy recollection of the storm of 1876, being then but five years of age, but, as a youth, he has a vivid recollection of the storm of 1889 and of its effects on the beach. According to the reliable testimony of old residents, the waves, during the 1857 and 1876 storms, sent drenching clouds of spray well inland of the sand dunes, a condition of things which was only reproduced to a slight extent during the great storm of 1889.

In Plate VII is a representation of the beach to-day near its northern end. Here the cliffs of erosion in the dunes are lower than those towards the southern and central portions of the beach. The terrace of accumulation during 1912–1916 may be seen landward of the present beach cusps; above that rises the cliff made in 1912. Above that again is the subhorizontal surface of the sand accumulated since the 1889 storm, while beyond that may be seen the action of erosion by the waves of the 1889 and 1876 storms. The writer has not been able to trace the effect of the 1857 storm on the sand dune area, and it is believed by him that it coincides practically with the erosion of the 1876 storm.

Here then is a striking confirmation of Gilbert's principle of the action of the dominant wave in the formation of the salient forms of the shoreline.

The Action of the Wind—Another highly interesting and significant point has been brought out by these simple but direct observations. The writer has never seen his way clear to the acceptance of the idea of the formation of peneplains by wind action at high levels in dense masses of heterogeneous rocks, because it has seemed to him that an eroding wind must, like other streams, take account of the varying degrees of hardness and strength in the material attacked, and that it must tend to carve ravines and valleys in the softer rocks and leave the harder masses as residuals. Furthermore it seems improbable that a wind should blow steadily over great regions with constant direction and uniform strength during a geological period so as to accomplish peneplanation.



A B C—Trenches cut by wind.

Fig. 2.—Diagram of central portion of Lady Robinson's Beach in 1915. The V-shaped trenches have been cut by wind in the subdued storm profiles of the 1912 storm.

The terrace beneath the subdued cliff is a growth since July 1912.

No sooner had the cliff been cut in the sand dunes of Lady Robinson's Beach by the storm waves of July 1912, than the unstable profile was subdued rapidly in great measure. Children in hundreds, attracted by the unaccustomed and enticing nature of the sand cliff, tumbled, cascaded, and slid, down the face until the slope was reduced rapidly to an angle less than 50° to the horizontal. The wind also attacked it vigorously, especially on the cliff edge. Many sand binders had fixed the dunes in great measure previously, for example, *Spinifex hirsutus*, *Leptospermun lœvigatum*, *Zoysia pungens*, *Correa alba*, *Mesembryanthemum equilaterale*, *Xerotes longifolia*, *Rhagodia Billiardieri*, *Imperata arundinacea*, *Cynodon dactylon*, *Leucopogon lanceolatus*, *Scœvola suaveolens*, and *Acacia longifolia* var. *sophora*. Many of these, however, had been removed from the sand dunes for purposes of park-making prior to the 1912 storm, and the chief sand binders at that time were *Spinifex hirsutus*, *Leucopogon lanceolatus*, *Xerotes longifolia* (Liliaceæ), and *Zoysia pungens*. The storm waves of 1912 undercut the long trailing stems of the Spinifex, and exposed the long, broad, and deeply-set, tufts of the roots of Xerotes in the sand cliff. Within a year from July 1912, the wind had cut gullies or gutters in the cliffs (Fig. 2 and Plate VI). The mouths of such gullies or deep trenches opened out at the beach level and the gutters of the trenches rose steeply to the crests of the dunes in which they had been cut by the wind. The sand moved in cutting the trenches may be seen piled behind the heads of the trenches so formed where it was fixed quickly by *Cynodon dactylon*, *Zoysia pungens*, and other sand binders. The longer axes of these trenches point, in the main, to the north-west or west-north-west, indicating the southerly gales as their originators.

The erosive action of the wind is thus seen to be decidedly differential. As a rule the wind corroded an unprotected sand area lying between a mass of Xerotes and a grass patch. The wind removed the unbound sand while the grass-covered patch of the Xerotes mass remained unscathed. Unless a great storm in the meantime, should arise to modify the beach profiles profoundly, the later history of the wind action would be to build the lower terrace up to the tops of the dunes and to fill the gullies in the dunes formed by the wind acting on the sandcliff front.

Certain Observations on other Beaches around Sydney.

As throwing light on the reason for the existence of the *present* beach at Lady Robinson's, Botany Bay, it may be advisable to mention certain features connected with other beaches in the neighbourhood and with the hinterland of the subject beach.

The highest sand dunes of Lady Robinson's Beach rise about 25 feet above the average height of the bay, and these overlook the series of long sandridges and flat troughs which rise about 15 or 17 feet above the bay level and 1000 to 1400 yards in width.

Similar sand flats about 12 or 15 feet above sea level, and modified in places by sand ridges rising to accordant heights, tie various recent islands together around Sydney. On the seaward edge of these flats, high sand dunes have been piled.

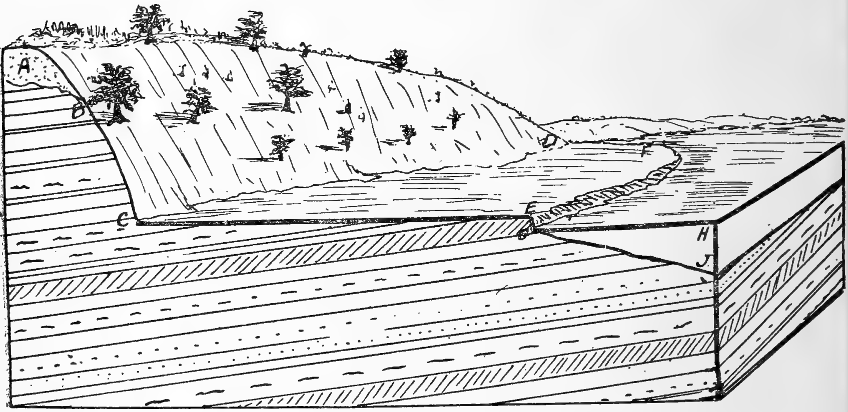


Fig. 3.—Diagram of shoreline forms near Long Reef.

A B C = a well-subdued profile of sapping. *C E* = subhorizontal terrace of erosion in gently-dipping rocks. *G* = Low water mark.

High cliffs of sandstone, dipping gently inland, occur around Sydney. At Long Reef and Narrabeen the cliffs are subdued and are formed of sandstone and other rocks dipping somewhat gently to the south-south-west. Under these cliffs horizontal ledges of sandstones occur, nevertheless such ledges transgress the bedding planes of the sandstones, thus shewing that the surfaces of the ledges have been formed independently of the bedding planes. Especially well is this feature shewn at certain points near Sydney as at Long Reef, examined in 1916 by Dr. H. E. Gregory of Yale, Mr. J. E. Carne, State Government Geologist, and the writer. These platforms vary in width from a few yards to as much, perhaps, as 150 or 200 yards. They are awash at high tide. The cliffs have been excavated in sandstone and tough shales and they are well subdued forms with a moderate thickness of soil and subsoil beneath, through which the rock structure is visible only in a few places of insignificant size. Trees also of considerable age are growing thereon. The general appearance of the exposures indicates that for some reason the sea has not sapped these subdued slopes for a hundred years if not much more. In addition to this evidence, it may be mentioned that certain of the more vertical cliffs in the hard sandstone around Sydney overlook rock platforms lying above high water mark. These cliffs have their bases cumbered with heavy rock masses which have fallen from the cliffs above. So high out of the water and so heavy are these fallen masses that they were not moved by the 1912 storm, neither indeed do the great storms of 1889 nor 1876 appear to have moved them. These platforms are at such heights that heavy storm waves could not have carved them during the period which the sea has stood at its present level, seeing that the action is not due to benching, but to actual truncation of rocks dipping gently inland, and moreover, a low cliff of submarine erosion forms the seaward aspect of the bench or terrace. The present position of these benches of marine erosion can be explained satisfactorily only upon the assumption of a recent and slight emergence of the land.

Inasmuch as Lady Robinson's Beach is centred among all these emerging features, it may be explained, therefore, as a beach formed upon a set of shoals which have emerged only recently from Botany Bay. The emergence was due either to an elevation of the land or to a sinking of the sea level. The movement appears to have taken place several hundreds of years ago.

EXPLANATION OF PLATES.

Plate V.

Fig. 1.—Illustration of beach forms during September 1916, at southern end of Lady Robinson's Beach. The terrace of accumulation since July 1912, and the subdued profile of the 1912 storm may be seen.

Fig. 2.—Shore profiles at northern portion of Lady Robinson's Beach. The scallops of the present beach, the terrace of accumulation (1912 – 1916), and the subdued profiles of the cliffs made by the 1912 and 1889 storms may be seen.

Plate VI.

Fig. 1.—Shoreline profiles along northern portion of Lady Robinson's Beach, showing action of wind upon terrace of accumulation built during the period 1889 – 1912.

Fig. 2—Shoreline profiles at southern portion of Lady Robinson's Beach.

Fig. 1.

Fig. 2.

Fig. 1.

Fig. 2.

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ON THE ESSENTIAL OIL FROM THE BARK OF *EUCALYPTUS MACARTHURI.*

By HENRY G. SMITH, F.C.S.

[*Read before the Royal Society of N. S. Wales, October 4, 1916.*]

IT has been generally known to distillers, who have extracted the essential oil from the leaves of this Eucalyptus, that the bark is particularly odoriferous. The leaf oil is very rich in geranyl-acetate and appears never to contain less than 60 per cent. of that constituent, while a considerable amount of free geraniol is present also.

The first analysis of the oil of this species will be found in the Journal of this Society, November 1900. Since that time numerous analyses have been made with the oil distilled at various times of the year, and these have all been in agreement with the one first published.

Quite recently a considerable demand has arisen in Australia for perfumery oils from indigenous trees, and consequently a good deal of oil has been distilled from the leaves of *E. Macarthuri*, the product being one of the best geraniol bearing oils obtainable from Australian plants.

It was found that an essential oil could also be distilled commercially from the bark of this species, and it was thus considered desirable that the composition and quality of this bark oil should be determined prior to it being placed on the market.

The Technological Museum is indebted to Mr. J. Quigg of Wingello in this State, who kindly forwarded the freshly stripped bark for the purpose of distillation. It had been obtained from fair sized trees, and ranged in thickness up to 1½ inches. The odour of geranyl-acetate was distinctly marked on the freshly cut edges, and when coarsely ground for distillation had a very pleasant odour.

The yield of oil by steam distillation from this ground bark was somewhat disappointing, as it did not exceed that obtainable from the mature leaves; but the statement has been made that at certain times of the year, the yield of oil is much greater than that obtainable from the leaves at the same period.

The analyses of the oil from the bark show it to be identical in composition with that obtainable from the leaves, so that no separation need be made for commercial purposes. With trees of fair size it should be profitable to steam distil the bark for its oil, that is, if it be considered necessary to cut down the trees in the process of manufacture. The production of "suckers" from the stumps of the felled trees is somewhat rapid, so that a fresh supply of leaves would soon be available, and an excellent oil is obtainable from this young foliaceous growth.

Experimental.

The bark, which was stripped in November 1915, was chopped into small pieces and coarsely ground in a mill. It was then steam distilled. The yield of oil was equal to 0·12 per cent.

The crude oil was of a light amber colour and had a very marked odour of geranyl-acetate, and in this, as well as in other respects, was in agreement with the leaf oil. The crude oil had the following characters:—

Specific gravity at 15° C. = 0·9214
Optical Rotation a_D = + 1·2°
Refractive index at 20° C. = 1·4718
Soluble in 1·2 volumes 70 per cent. alcohol.

The optical activity of the oil is due to the presence of a small quantity of dextrorotatory pinene. The stearoptene

—eudesmol—, which is a constant constituent in the leaf oil, has not been noticed in the bark oil.

A determination of the ester by cold saponification in alcoholic potash with two hours' contact, gave the following result:—1·107 gram oil required 0·1876 gram KOH, giving as saponification number 169·5, equal to 59·3 per cent. geranyl-acetate.

A portion of the oil was acetylated by boiling with acetic anhydride and sodium acetate in the usual way.

1·028 gram of the acetylated oil by cold saponification required 0·2044 gram KOH, giving as saponification number 198·8, equal to 69·6 per cent. of ester. The saponification number was thus increased by 29·3, corresponding to 10·25 per cent. ester derived from the free geraniol in the oil.

* * * *

A sample of crude oil was distilled in October 1915, at Wingello, by Mr. J. Quigg from the bark of this species, and forwarded to the Technological Museum. This oil was light amber in colour and had a good odour. It contained a larger amount of ester than did the oil distilled at the Museum, and had the following characters:—

Specific gravity at 15° C. = 0·9099
Optical rotation a_D = + 1·4°
Refractive index at 20° = 1·4648
Soluble in 1·2 volumes 70 per cent. alcohol.

The saponification number for the ester by cold saponification with two hours' contact was 195, equal to 68·2 per cent. geranyl-acetate.

The saponification number of the acetylated oil by cold saponification was 224, equal to 78·4 per cent. of ester, an increase in the saponification number of 29, representing 10·2 per cent. of ester formed with the free geraniol in the oil.

* * * *

A commercial sample of the bark oil of this species, distilled by Mr. Quigg at Wingello, in March 1913, and presented to the Museum by De Meric Ltd., George Street, Sydney, had the following characters:—

Specific gravity at 15° C. = 0·9218
Optical rotation a_D = + 1·2°
Refractive index at 20° = 1·4711
Soluble in 1·2 volumes 70 per cent. alcohol.

The saponification number by cold saponification with two hours' contact was 169, equal to 59·2 per cent. geranyl-acetate. The results obtained with this sample are almost identical with those given by the oil distilled at the Museum two years later.

The results are tabulated for comparison:—

Samples.	Sp. gr. at 15°C.	Rot. a_D	Ref. ind. at 20°C.	Sap. No. Ester.	Sap. No. acetylated oil.	Solubility 70% alcohol
Museum, 11/1915	0·9214	+1·2°	1·4718	169·5	198·8	1·2 vols.
Quigg's 10/1915	0·9099	+1·4°	1·4648	195	224	1·2 „
Quigg's 3/1913	0·9218	+1·2°	1·4711	169	...	1·2 „

This Eucalyptus is one of the very few species of the genus from which an essential oil can be distilled from the bark, and, so far as at present known, it is the only one which, in this respect, may be considered of value from a commercial point of view.

ON AN UNDESCRIBED DARWINIA AND ITS ESSENTIAL OIL.

By R. T. BAKER and H. G. SMITH.

With Plates VII and VIII.

[*Read before the Royal Society of N. S. Wales, December 6, 1916.*]

DARWINIA GRANDIFLORA, Sp. nov.

(Syn. *D. taxifolia* var. *grandiflora*, Benth.)

Remarks.

In a paper read by us before this Society in 1899 we state p. 164, *inter alia*, that "it is intended to raise this variety to specific rank when its chemical constituents have been investigated."

At that time its botanical affinities to and specific differences from its congeners, *D. taxifolia*, A. Cunn., and *D. fascicularis*, Rudge, were worked out, but we preferred to wait until the oil had been procured and analysed, before specially describing it.

Several attempts were made from time to time to procure leaves, but it was not until Dr. Cleland informed us of a locality on the Hawkesbury River that sufficient material was procurable for a distillation.

Even in this case the amount of leaves was not what we could have wished, but sufficient was obtained to give the required data for this paper.

In botanical sequence it stands between *D. taxifolia*, A. Cunn., and *D. fascicularis*, Rudge, having some characters of each and differences from both, and the same remarks apply to the chemistry.

The flowers have a greater resemblance to those of the latter rather than the former, and the leaves to the former rather than the latter.

It differs from *D. taxifolia* in being a more erect and higher growing shrub, and the leaves being distinctly decussate and not nearly so much crowded, larger and flatter, and not glaucous. Its flowers are also more fleshy, and the calyces lack the ribs so prominent a feature in both the other species. The bracts also differ in shape from both species, whilst the disposition and the shape of the leaves clearly separate it from *D. fascicularis.*

Chemically the constituents obtained from the leaves place the oil intermediate between those of its congeners.

Description of Species.

It is an erect shrub growing to a height of fifteen feet, never arborescent as far as seen, with reddish terminal branchlets.

Leaves decussate, distant in the upper branchlets, and never so close together or crowded as in *D. taxifolia* and *D. fascicularis*, nor glaucous as obtains in the former species; falcate, laterally compressed, acute, 7 to 8 lines long, the mid-rib not showing, the upper surface channelled with acute edges, oil glands not so pronounced as in the above species, uniform colour to the articulation with the decurrent petiole in the stem.

Flowers terminal, about 5 lines long, in clusters of 3 to 4, pink, white, and green in colour.

Bracteoles broad, with scarious edges, oil glands very numerous, acuminate, not so long as the calyx.

Calyx fleshy, the lower half quite round, not ribbed or corrugated, shining and much pitted, the upper portion with five narrow channels between each portion of sepal, which may be said to be here valvate, the free lobes small, acuminate and incurved.

Petals white, broad, about 1 line long.

Staminodia very small, subulate, about as long as the filaments.

Style well exserted, sometimes over an inch long.

Histology of Leaf.

In a transverse section the usual leaf structure of angiosperms obtains, except the guard cells of the stomata, which are of rather unusual form, being shaped in transverse section like the arms of a pair of callipers.

In the centre is the midrib, proportionately small to the area of the section, and surrounded by a ring of endodermic cells supported by a very loose mesophyll or spongy tissue which is bounded by parenchyma carrying chloroplastids, followed outward by palisade layers, the whole encircled by a single row of deep epidermic cells in length equalling the depth of the palisade cells. Sparsely scattered throughout the latter are the oil glands.

Interpolated between the palisade and loose parenchyma tissue are found elongated water storage tracheides with spiral thickenings, a useful provision of nature for this arenaceous plant.

The stomata are not numerous, but are interesting, for the guard cells are quite unique in shape, being curved like the mandibles of some coleopterous insect or a pair of callipers, the free ends in section tapering to a sharp point.

A high magnification shows a few scattered hairs on the surface of the leaf.

Essential Oil.

The material for distillation was collected at the Hawkesbury River, New South Wales, early in November, and when distilled was quite fresh. The average yield of oil from the leaves with terminal branchlets was 0·12 per cent.

The oil was red in colour, somewhat mobile, and had a terpene like odour. In general characters and appearance it more closely resembled the oil of *Darwinia fascicularis* than that of *D. taxifolia*, and the study of the chemistry of the oil indicates its intermediate position between those two species. The crude oil had

Specific gravity at 15° C. = 0·9150
Optical rotation a_D = + 23·1°
Refractive index at 20° C. = 1·4773
Scarcely soluble in 10 volumes 80 per cent. alcohol.

Determination of ester with alcoholic potash.

(*a*) Heated to boiling on water bath for half an hour, 1·5345 gram required 0·154 gram KOH ∴ S.N. = 100·4

(*b*) In cold with two and three-quarter hours contact, 1·5340 gram required 0·1484 gram KOH ∴ S.N. = 96·7 equal to 33·84 per cent. geranyl-acetate.

This result shows that the saponification number 3·7 represents an ester not saponified in the cold with two and three-quarter hours contact, and as butyric acid was detected during the determination of the fatty acids, it is possible that this ester is a butyrate.

Determination of the fatty acids.

Sulphuric acid was added to the aqueous portion after saponification, which was then distilled until all the volatile acids had come over. The perfectly clear distillate was exactly neutralised with barium hydrate solution, evaporated to dryness and heated in air bath at 100 – 105° C. The sulphate was prepared from a weighed portion in the usual way; 0·2716 gram of the barium salt gave 0·2446 gram $BaSO_4$ = 90·07 per cent.

The odour of butyric acid was distinctly marked, and, assuming the two combined acids to be acetic and butyric, the results show the barium salt to contain 92·15 per cent. barium acetate, and 7·85 per cent. barium butyrate. The separated oil after saponification had a distinct odour of geraniol.

The investigation of the oil of *Darwinia fascicularis*[1] showed the ester to be geranyl-acetate, the alcohol being separated in a pure condition. The amount of oil of the present species, at our disposal, did not permit the isolation of the alcohol, but from the saponification results in the cold, together with the odour of the saponified oil, it is evident that the principal ester in this species is geranyl-acetate also.

Determination of the chief terpene.

When the oil was distilled directly a considerable portion came over between 156 – 160° C., and no less than 30 per cent. distilled below 165° C. This fraction had a pinene-like odour and had :—

Specific gravity at 15° C. = 0·872.
Optical rotation a_D + 41·6°.
Refractive index at 20° = 1·4685.

The nitrosochloride was prepared with it, and this, when purified, melted at 104° C. It is thus evident that the lower boiling terpene in this oil is a highly dextrorotatory pinene.

The pinene in the oil of *D. taxifolia* is lævorotatory, while the corresponding terpene in the oil of *D. fasicularis* has a dextro rotation. The presence of a small quantity of a volatile acid with a higher molecular weight than that of acetic was also determined in the esters of *D. fascicularis*, so that the resemblances between the characters of the oils of *D. grandiflora* and *D. fascicularis* are distinctly shown.

For comparison the results obtained with the crude oils of the three species of Darwinia are here tabulated.

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[1] This Journal, Vol. XXXIII, (1899), p. 163.

	D. fascicularis.	*D. grandiflora.*	*D. taxifolia.*
Sp. gr. at 15° C. ...	0·9184	0·915	0·8779
Rotation a_D ...	+ 1·2°	+ 23·1°	− 6·5°
Ref. index at 20°C.	...	1·4773	...
Ester by boiling ...	60%	35·1%	5·3%
Ester in the cold...	58%	33·8%	...
Yield of oil ..	0·318%	0·12%	0·313%

Distribution.

Berowra, R. T. Baker. Left bank of the Hawkesbury River, opposite Milson Island, Dr. J. B. Cleland.

EXPLANATION OF PLATES.

Plate VII.

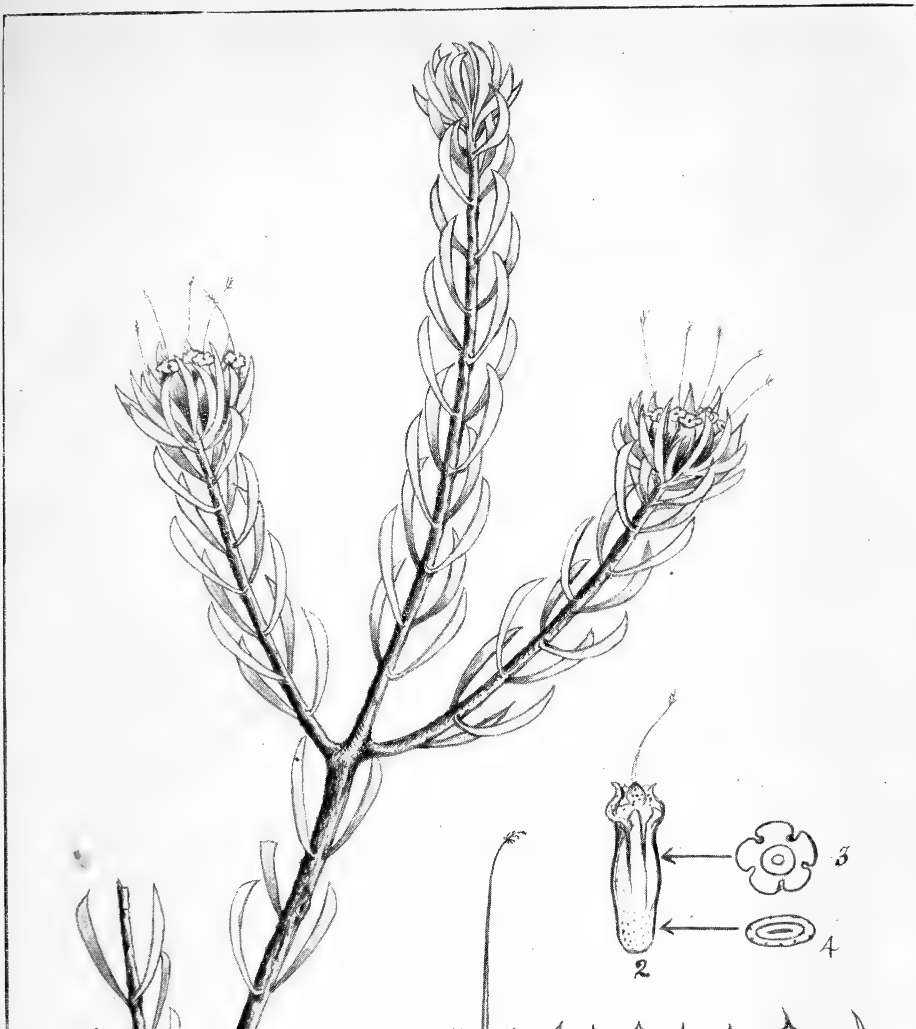
1. Flowering twig.
2. Individual flower.
3. Transverse section of calyx.
4. Transverse section of calyx.
5. Longitudinal section of lower portion of flower.
6. Flower cut open to show disposition of stamen and staminodia.

7 and 8. Two bracts.

1 to 8 enlarged.

Plate VIII.

Transverse section of leaf, showing anatomical structure.



DARWINIA GRANDIFLORA, Sp. Nov.

TRANSVERSE SECTION OF LEAF OF
DARWINIA GRANDIFLORA, Sp. Nov. × 50.

ON THE TREMATODES OF AUSTRALIAN BIRDS.

By S. J. JOHNSTON, B.A., D.Sc.

With Plates IX to XIX.

[*Read before the Royal Society of N. S. Wales, December 6, 1916.*]

Introduction.

THE subject-matter of this paper naturally falls into two parts. In the first part twenty-one species, belonging to nine families or sub-families of Trematodes, are described as new. Up to this time thirty-three species were already known from birds as hosts, and in the second part of this paper the relationships of all fifty-four are discussed and some attempt made to show the meaning of their relationships and distribution.

For many of the specimens which form the subject-matter of Part I, I am indebted to four of my friends, Dr. T. Harvey Johnston, of the University of Queensland, Dr. S. J. Moreau of the Queen Victoria Sanatorium, Wentworth Falls, Dr. J. B. Cleland of the Government Bureau of Microbiology, Sydney, and Mr. Launcelot Harrison, lately demonstrator of Zoology in the Sydney University. Where possible, that is, in the case of those collected by myself, the worms have been studied in the living condition; and in all cases by means of whole mounts and serial sections, except in two, where there was only a single specimen. The whole mounts have been in most cases stained with hæmatoxylin which I have found, on the whole, the most suitable stain for these worms; and the serial sections with hæmatoxylin (either iron or Ehrlichs) and eosin.

In describing each new species a short diagnosis has been given in every case, summarising the principal features of the species; those which are regarded by me as being specially characteristic are printed in italics. In addition to this diagnosis a sufficiently detailed account of its anatomy has been given, and its relationships to other forms discussed.

PART I.

Family FASCIOLIDÆ.

Subfamily CŒNOGONIMINÆ.

SCAPHANOCEPHALUS AUSTRALIS, sp. n. (Fig. 1 and 1a.)

Diagnosis.—Body like *S. expansus* in shape, but *shorter and broader*, yet with larger suckers and pharynx. Integument with a few small spines. Testes not deeply lobed, but *fairly solid bodies*, with their surfaces marked into low ridges by shallow grooves. Eggs larger, but especially broader than in *S. expansus*, from 0·024 × 0·019 mm., to 0·032 × 0·0213 mm.

Host—Haliaetus leucogaster, in the small intestine.

Type specimen in the Australian Museum, Sydney, No. W. 426.

In June 1910, at Terrigal, a coastal village fifty miles north of Sydney, I collected three specimens of a trematode from the small intestine of a white-bellied sea-eagle, *Haliaetus leucogaster*, which appeared at once to be very closely related to, if not identical with *Scaphanocephalus expansus*, Crepl., described by Jägerskiöld[19] and obtained from the stomach of a sea-eagle near Tor, on the Red Sea. A more exhaustive examination with the microscope revealed a number of characteristic differences in the Australian form, which I now describe as a new species under the name of *S. australis*. My specimens, after an examination with a simple lens in a living state, were shaken up in salt solution, fixed in sublimate acetic and transferred to 70% alcohol. One specimen was mounted whole, and the other two cut into sections. Both in the living state and after preservation, the body in all cases was bent in the form of a narrow V, the anterior half bending down sharply, in a ventral direction on to the posterior half. When this was pushed back, the worm showed the very characteristic T shape, with the thin, expanded anterior end, produced outwards into a pair of lateral wings. The worms were quite flat, *i.e.*, their dorso-ventral thickness was quite small in comparison with their width. The Australian form proved to be shorter and broader than the African. The length varied from 3 to 3·25 mm., the breadth of the anterior part being 2·2 mm., that of the posterior part 1·17 mm. The cuticle is smooth, but sections showed the presence of small spines lying in the cuticle, hardly projecting on the surface: the striping of the anterior end mentioned by Jägerskiöld, and produced by the presence of numerous longitudinal grooves on the surface, was hardly noticeable. The suckers are small, but larger than those of its congener, though the latter worm is larger. The oral sucker is 0·134 × 0·107 mm.; the pharynx is 0·096 × 0·075 mm., the combined ventral and genital sucker 0·276 × 0·214 mm.

The excretory pore is situated on the dorsal aspect of the body 0·07 – 0·13 mm., from the posterior end.

Alimentary Canal.—The pharynx is fairly well developed, the œsophagus narrow and moderately long (0·27 mm.), the intestinal limbs reaching almost to the posterior end of the body, and following the contour of the lateral borders, so that in the anterior part of the body they form wide bays extending into the lateral wings of the worm. The intestinal limbs, while being comparatively narrow, (0·05 mm.) in diameter, are much wider than in *S. expansus*, where they measure only 0·012 mm.

Excretory System.—The excretory vesicle, while conforming, in general, pretty closely to the form described

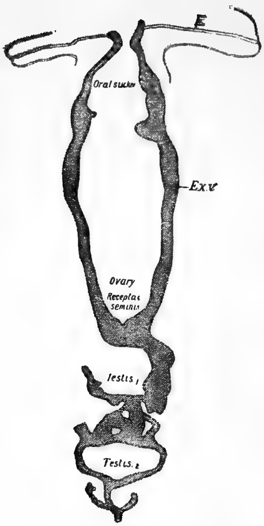


Fig. 1.—Excretory system of *Scaphanocephalus australis*. *Ex. v.* excretory vesicle; *E.* collecting vessels. Projection on squared paper from a series of transverse sections. The names of the organs that form easily recognisable features are written down in the position in which the organ occurs.

by Jägerskiöld in *S. expansus* shows some differences. Text figure 1 is a projection on squared paper, made from a series of transverse sections of the ventral aspect of the excretory vesicle and the two chief vessels. This vesicle differs from that of the African form chiefly in the fact that the main stem, just behind the posterior testis, divides into two branches which unite again in front of it, instead of the right branch ending blindly. Then in the space between the two testes these two wide branches form a network from which, at the level of the posterior end of the anterior testis two wide branches emerge, one passing round either side of the testis. One of these branches ends blindly and the exact arrangement seems to be subject to variation, for in one of my specimens it is the right which so ends, while in another it is the left.

The remaining branch, behind the ovary and receptaculum seminis, divides into two long arms which run forwards, widely separated from one another by the loops of the uterus, but converging in front of this so as to come almost into contact in front of the ventral sucker, where they end as more or less wide pockets. Each of these pockets gives off a tube that runs out fairly straight at right angles to the long axis of the body, into the lateral wings: these transverse tubes are excretory *vessels*, as distinct from the vesicle, their walls being of a character entirely different from those of the latter. They pass to the outer side of the intestinal limbs and divide each into two branches, one of which runs forwards and inwards, the other backwards and inwards (fig. 1).

In addition to these vessels, a number of minute vessels arise from the vesicle at various points, and end in flame cells. The flame cell (fig. 1a) has a rounded body with a large nucleus and an elongated tuft of cilia.

Nervous System.—The cerebral ganglia lie just behind the pharynx, one on either side of the œsophagus. Large nerve trunks pass off from them backwards and outwards to the lateral border of the wings (fig. 1).

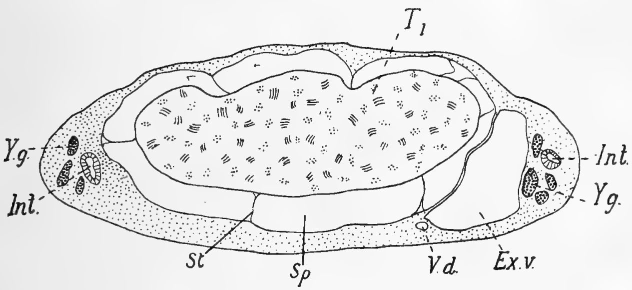


Fig. 2.—Transverse section through the region of one of the testes, showing the space by which the testis is surrounded, and the strands of connective tissue by which it is held in place. *Ex. v.*, excretory vesicle; *Int.*, intestine; *Sp.*, spaces round the testis; *St.*, strands crossing the space; *V.d*, vas deferens; *Y.g.*, yolk-glands.

Genitalia.—The genital opening lies in the depth of the genital sinus, which is situated just in front of the junction of the wide anterior and the narrow posterior parts of the body. The ventral sucker, bounding the genital sinus in front is placed 0·543 mm., behind the oral sucker. The gonads lie in a straight line, one behind the other in the posterior half of the body, the ovary in front and the testes behind. The testes are large, oval, fairly solid bodies, (fig. 1), the surfaces raised up into a few wide, low ridges, but not deeply divided into lobes as in *S. expansus*. They are approximately equal in size and lie with their long axes at right angles to the long axis of the body, and are surrounded by a very loose connective tissue or a cavity crossed by strands of connective tissue (Text fig. 2). The two vasa deferentia unite at a level some distance in front of the ovary after running for a space closely applied to one another, to enter together a more or less capacious vesicula seminalis; in some specimens it is very much larger than in others. There is no cirrus sac nor cirrus, but a fairly long ejaculatory duct with a group of prostate cells round its proximal end, lying free in the body parenchyma. This duct opens, close alongside the female opening, into a tubular common chamber 0·107 mm. long by 0·05 mm. wide. The walls of the vagina or metraterm are muscular and similar in structure to those of the ejaculatory duct. Surrounding the epithelial lining is a strong layer containing radial fibres, and in addition, longitudinal fibres closely applied to the layer of circular (text fig. 3).

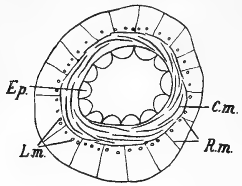


Fig. 3.—Transverse section through the vagina of *Scaphanocephalus australis*, showing the muscular layers in its walls. *E.p.*, lining epithelium; *C.m.*, circular muscle; *Rm.*, radial muscle; *L.m.*, longitudinal muscle.

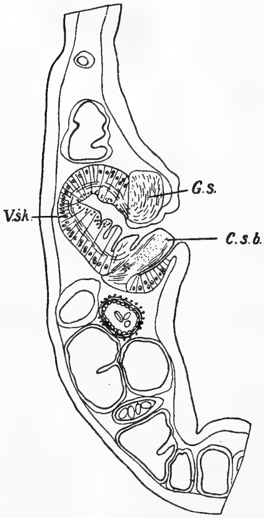


Fig. 4.—Longitudinal section of *Scaphanocephalus australis*, passing through the genital sucker. *C.s.b.*, cone-shaped body; *G.s.*, genital sucker; *V.sk.*, ventral sucker.

The form of the "cone shaped" body of Jägerskiöld, and the arrangement of the muscular layers round the combined genital sinus and ventral sucker correspond closely with what is described for *S. expansus.*(19, pp. 6–10) The part of this complex sucker that represents the "genital sucker" is in the form of a thick horseshoe-shaped band or semi-circular arch of muscle fibres, with the bow of the arch directed forwards. At the posterior end the two limbs give off a number of fibres that run into the circular layer of the ventral sucker. (Text fig. 4). Apparently this does not occur in *S. expansus* or it has been overlooked by Jägerskiöld.

The function of the "cone-shaped" body may be, as Jägerskiöld suggests, to "button" two copulating individuals together; and this may happen in such a way that the openings of the genital sinus in the two individuals are closely applied together so that the genital sinus of the one acting female at the time becomes filled with sperms from the one acting male. The peristaltic movements of the "vagina," movements which the structure of its muscular walls with its well marked circular and radial fibres shows it well able to perform, would then cause these sperms to pass into the female duct.

But the formation of these parts suggests another possible explanation to me. The absence of a proper cirrus or penis suggests that the animal is, perhaps, like so many other Trematodes that possess this character, self-fertilized. The "cone-shaped" body is of such a form and size, and so placed, that it would fit pretty accurately into the concavity of that specially well developed semicircular band of muscle fibres at the anterior border of the sinus, thus forming a closed cavity of that spacious depression formed by the combined sinus and ventral sucker (text fig. 5). Into this closed cavity the sperms could be ejected by the ejaculatory duct, to be taken up in turn by the movements of the vagina. The ovary is fairly large (0·407 × 0·155 mm.) placed with its long axis transverse, just behind the middle of the body. It is divided up into a considerable number of lobes. The ootype, yolk reservoir and transverse yolk ducts lie behind the ovary. A receptaculum seminis, of considerable size, pear-shaped or rather like a cornucopia, lies on the right side, while at the same level but to the left is a fairly large "shell-gland."

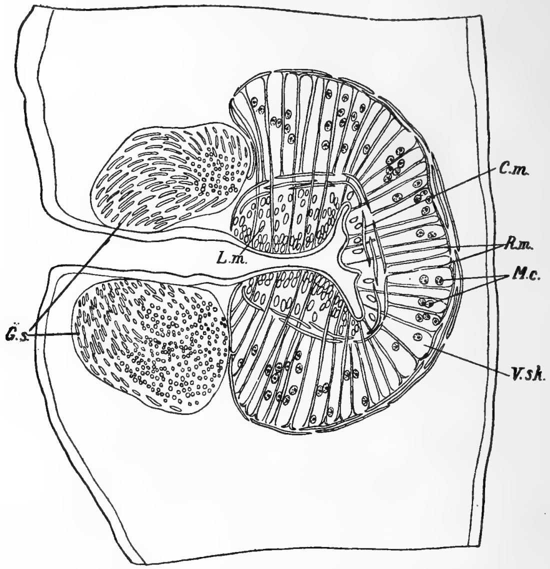


Fig. 5 —Transverse section *Scaphanocephalus australis,* in region of the ventral sucke , to show the arrangement of the muscle fibres in the genital and ventral suckers. *C.m.*, circular muscle; *G.s*,, genital sucker; *L.m.*, longitudinal muscle; *M.c.*, muscle cells; *R.m.*, radial muscle; *V.sk.*, ventral sucker.

There is a short straight Laurer's canal in the middle. The uterus, filled with numerous eggs, proceeds forwards to the genital opening in a series of five or six loops, transversely placed, and occupying the middle half of the body's width, not extending outwards beyond the intestinal limbs. The follicles of the yolk glands are small (0·027 mm.) and exceedingly numerous; in front not extending further forwards than the widely diverging parts of the intestinal limbs and reaching back, along the lateral aspects of the body to the extreme posterior end. Between and behind the testes they extend inwards towards the middle line. This disposition corresponds pretty closely with what occurs in *S. expansus.*

The eggs are a broad oval, the average size of all those measured (a large number) being 0·029 × 0·02 mm. The smallest egg measured was 0·024 × 0·019 mm., the largest 0·032 × 0·022 mm. They are thus distinctly larger, and especially broader than those of *S. expansus*, which measure 0·027 × 0·016 mm.

The chief differences between *S. expansus* and *S. australis* are that the latter is shorter and broader, but at the same time has somewhat larger suckers and pharnyx; the testes are very deeply lobed in *S. expansus*, but solid bodies with their surfaces marked rather into low ridges by shallow grooves in *S. australis;* and the eggs are larger, especially broader, in the latter.

Subfamily ECHINOSTOMINÆ.

HIMASTHLA HARRISONI, sp. n. (Fig. 10.)

Diagnosis.—Elongated, attenuated worm, flattened dorso-ventrally. Integument closely beset with thick spines. Head-collar with *twenty-four* spines in a single row on its border. Ratio of oral to ventral sucker 1 : 4. Testes and ovary close together in the posterior fifth of the body length. Yolk-glands confined to the posterior half of the body. Eggs broad elliptical, but pointed at both ends, 0·091 × 0·069 – 0·096 × 0·074 mm.

Host—Numenius cyanopus, in the intestine.

Type specimen in the Australian Museum, Sydney, No. W, 427.

Three specimens of this worm were obtained from the Curlew, *Numenius cyanopus*, at Masthead Island, off the Queensland Coast, and one at Gladstone Q., by Launcelot Harrison, demonstrator of Zoology in Sydney University.

As is usual in this genus the body is very elongated and flattened. The anterior part of the body is very thin and delicate, and in the region of the ventral sucker is deeply concave. All the specimens are about 12 mm. long, and find their greatest breadth at the level of the gonads where they are 0·809 mm. wide. Just behind the cirrus sac the body is only 0·326 mm. wide, and gradually increases down to the level of the gonads. At the middle of the body the width is 0·632 mm. Behind the testes the body narrows to a blunt, rounded point. Down to the hinder end of the cirrus sac the integument is armed only with fine spines, but behind that level the body is covered with transverse rows of closely placed, thick spines which give it a transversely striped appearance. The spines stand very close together, without measurable interval and have the form of almost cubical blocks with the free end produced into a backwardly directed point. They gradually increase in size up to the level of the ovary and behind this point gradually fade away. At the middle of the body they are 0·021 mm. thick by 0·018 mm. high, while at the level of the ovary they are ·027 mm. thick.

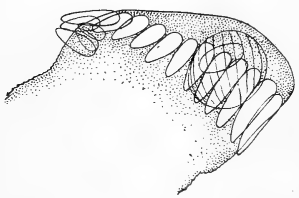


Fig. 6.—Head collar and spines of *Himasthla harrisoni.*

The head-collar is comparatively poorly developed but bears a row of conspicuous spines round its border. There are twenty-four of these spines, the largest along the lateral border measuring 0·069 × 0·015 mm. On the ventral side of the collar the largest is 0·057 × 0·015 mm. In addition to the spines round the border the ventral angles bear each four spines arranged in two pairs: two large and two small.

The oral sucker is very small; it is spherical in shape and has a diameter of 0·085 mm. The ventral sucker lies about

1 mm. behind the anterior end and projects prominently on the surface. It is fairly globular and has a diameter of 0·347 mm.

The ratio of the oral to the ventral sucker is 1 : 4. The œsophagus leading back from the small pharynx (0·116 × 0·106 mm.) bifurcates just in front of the anterior end of the cirrus sac, and the two intestinal limbs run back to the posterior end of the body.

The tubular excretory vesicle divides into two main branches immediately behind the posterior testis.

The genital pore lies in the middle line of the ventral surface just in front of the anterior border of the ventral sucker. The cirrus sac, which is nearly filled by the voluminous vesicula seminalis projects far behind the ventral sucker towards the posterior end.

The gonads are situated very far back and lie in the posterior body-fifth. The testes are large, somewhat irregular, elliptical bodies lying close together and one behind the other in the middle line. In one specimen the posterior 0·776 × 0·33 mm., was a little longer than the anterior 0·698 × 0·31 mm., but in two others they were equal in size and measured 1·028 × 0·388 mm. The ovary is oval, 0·252 × 0·194 mm., with the long axis transversely placed. It lies in the middle line a short distance in front of the testes. A very large shell-gland, which is traversed by the transverse yolk-ducts, occupies the space between the ovary and testis. The yolk-glands, which consist of large oval follicles, 0·063 – 0·074 mm. long by 0·043 mm. wide, occupy two lateral fields stretching from the middle of the body to the posterior end. These fields are interrupted at three places, at the level of the ovary and each of the testes, the intervals being bridged over by the longitudinal yolk-ducts only.

The uterus is extremely long and is thrown into numerous transverse coils. It contains numerous eggs. The eggs are broad, elliptical and pointed at the ends, and vary a good deal in size, the smallest measuring 0·091 × 0·069 mm., and the largest 0·096 × 0·074 mm.

This species is obviously closely related to *H. rhigedana* Dietz,[13] parasitic in the intestine of *Numenius arabicus* and *N. arquatus*, of the Sinai peninsula. Among the differences one finds in these two forms is the number of spines on the border of the head-collar, twenty-four in the one and thirty in the other. While the ratio of the diameter of the oral to the ventral sucker is 1 : 4 in the Australian species, it is 1 : 3 in the Asian. The size of the spines on the posterior part of the body seems to be considerably larger in the Australian form, and the gonads much closer together.

ACANTHOPARYPHIUM SPINULOSUM, sp. n. (Fig. 7.)

Diagnosis.—Small form, 5·55 mm. long by 0·8 mm. broad. Integument of the anterior part of the body spiny. Head-collar *only half as broad* as the body. Collar spines twenty-three in number. Ratio of oral to ventral sucker 2 : 7. Ventral sucker situated *entirely in the first quarter* of the body length. Cirrus sac elongated, reaching back far beyond the posterior end of the ventral sucker. Cirrus spiny.

Host.—*Charadrius dominicus*, in the duodenum.

Type specimen in the Australian Museum, Sydney, No. W. 428.

Two individuals and a number of fragments of this species were obtained from the duodenum of a Golden Plover, *Charadrius dominicus*, at Cronulla, near Sydney, by Dr. Harvey Johnston and Dr. J. B. Cleland. It is a small worm 5·55 mm. long by 0·8 mm. broad in the region of the ventral sucker. There is little diminution in the width as far back as the posterior testis, but from this point to the posterior end the worm gradually tapers to a blunt point. There is a narrow neck just behind the head-collar. The latter, 0·407 mm. broad, is only half as wide as the body. The collar-spines are arranged in an uninterrupted, single row, those along the lateral borders being the largest. There are twenty-three of these spines, and special groups on the ventral angles are wanting. The spines on the lateral border measure 0·075 × 0·016 mm.

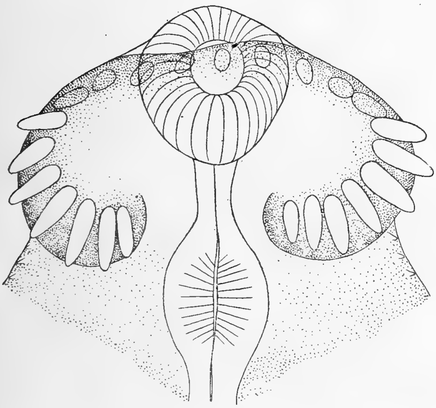


Fig. 7. Head collar and spines of *Acanthoparyphium spinulosum.*

The integument is closely beset with sharp-pointed spines as far back as the ventral sucker, where they begin to diminish in numbers and quite disappear at a point a little behind the sucker.

The oral sucker is nearly spherical, 0·155 × 0·145 mm., the ventral sucker is also approximately spherical and measures 0·582 × 0·543, so that the ratio of the former to the latter is about 2 : 7.

There is a short prepharynx followed by a pharynx 0·133 mm. long by 0·107 mm., transverse diameter. The œsophagus is 0·388 mm. long, and the bifurcation of the intestine is situated just in front of the genital pore, and close to the anterior border of the ventral sucker.

The genital pore lies in the middle line close to the anterior border of the ventral sucker. The testes are placed one behind the other in the middle line in the middle of the body, and in one specimen are approximately spherical (0·582 × 0·542 mm.), in the other elliptical (0·776

× 0·542 mm.). The ovary is oval in form, obliquely placed on one side of the middle line, and measures 0·194 × 0·136 mm. It lies only a short distance in front of the testes, the space between being filled by the large gland of Mehlis. The cirrus sac is very elongated and reaches back to the level of the ovary. For the whole length of the ventral sucker it is tubular in form, but behind that point it swells out into a more or less pear-shaped structure, and in this part the coiled vesicula seminalis is contained. The long cirrus is lined by chitinous tubercles or blunt spines (text fig. 8). A number of prostate cells lie in the parenchyma of the cirrus sac in the posterior part of the division lined by the spines, and further back.

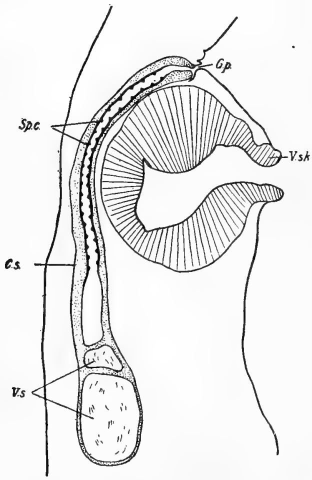


Fig. 8.—Figure combined from several longitudinal sections of *A. spinulosum* showing cirrus etc. *C.s.*, cirrus sac; *G.p.*, genital pore; *Sp.c.*, spines on the cirrus (which is represented inverted in its position of rest); *V.s.*, vesicula seminalis; *V.sk.*, ventral sucker.

The yolk-gland field begins anteriorly at the level of the ovary some distance behind the ventral sucker, and is confined to the lateral parts of the body down to the posterior end of the testes. From this level the yolk-glands spread inwards to the middle, but stop short some little distance from the posterior end. The follicles are fairly large and round, varying in size from 0·068 to 0·106 mm., in diameter. The uterus is short and contains comparatively only a few oval eggs 0·085 × 0·069 mm.

This species differs from *A. phœnicopteri*, Lühe, parasitic in a Flamingo *Phœnicopterus roseus*, at Tunis, the only other member of the genus, in a number of easily recognisable characters. In the first place it is larger, being more than twice as long and twice as broad. The relative size of the head-collar is very different, for while it is as wide as the body in its widest part in *A. phœnicopteri* it is only half as wide in the Australian form.

In regard to the suckers, again, while the diameter of the ventral sucker in the latter is three and a half times as great as that of the oral sucker, in the former it is only twice as great, and is situated much farther back in the body. Though Dietz, in his account of the African species [13, pp. 365-8] makes no mention of the spines on the cirrus, I have no doubt that they will be found to be present if they are looked for in a series of longitudinal sections.

ECHINOPARYPHIUM OXYURUM, sp. n. (Fig. 6.)

Diagnosis.—Small worms, 5·8 mm., long with a well developed head-collar, and a *very distinct sharp-pointed tail.* Collar spines long. Integument armed with transverse rows of *rounded scales.* Ratio of oral to ventral sucker 1 : 4. Testes in the middle of the body. Eggs 0·096 – 0·107 mm. long by 0·054 – 0·08 mm. broad.

Host.—Herodias timoriensis, in the intestine.

Type specimen in the Australian Museum, Sydney, No. W. 429.

Four individuals of this species were sent me by Dr. Harvey Johnston, who obtained them from the intestine of an Egret, *Herodias timoriensis*, shot on the Burnett River in Queensland. They are all about the same length, 5·8 mm., and attain a maximum width at the ventral sucker of 0·698 mm. From the region of the testes the sides of the body, which is fairly flat, run parallel to a level near the posterior end when they converge in such a way as to form a distinct, sharp-pointed tail, which seems to be a very characteristic feature. The intestinal limbs and the yolk-glands do not extend into this tail. The posterior half of the body is 0·425 mm. wide.

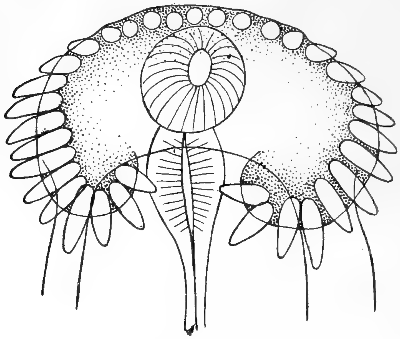


Fig. 9.—Head collar and spines of *Echinoparyphium oxyurum*

The head-collar is well developed, and nearly as wide (0·543) as the body in its widest part. It has the usual reniform shape and bears along its edge a single uninterrupted row of thirty-four spines. In his diagnosis of the genus Dietz says(13, p. 379) "Kopfkragen nierenförmig mit *doppelter*, dorsal nicht unterbrochener stachelreihe bewaffnet." But I do not consider this feature of sufficient importance to make a generic distinction. Indeed, in a second species of this genus, which I describe below, the collar spines might be considered to be in a double row (see fig. 9, pl. XII), but they are so nearly in a single row that the difference in position might easily be overlooked. In *E. oxyurum*, however, they cannot be detected to lie in two rows. In addition to the row round the edge this species bears a group of four spines on each ventral lobe set at a different angle to the others, so that there are forty-two collar-spines altogether. The longest spines are 0·091 mm. long.

The integument in the region between the head-collar and the ventral sucker is armed with closely set scales or scale-like spines. These scales have a rounded free edge, and the part projecting on the surface is rather broader than long. The region of the body between the head-collar and the ventral sucker is concave through the bending down of the lateral edges of the body.

The oral sucker is small and globular, 0·15 mm. in diameter. The ventral sucker, which is rather more than its own length behind the oral, is 0·62 mm. long by 0·52 mm. broad, so that the ratio of the oral to the ventral sucker is 1 : 4. The pharynx is 0·194 × 0·097 mm. and the œsophagus 0·388 mm. long. The intestinal fork lies just in front of the ventral sucker. The intestinal limbs end 0·388 mm. from the posterior extremity.

The genital pore lies a little behind the intestinal fork on the ventral surface, in the area dorsal to the anterior part of the ventral sucker. The cirrus sac is pear-shaped and extends back as far as the middle of the ventral sucker. The testes, elliptical in shape, are equal in size, and measure 0·582 × 0·252 mm. They lie very close together, one behind the other in the middle line. They lie aproximately in the middle of the body. The ovary is nearly globular in shape 0·16 × 0·19 mm., and lies on the right side of the middle line, a short distance in front of the testes, with the gland of Mehlis directly behind it.

The yolk-glands consist of rather large, oval follicles 0·037 – 0·043 mm. long by 0·032 mm. broad. In front they do not extend as far forward as the ventral sucker, and behind the testes completely surround the intestinal limbs on each side, leaving for the most part a clear space in the middle. In the region of the testes and in front of this they are entirely confined to the lateral fields between the intestinal limbs and the sides of the body.

The uterus is short and contains in each specimen only a few large eggs. The eggs are rather variable in size, and in those of three specimens measured 0·096 – 0·107 mm. long by 0·058 – 0·064 mm. broad, but in the fourth specimen they were considerably broader and measured 0·107 mm. long by 0·08 mm. broad.

This species differs from *Echinoparyphium agnatum*, Dietz, in being much larger, in its much more markedly developed collar, in its much larger collar spines (they are more than twice as long), and in its specially characteristic tail; while its integument is armed with broad scales, that of *E. agnatum* possesses fine spines.

Again, the ratio of the diameter of the oral to that of the ventral sucker in the latter is 1 : 5, but in the Australian form it is 1 : 4. Moreover the testes in the European form are much nearer the posterior end of the worm than in the Australian form.

It differs from *E. aconiatum*, Dietz, in being very much larger (four times as great); in the number of collar spines, forty-two as against thirty-seven; and in having the scales with which the integument is armed much less closely set. In *E. aconiatum* the ratio of the diameter of the oral to the ventral sucker is 1 : 3.

Further it differs from *E. elegans* Looss, not only in being much larger and different in shape, but also in the relationship of the suckers, as in Looss' species the ventral sucker is twice as great in diameter as the oral, while in the Australian form it is four times as great. The testes are situated much nearer the posterior end in *E. elegans* Looss.

Echinoparyphium harveyanum, sp. n. (Figs. 8 and 9).

Diagnosis.—A small worm with well developed head-collar, *bearing twenty-nine collar-spines*, including six on the ventral angles of the collar. Integument armed with sharp spines. Ventral sucker very prominent. Ratio of ventral to oral sucker 6 : 1. Cirrus sac reaching the middle of the ventral sucker. Testes in the middle of the body. Follicles of the yolk-glands very numerous and confined to the lateral fields of the body. Eggs 0·099 – 0·117 mm. long by 0·063 mm. broad.

Host.—*Micrœca fascinans*, in the gizzard.

Type specimen in the Australian Museum, Sydney, No. W. 430.

A single specimen of this worm was obtained by Dr. Harvey Johnston from the gizzard of *Micrœca fascinans* at the Burnett River. It is a small worm 5·75 mm. long by 0·523 mm. broad. The body was twisted through a right angle just behind the ventral sucker, so that in figure 8, while the anterior end is viewed from the side, the posterior part is viewed from the ventral surface.

The head-collar is well developed and is armed by twenty-three collar-spines arranged in a double row, but the two rows are set very nearly together so that without very close inspection they appear to be arranged in one row. These spines measure 0·069 × 0·021 mm. In addition, there is a group of three large spines on each ventral angle of the collar, set in a direction very nearly at right angles to those of the edge of the collar. For the greater part of its length the body exhibits a fairly even breadth, but gradually becomes narrowed to a blunt point at the posterior end. The integument in the anterior part of the body is armed with sharp spines. These spines are very numerous in front of the ventral sucker: from this on to the region of the testes they become more scattered and further back vanish completely. The ventral part of the body in front of the ventral sucker is deeply concave, and into this hollow the ventral sucker projects very prominently (fig. 9).

The ventral sucker is 0·62 mm. long, and lies nearer the anterior end than in the other species of Echinoparyphium. The oral sucker is spherical and 0·106 mm. in diameter: so that the ratio of the oral to the ventral sucker is 1 : 6. The fork of the intestine lies just anterior to the ventral sucker and immediately behind it lies the genital pore. The comparatively large cirrus sac extends nearly to the middle of the sucker.

The testes are elliptical and smooth-edged, 0·485 × 0·194 mm. in size. They lie close in the middle line, one closely behind the other. The small almost spherical ovary, 0·136 × 0·126 mm., lies in front on the left side.

The yolk-glands, which run from a point some distance behind the ventral sucker to the posterior end, are confined to the lateral fields of the body, and do not anywhere pass beyond the intestinal limbs towards the middle line. The follicles are rounded 0·027 – 0·037 mm. in diameter. The uterus is short and little coiled, and the eggs few, large and variable in length, 0·099 – 0·117 long by 0·063 broad.

E. harveyanum differs from all the other species of Echinoparyphium in the small number of its collar-spines and in the close approximation of its ventral sucker to the anterior end. It differs from *E. aconiatum* and *E. oxyurum* in having the integument armed with sharp-pointed spines instead of rounded scales. The ratio of the oral sucker to the ventral is 1 : 6. The relationship in size of the oral and ventral suckers shows a very interesting gradation in the species of this genus. In *E. elegans*, Lss. it is 1 : 2; in *E. aconiatum*, Dietz, it is 1 : 3; in *E. oxyurum*, mihi, it is 1 : 4; in *E. agnatum*, Dietz, it is 1 : 5; and in *E. harveyanum*, mihi, it is 1 : 6.

Echinochasmus tenuicollis, sp. nov. (Fig. 5.)

Diagnosis.—Small worms of slender form, with a *slender neck*. Collar spines twenty-seven. Ratio of oral to ventral sucker 1 : 5. Genital pore at the anterior edge of the ventral sucker. Testes three-lobed. Ovary on one side of the middle line. Uterus little coiled. Anteriorly the field of the yolk glands ends *some distance behind* the ventral sucker, and spreads over to the middle line behind the testes. Eggs 0·084 × 0·058 mm.

Host.—The common Shag, *Phalacrocorax melanoleucus*, in the intestine.

Type specimen in the Australian Museum, Sydney, No. W. 431.

I obtained a large number of specimens of this little worm from the intestines of the Shag or black and white cormorant *Phalacrocorax melanoleucus*, near the Tuggerah Lakes, New South Wales.

It is a small form and varied little in size, the smallest measured being 3·134 mm. long by 0·52 mm. broad, the largest 4·05 mm. long by 0·59 mm. broad, while the average of a large number measured was 3·16 × 0·503 mm. It is a rather delicate and slender form, broadest in the region of the ventral sucker. Behind this it becomes somewhat narrowed, and then gradually increases in width up to the region of the anterior testes, so that this region forms a kind of waist; behind this the sides of the body are fairly parallel till near the posterior end which becomes fairly suddenly rounded off. Between the head collar and the ventral sucker the body is slender, so that a very distinct, slender neck is present. On the ventral surface the neck region is fairly deeply concave. The integument is fairly thickly beset with small spines in the anterior part of the body. Beginning at the extreme anterior end, these spines are very numerous down to the level of the ventral sucker, where they begin to thin out, and entirely vanish at the level of the ovary.

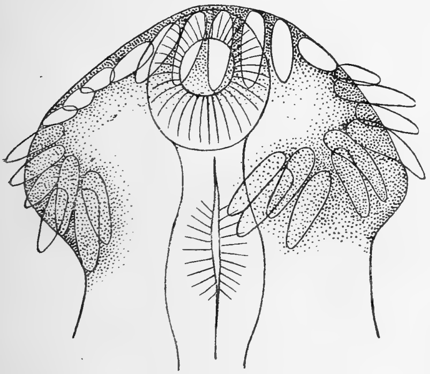


Fig. 10.—Head collar and spines of *Echinochasmus tenuicollis*.

The head collar is well marked, with somewhat prominent ventral lobes or angles. It bears twenty-seven spines altogether, an uninterrupted row of flat rod-like spines nineteen in number, with a group of four arranged in two pairs on each of the ventral angles (text fig. 10). They vary little in size (the smaller ones in the text figure are drawn fore-shortened) and measure 0·069 × 0·013 mm. The oral sucker is bowl-shaped, rather broader than long (0·085 × 0·107 mm.) while the ventral sucker is very much larger 0·504 × 0·407 mm., so that the ratio of the diameter of the oral to the ventral sucker is practically 1 : 5.

The distance between the suckers in specimens fixed in sublimate acetic is 0·543, little more than the length of the ventral sucker. In living specimens and in several preserved ones where the contraction, for some reason, was less marked, this space is much longer. There is a short prepharynx (0·08 mm.) and an oval muscular pharynx 0·107 × 0·28 mm. The œsophagus, 0·277 is comparatively long. The bifurcation of the intestine lies anterior to the ventral sucker. The intestinal limbs quickly make their way to the sides of the body and terminate a little in front of the posterior end. The excretory vesicle is very voluminous and divides into two large collecting tubes at the posterior border of the testis, which are continued forwards right into the head collar. These vessels and their branches form a conspicuous feature in transverse sections.

The genital pore lies immediately in front of the anterior edge of the ventral sucker, to the centre of which the cirrus sac reaches back. The testes are triangular or three lobed, with the base of the triangle anterior and the apex pointing backwards.

They lie in the middle line and in the middle of the space between the ventral sucker and posterior end: but the exact position is variable a little, *e.g.*, in the specimen from which figure 5 was drawn they are a little nearer the posterior end than the middle of the field. The size of the testes is considerable, but not so large comparatively as in some other members of the genus, (Nicoll[39], fig. 7, and Dietz[13], fig. 36). The anterior, 0·291 mm. broad and long is rather smaller than the posterior 0·35 × 0·31 mm.

The ovary lies shortly in front of the anterior testis, on the right side of the middle line. It is nearly spherical in form, 0·126 × 0·116 mm. in size. There is no receptaculum seminis, but the terminal part of the uterus is filled up with sperms, forming a receptaculum seminis uterinum. The space between the ovary and the testis is mainly taken up by the large gland of Mehlis. The uterus is little coiled and fairly long.

The yolk glands consist of very numerous small follicles varying in shape from spherical to oval, and in diameter from 0·027 to 0·021 × 0·018 mm. In the extent of their field they differ from all the other members of this genus, for anteriorly they do not extend beyond a level halfway between the ovary and the ventral sucker. From this point they extend back in two lateral fields to the posterior testis, behind which they spread over to the middle line and almost reach the posterior extremity.

The eggs are large and showed little variation in size, the average measurement of a large number measured being 0·084 × 0·058 mm.

The nearest relative of this worm, *E. coaxatus*, Dietz, is also parasitic in a water bird, the crested grebe, *Podiceps cristatus*. The two worms differ in a number of points. The collar spines of *E. coaxatus* are distinctly longer than those of *E. tenuicollis*. The relative size of the suckers is quite different, being 1 : 5 in the latter and 1 : 2 in the former. The shape of the testes is different and the cirrus sac larger in the Australian form, but one of the most striking differences is in the stopping short of the yolk gland fields some distance behind the ventral sucker. In this point, in the relative size of the testes, and in its more slender habit, it differs from *E. prosthovitellatus*, Nicoll, and *E. bursicola*, Crepl.

PATAGIFER ACUMINATUS, sp. n. (Figs. 2 and 3.)

Diagnosis.—Body slender, acuminate; head collar *narrower than body*, ratio of oral to ventral sucker 1 : 5. Intestinal fork lying dorsal to the ventral sucker; genital pore *in front of* intestinal fork; fields of the yolk glands narrow, not passing inwards beyond the intestinal limbs; eggs long and narrow, 0·096 × 0·043 to 0·107 × 0·048 mm.

Host.—*Ibis molucca*, in the intestine, Burnett River, Q.

Type specimen in the Australian Museum, Sydney, No. W. 432.

Nine specimens of this worm were obtained by Dr. Harvey Johnston from the intestine of the White Ibis, *Ibis molucca*. They varied in size from 7·7 × 1·012 mm. up to 10·45 × 1·56 mm. The body is deeply concave on the ventral surface behind the collar, and into this concavity the ventral sucker projects very prominently. When the thin sides of the body are spread out (and this is apt to be the case in a whole mount in balsam) this is the widest part of the body, but in the natural position of the parts, the widest part succeeds a "waist" at the posterior end of the ventral sucker. From this level the body tapers gradually to a long drawn out point so that it may be designated acuminate.

The collar is not so strongly developed as in *P. bilobus*, and is always less than the width of the body. The division or bay in its dorsal edge ends in front of the oral sucker, and the two dorsal lobes overlap; but there is a wide bay on the edge of the collar so that the two ventral angles are widely separated. There are twenty-five spines in a single row round the edge of the collar on each side. The last in the dorsal bay is the smallest, 0·0427 × 0·0213 mm. and they gradually increase in size to the fifteenth, in the vicinity of which a number are equal in size and measure 0·122 × 0·048 mm. On each ventral angle there is a group of three spines not lying in series with the row round the edge and pointing obliquely inwards towards the middle line. The innermost, which is the largest, measures 0·1602 × 0·0534 mm., the second 0·1335 × 0·0427, and the third which is much smaller than the others 0·096 × 0·026 mm. All the collar spines have a flattened rod-like form, bluntly pointed at each end.

The integument of the body is entirely devoid of spines. The oral sucker is broader than long, 0·194 × 0·116 in the smallest, and 0·29 × 0·232 in the largest specimen. The ventral sucker measures 0·97 × 0·77 mm. in the smallest, and 1·55 × 1·21 mm. in the largest specimen, so that the ratio of the oral to the ventral is about 1 : 5. The pharynx is elongated oval, nearly twice as long as broad, 0·175 × 0·097 mm. in the smallest, and 0·31 × 0·19 mm. in the largest individual. The bifurcation of the intestine lies some distance behind the anterior edge of the ventral sucker.

The intestinal limbs immediately run straight out to the sides of the body, and course parallel to the sides of the body up to their termination near the posterior extremity.

The main stem of the excretory vesicle is very long and wide, and divides into two large arms just behind the posterior testis. The arms run forwards to the middle of the ventral sucker, giving off in their course, on the outer side, many branches.

The two large cerebral ganglia lie one on either side of the pharynx, immediately behind the oral sucker, and are joined together by a transverse commissure that passes on the dorsal side of the pharynx. The genital pore is situated just behind the anterior edge of the ventral sucker, and some distance in front of the bifurcation of the intestine. The pear-shaped cirrus sac lies dorsal to the ventral sucker, reaching nearly to its posterior end. The testes lie in the anterior half of the body and overlap a little into the posterior half. They are slightly lobed elongated bodies about equal in size, the anterior measuring 0·815 × 0·582 mm. and the posterior 0·873 × 0·524 mm.

The spherical ovary is much smaller and lies some distance (0·388 mm.) in front of the testes. It is median in position. The large gland of Mehlis lies just behind it. The uterus exhibits only a few transverse coils and then runs forwards in a wavy course to the genital opening.

The yolk-glands are confined to a narrow lateral field on each side, not extending inwards beyond the intestinal limbs and reaching from the ventral sucker to the extreme posterior end.

The follicles are very numerous, small, and oval, 0·053 × 0·027 to 0·08 × 0·032 mm.

The eggs are more than twice as long as broad, 0·096 × 0·043 to 0·107 × 0·048 mm.

P. acuminatus differs from *P. bilobus*, Rud., which is parasitic in *Ibis falcinellis* and *Platalea leucorodia* in the shape of its body and narrower collar, in having the genital pore situated in front of the intestinal fork instead of behind it as it is in *P. bilobus;* also in having the gonads further apart, in the narrower fields of its yolk-glands, in the fewer coils of the uterus and in its much narrower eggs.

The Australian form differs also from *P. consimilis*, Dietz, found in *Geronticus albicollis*, in Brazil, in its acuminate posterior end and more slender form; in having much larger spines on the collar, a smaller oral sucker, narrower yolk-gland fields and narrower eggs. The position of the genital pore and the gonads in *P. consimilis*, Dietz has not been able to determine owing to his material being badly preserved.(13)

PATAGIFER FRATERNUS, sp. nov. (Fig. 4.)

Diagnosis.—Body linear, with sides parallel to behind the middle. Head collar *as wide as* the body. Ratio of oral to ventral sucker 1 : 6. Genital pore *in front of* the intestinal fork. Gonads close together; ovary oval, obliquely placed in the middle line. Eggs oval, 0·107 × 0·069 mm.

Host.—Herodias timoriensis, in the intestine.

Type specimen in the Australian Museum, Sydney, No. W. 433.

Five specimens of this worm were obtained by Dr. Harvey Johnston from the intestine of the egret, *Herodias timoriensis*, at Burnett River, in Queensland. While it is fairly similar in most respects to *P. acuminatus*, and must be looked upon as closely related to that worm, it differs in detail in a number of respects.

The body is linear with the sides parallel in the anterior two-thirds; behind this it tapers to a point. The average size is over 10 mm. long by more than 1·25 broad. The largest specimen measured 11·75 × 1·44 mm. The head collar is as wide as the body; its dorsal bay is wide and gaping. There are twenty-eight collar spines in a single row on each side, being very small in the dorsal bay and large laterally. The spines along the lateral border (0·144 × 0·04 mm.) are longer than those of *P. acuminatus*. In the ventral corners, on the inner surface of the collar, on each side there lies a group of four spines not in series with those running round the edge. They point in towards the middle line and are placed further back from the edge than the others. Two are large 0·128 × 0·054 mm., and two very small. The oral sucker measures 0·291 mm. in diameter, only one-sixth of the ventral, which is 1·75 mm. long by 0·97 mm. broad. The suckers are 0·77 mm. apart. The fork of the intestine is just on a level with the anterior edge of the ventral sucker, and the genital pore stands a little (0·02 mm.) in front of this.

The testes are large oval bodies with indented edges lying close together in the middle of the body, close to them the oval ovary lies in the middle line, but obliquely disposed. The two testes are equal in size and measure 1 028 × 0·485 mm. The ovary, 0·388 × 0·291 mm., is much smaller. The proximal part of the uterus is dilated to form a relatively very large receptaculum seminis uterinum, which lies for the most part posterior to the ovary and gland of Mehlis. The eggs are relatively broader than in *P. acuminatus*, measuring 0·107 × 0·069 mm.

Subfamily PLAGIORCHIINÆ (Lepodermatinæ).

Plagiorchis spatulatus, sp. n. (Fig. 11.)

Diagnosis.—Body spathulate and flat; size small, less than 1 mm. long. Integument spiny. Suckers large, oral greater than the ventral. Testes *equal in size, lying one behind* the other in the posterior half of the body. Ovary in front of posterior testis. The three gonads separated by loops of uterus. Yolk glands in the lateral fields; *not crossing* the intestinal limbs except behind the testes. Eggs 0·031 × 0·017 mm.

Host.—Anthus australis, in the intestine.

Type specimen in the Australian Museum, No. W. 434.

The specimens of this worm in my possession were collected by my friend Dr. T. Harvey Johnston, of the University of Queensland, at Caloundra in that State. It was obtained from the intestine of the Australian Pipit, *Anthus australis*, and is quite a small worm, flat and spatula-like in form, rather less than a millimetre long, and a little more than one-third of a millimetre broad.

The largest specimen measured was 0·99 mm. long, and 0·39 mm. broad, while the smallest was 0·815 mm. long, and 0·349 mm. broad. The body reaches its greatest breadth in the region of the testes and is very bluntly pointed at each end.

The integument at the anterior end is thickly covered by small, backwardly directed spines. The suckers are comparatively large, especially the oral (0·161 mm. in diameter) which is considerably larger than the ventral (0·133 mm.). The pharynx is also comparatively large (0·075 mm.) and muscular, but the œsophagus is very short. From its posterior end the limbs of the intestine run out towards the sides for some distance, then bend sharply through a right-angle and course backwards parallel to the lateral edges of the body, ending a short distance in front of the posterior end.

The excretory pore is placed at the extremity of the body and leads into an elongated vesicle which runs forwards, passing between the testes on the dorsal side of the body. At about the level of the ovary it bifurcates into two branches.

The genital pore lies just in front of the ventral sucker, near the middle line. The testes are equal in size, large and oval 0·138 mm. long, and 0·117 mm. broad. They are obliquely placed one behind the other, the right being posterior. The ovary is nearly spherical and smaller than the testes, 0·085 mm. in diameter, lying on the right side, at a level just in front of the anterior testis but behind the ventral sucker.

The cirrus sac is very elongated and tubular, extending from the anterior testis to the genital opening, curving round on the dorsal and right side of the ventral sucker.

The vesicula seminalis lying within it is not coiled. The uterus has a descending limb running backwards between the testes to a point near the posterior ends of the intestinal limbs. From this point it bends sharply round and runs forward in a number of close coils, again passing between the testes on its way towards the genital opening. Its terminal part which is thick-walled and muscular, may be distinguished as the vagina. The uterine coils fill up the field between the intestinal limbs behind the testes. A receptaculum seminis and Laurer's canal are absent. The yolk glands consist of very numerous, small, rounded follicles 0·011 to 0·014 mm. in diameter. In front they are confined to the space between the intestinal limbs and the lateral edges of the body, but behind the testes the field of these glands widens out, crossing over the intestinal limbs and invading the space between them to a certain extent.

The average size of the eggs is 0·031 × 0·017 mm., the largest being 0·033 mm., and the smallest 0·029 mm. long, while the breadth remains practically constant.

In its structure this species appears to resemble more closely than other species, *P. maculosus*, Rud., parasitic in various species of swallows *(Hirundo)* in Europe.

PLAGIORCHIS CLELANDI, sp. n. (Fig. 11*a*.)

Diagnosis.—Small worms, with sides parallel for the most part and the body narrowed towards each end. Integument in the anterior end covered with small scale-like spines. Suckers almost equal in size. Intestinal limbs *wide and voluminous.* Yolk-glands *closely surrounding* the intestinal limbs and not extending inwards; anteriorly they only reach a point half-way between the pharynx and the ventral sucker.

Host.—The Fairy Martin, *Petrochelidon ariel.*

Type specimen in the Australian Museum, Sydney, No. W. 435.

A dozen of these small worms were obtained from the intestine of a Fairy Martin *(Petrochelidon ariel)*, at Gular in New South Wales, by Dr. J. B. Cleland of the Government Bureau of Microbiology, N.S.W. The worms are quite small, averaging only 2 mm. long by 0·5 mm. wide. The largest measured 2·19 × 0·65 mm. The body is flat with the sides parallel for the greater part of the length, but tapering at each end into a blunt rounded point. At the anterior end the integument is covered by small half-moon shaped scales. The oral sucker, which is situated on the ventral side of the body, is a little longer than broad, 0·291 × 0·252 mm. The ventral sucker, lying in the middle of the second quarter of the body length is circular in form, with a diameter of 0·252, equal to the transverse diameter of the oral sucker. A distinct prepharynx is present, with a globular pharynx 0·112 mm. in diameter.

There is practically no œsophagus and the intestinal limbs are wide and stretch nearly to the posterior end. The genital pore lies just in front of the ventral sucker, in the middle line or a little to one side. The cirrus sac is very elongated, C-shaped, and beginning at the anterior testis curves round the ventral sucker on one side and in front to reach the genital pore.

The testes are large oval bodies placed obliquely one somewhat in front of the other, the anterior, 0·31 × 0·29 mm. a little smaller than the posterior 0·369 × 0·29 mm. The ovary which is also comparatively large, lies on one side of the middle line in front of the posterior testis on a level immediately behind the ventral sucker. It measures 0·233 × 0·175 mm., and its long axis is transversely placed.

The yolk-glands, consisting of comparatively large oval follicles 0·043 × 0·037 mm., surround the voluminous intestinal limbs; anteriorly they extend to a level half-way between the pharynx and the ventral sucker, and cover the intestinal limbs right to their posterior end. They do not extend inwards beyond the intestine to any appreciable extent, and remain separated behind.

The uterus is very thin-walled and occupies the middle field behind the testes almost reaching the posterior end of the intestine. One coil runs between the testes on the dorsal side, and between the testes and the ovary.

The eggs are comparatively numerous and quite small, the average size being 0·032 × 0·019 mm., while the smallest measured 0·0304 × 3·017 mm., and the largest 0·033 × 0·022 mm.

Plagiorchis clelandi is more closely related to *P. maculosus*, Rud., parasitic in the European swallow, *Hirundo*, than to the other species of the genus. It differs from this species mainly in the arrangement of the fields of the yolk-glands, which in Australian species never extend as far forwards as the fork of the intestine, indeed only reach a level half-way between the ventral sucker and the pharynx, and which always remain separate in the posterior region. The eggs in the Australian form are smaller than those of the European.

P. clelandi differs from the other Australian species of the same genus *P. spatulatus*, mihi. and *P. (Lepoderma) nisbetii*, Nicoll,[38] in a number of points such as the very closely placed gonads, but especially in the extent of the yolk-gland fields which extend further forward in the two last named species and in *P. spatulatus* in addition are more lateral in front of the testes and extend further in towards the middle behind them.

Dolichosaccus solecarius, sp. n. (Fig. 12.)

Diagnosis.—A minute worm, cylindrical in form, with large suckers. *Ratio of oral* to ventral sucker 3 : 2. Integument spiny, except at the posterior end. Prepharynx,

pharynx and œsophagus present. Intestinal limbs wide and voluminous. Genital pore just in front of ventral sucker. Cirrus-sac long and wide containing a voluminous vesicula seminalis constricted in its middle. Ovary *some distance* behind the ventral sucker. Testes one behind the other, in the *posterior body-third.* Yolk-gland extending from ventral sucker to end of intestinal limbs, not extending inwards beyond the intestinal limbs.

Host.—Phalacrocorax melanoleucus, in the intestine.

Type specimen in the Australian Museum, Sydney, No. W. 436.

A single specimen of this little worm was found in the intestine of a shag, *Phalacrocorax melanoleucus* at Tuggerah Lakes. It is only 1·1 mm. long and 0·184 mm. broad. It is cylindrical in shape, of even diameter throughout almost its whole length, being bluntly rounded off at each end. The anterior part of the body as far back as the "shell-gland" is densely covered with small spines. Behind the "shell-gland" they become a little less dense, and end abruptly at the level of the anterior testis. The oral sucker is circular in form and comparatively very large, almost as wide as the body. Its diameter is 0·1602 mm. The ventral sucker also circular, is situated in the beginning of the middle third of the body. Its diameter is 0·1068, so that the ratio of the oral to the ventral sucker is 3 : 2.

There is a very distinct prepharynx, 0·032 mm. long. The pharynx is globular, with thick muscular walls, and has a length of 0·064 mm. The œsophagus 0·032 mm. long is only half as long as the pharynx. The intestinal limbs are wide (0·048 mm.) and voluminous, and run back to the posterior end of the body, nearer to the middle line than to the sides of the body.

The cirrus sac is long (0·24 mm.) and wide, and contains a voluminous vesicula seminalis, constricted in its middle.

It extends back as far as the ovary. The vesicula seminalis is filled with sperms. The genital pore lies in the middle line a little in front of the ventral sucker.

The ovary is a conspicuous oval structure, 0·069 × 0·058 mm., lying some distance behind the ventral sucker and to one side of the middle line. A large "shell-gland" lies immediately behind it. The testes lie in the posterior third of the body, close together, one behind the other in the middle line. They are oval in shape, with the long axis longitudinal, and the anterior (0·096 × 0·0801 mm.) is slightly smaller than the posterior (0·106 × 0·0801 mm.). The yolk-glands consist of very small, rounded follicles 0·014 mm. in diameter. They extend from the anterior border of the ventral sucker to the posterior end of the intestine. As far back as the ovary they are confined to the lateral fields lying between the intestinal limbs and the sides of the body, but behind the ovary they spread out on the ventral surface of the intestinal limbs, but do not anywhere extend inwards towards the middle line beyond the inner edges of the intestine. The uterus is short and does not extend back beyond the shell-gland. There is a long Laurer's canal. The uterus contains no eggs, though the ovary has every appearance of being mature, and the vesicula seminalis is filled with sperms.

The other species of *Dolichosaccus*[21] are parasitic in Frogs and do not seem to be very closely related to the the present species, which indeed, with some doubts, I include in this genus. It differs from the three species from frogs in its cylindrical form, in the relative size of the two suckers and in the topography of the fields of the yolk-glands.

Subfamily MICROPHALLINÆ.

LEVINSENIELLA HOWENSIS, sp. n. (Fig. 13.)

Diagnosis.—Minute worms, rather less than a millimetre long; elongated pear-shaped, flattened dorso-ventrally.

Integument spiny. Suckers *equal in size;* the ventral far back in the posterior region of the body. Very *long prepharynx* and œsophagus. Intestinal limbs moderately long, *wavy, without diverticula.* Genital pore on a level with the ventral sucker on the left side.

Testes symmetrically placed, one on either side, behind the ventral sucker. Ovary on a level with the ventral sucker. Eggs very small.

Host.—*Charadrius dominicus*, in the cæcum.

Type specimen in the Australian Museum, Sydney, No. W. 437.

A very large number of these minute worms were obtained by Dr. Harvey Johnston from the cæcum of *Charadrius dominicus* at Lord Howe Island. They vary in length from 0·77 to 1·07 mm.

The specimen from which figure 13 was drawn, which is fairly typical in size and shape, except that the body is a little wider than usual in the region of the intestinal bifurcation, measured 0·97 mm. long by 0·194 mm. wide at the level of the pharynx and 0·368 mm. in the widest part of the body, in the region of the testes. The worms are elongated pear-shaped, and flattened dorso-ventrally. The integument in the anterior part of the body in front of the intestinal fork is densely covered by small spines.

From that level they gradually become more scattered right back to the posterior end. The oral sucker is situated on the ventral surface at the narrow end of the body; the ventral sucker is far back, lying in the posterior quarter of the body length. Both the suckers are circular in form and exactly equal in size, varying from 0·064 to 0·074 mm. in diameter. The pharynx is well marked, and owing to its isolated position, a conspicuous structure in whole mounts. It measures 0·048 × 0·042 mm. In front of it and behind it lie the prepharynx and œsophagus respectively, exactly equal and conspicuous for their length, varying in different specimens from 0·079 to 0·107 in length. The intestinal limbs are wide and without cæca, but pursue a wavy course, gradually diverging from the middle line to the level of the ventral sucker.

Branched excretory vessels run back along the sides of the body to join the V-shaped excretory vesicle. The genital pore is situated on the left side of the ventral sucker, about its middle. There is a voluminous cirrus-sac and pars prostatica, and the copulatory bursa is rather smaller than in the other species of this genus. The gonads are all oval and have their long axes placed transversely, the ovary on a level with the ventral sucker and to its right; the testes symmetrically one on either side of the middle line. The testes are equal in size, 0·107 × 0·08 mm.; the ovary is smaller, 0·08 × 0·053 mm.

The yolk glands are arranged in three main groups of follicles on each side, and in whole mounts are a good deal concealed by coils of the uterus, which forms a number of loops in the posterior part of the body behind the testes. The eggs are very small and oval, varying from 0·017 × 0·0138 up to 0·018 × 0·0138 mm.

This pretty little worm seems to be most closely related to Jägerskiöld's *L. brachysoma*[15] parasitic in the cæcum of a bird of the same genus in Scandinavia, namely *Charadrius hiaticula*. It differs from this species, however, in its more elongated and slender form; and in the ratio of the suckers to one another. In the present species they are exactly equal, while in *L. brachysoma*, Jag. the oral is twenty per cent. larger than the ventral.[15, p. 140] The pharynx is smaller in *L. howensis* and the limbs of the intestine are without cæca. While on the whole, the arrangement and structure of the genital organs are pretty much the same in these two species; in *L. howensis* the male bursa copulatrix is considerably smaller. The eggs also are a good deal smaller in the Australian form.

Subfamily DICROCŒLIINÆ.

LYPEROSOMUM PARVUM, sp. n. (Fig. 14.)

Diagnosis.—Elongated, cylindrical; suckers large, oral rather smaller than the ventral, œsophagus short; intestinal limbs reaching posterior end. Testes *placed close together* and *just behind* the ventral sucker. Genital opening in front of, but *close to* the ventral sucker; cirrus sac lying mainly *dorsal to the ventral sucker;* vesicula seminalis *much coiled.* Ovary behind and close to the posterior sucker. Yolk glands consisting of a *few large follicles* in two rows behind the ovary. Uterus very extensive. Eggs thick shelled, 0·039 × 0·023 mm.

Host.—*Strepera versicolor*, in the intestine.

Type specimen in the Australian Museum, No. W. 438.

This species is represented by a number of small trematodes collected at Rydal, New South Wales, by my friend Dr. S. J. H. Moreau, from the intestine of the grey crow-shrike, *Strepera versicolor.*

This species is much smaller than any *Lyperosomum* hitherto described, having a length of 3·6 mm., and breadth of 0·37 mm. The body is almost cylindrical, but only slightly flattened towards the posterior end. The suckers are rather longer than broad, the oral (0·213 × 0·194 mm.) being smaller than the ventral (0·252 × 0·233 mm.). The pharynx, broader than long (0·054 × 0·08 mm.), is very much smaller than the suckers. There is a short œsophagus, ending a little in front of the ventral sucker, and the two intestinal limbs, which are narrow and unbranched, run back to the posterior end of the body. The genital opening is situated in the middle line in front of, and close to the anterior edge of the ventral sucker. The cirrus sac is well developed and entirely surrounds the much coiled vesicula seminalis. Its position, relative to the ventral sucker, is more posterior than in the other species of *Lypersomum*, lying as it does almost entirely behind the anterior edge of the ventral sucker, only reaching in front of it where it passes forwards to reach the genital opening. The testes, which lie close together, one behind the other, are separated from the ventral sucker by a couple of coils of the uterus. They are almost cubical in form, smooth edged and very large, stretching right across the body, only leaving a small amount of room for a coil of the uterus to pass on their dorsal aspect. They are approximately equal in size, 0·35 × 0·27 mm.

The ovary, which lies close behind the posterior testis, is much smaller, measuring 0·194 × 0·116 mm. It is oval in form and has its long axis transversely placed. Posterior to the ovary and in the dorsal region of the body, the receptaculum seminis and gland of Mehlis or "shell-gland" are found. The yolk glands consist of a few (16 to 18) large oval follicles measuring 0·08 × 0·07 mm. They are arranged roughly in two rows and extend backwards from the posterior aspect of the ovary for a distance of rather more than half a millimetre. The uterus is very extensive, and in whole mounts serves to hide the other organs a good deal. In a number of closely packed coils it extends backwards to the extreme posterior end of the body. From this point it runs forwards in much looser coils on the ventral aspect of the body as far as the posterior testis, where it passes to the posterior side by making a coil between the ovary and the testis. It partly separates the testes by a short coil and throws two thick coils in between the anterior testis and the cirrus sac.

The eggs, especially those in the distal or ascending coils of the uterus, are very dark brown in colour, oval in shape, and very thick shelled. The eggs differed in size a little according to their position in the uterus, the smallest measuring 0·037 × 0·021 mm., the largest 0·043 × 0·026 mm., while the average of all those measured was 0·039 × 0·023 mm.

Comparing it with forms previously known, this species seems to be nearly related to *Lyperosomum lobatum*, Raill. from *Pica caudata*, and to an unnamed species in von Linstow's collection, figured by Braun in [10, fig. 66]. The latter is a parasite of *Corvus corone*.

LYPEROSOMUM MEGASTOMUM, sp. n. (Fig. 15).

Diagnosis.—Form elongated, cylindrical. Suckers very large, *wider than the body*, oral smaller than the ventral. Testes large, approximately equal, close together, a short distance behind the ventral sucker. Genital pore in front of intestinal fork; cirrus sac lying mainly *anterior to the ventral sucker*, ovary oval, half as large as testes, long axis transversely placed. Yolk glands consisting of few, large follicles, occupying a short field behind ovary; uterus very extensive, filling up posterior two-thirds of body. Eggs large, 0·038 × 0·023 mm.

Host.—Crested tern, *Sterna bergii* in the intestine. Locality: Tuggerah, N.S.W.

Type specimen in the Australian Museum, Sydney, No. W. 439.

The most striking character of this species is the size of the suckers which considerably exceed the narrow cylindrical body. The worms are about the same length as *L. parvum* (3·68 mm. on the average) but are much more slender, being only 0·194 mm., in breadth at the level of the testes, and 0·145 mm., in the region of the uterus. Both the suckers exceed this breadth in their diameter and so project beyond the lateral edges of the body. The oral sucker 0·203 mm. in diameter, is rather smaller than the ventral (0·239 mm.). The œsophagus is short (0·144 mm.) and the intestinal limbs very narrow. The genital pore lies nearer the anterior end than usual in other species, being nearer the oral than the ventral sucker. The cirrus sac, with the contained vesicula seminalis, lies mainly anterior to the ventral sucker, but with its base projecting backwards for a short distance behind the anterior edge of it. The testes are large and oval with the long axis longitudinal, while the oval ovary has its long axis transversely placed. The three gonads are placed close together in a line, one behind the other, without any loops of the uterus separating them. The posterior testis is always slightly smaller than the anterior, the measurements being 0·214 × 0·161 mm., and 0·239 × 0·171 mm., respectively. The ovary is considerably smaller, 0·107 × 0·161 mm. The receptaculum seminis and gland of Mehlis lie just posterior to the ovary.

The yolk glands, as in *L. parvum*, are few and large, occupying a short field in the body immediately behind the ovary. They are arranged in an irregular double row and are greatly obscured from view by the uterus filled with eggs. The whole of the posterior part of the body is taken up by the folds of the uterus.

The eggs are large, the largest measured being 0·041 × 0·024 mm., the smallest 0·037 × 0·021 mm., while the average of a large number measured was 0·038 × 0·023 mm.

Lyperosomum harrisoni, sp. n.

Diagnosis.—Elongate, cylindrical; suckers large, but *not so wide as the body*, oral sucker smaller than the ventral. Testes large, oval in shape; posterior larger than anterior; ovary oval. Long axis of *both testes and ovary transversely placed.* Genital pore midway between the suckers. Cirrus sac mostly in front of ventral sucker, but part dorsal to it. Coils of the uterus lying *between the testes and between the second testis and ovary.* Yolk glands of few, large follicles. Eggs 0·038 × 0·024 mm.

Host.—The boobook owl, *Ninox boobook.*

Type specimen in the Australian Museum, No. W. 440.

A small number of specimens from the boobook owl were given me by my colleague Mr. Launcelot Harrison, who obtained them from the intestine of an owl, secured at Lindfield, near Sydney. This species is similar in size to *L. parvum.* The oral sucker, 0·223 mm. in diameter, is smaller than the ventral, 0·262 mm. The testes are broader than long, and the anterior (0·33 mm. broad by 0·25 mm. long) is smaller than the posterior (0·33 mm. broad by 0·29 mm. long). The testes are separated from one another and from the ovary behind them by wide coils of uterus. The genital pore lies midway between the two suckers; most of the cirrus sac lies in front of the ventral sucker and the vesicula seminalis is coiled.

The yolk glands consist of twelve to fourteen large, oval follicles arranged in two rows in the field behind the ovary. The uterus, as usual, is very extensive, obscuring the yolk glands and occupying the whole field of the body posterior to them. The eggs which are light yellow in the proximal part, become dark brown in the distal part of the uterus. They measure 0·038 × 0·024 mm., and are very even in size.

This species is closely related to *L. parvum.* Indeed all three species, described here for the first time, are closely related to one another.

Subfamily HARMOSTOMINÆ.

Harmostomum pulchellum, sp. n. (Fig. 16.)

Diagnosis.—Size moderate, body cylindrical and pointed at each end. Spines absent. Oral sucker little larger than the ventral. Pharynx conspicuous; œsophagus wanting. Gonads not so close together as usual in Harmostomum. Cirrus sac rudimentary, not enclosing vesicula seminalis. Field of the yolk glands extending from *posterior border of ventral sucker to posterior border of the ovary.* Coils of the ascending loop of the uterus *extending* laterally *beyond* the intestinal limbs. Eggs 0·028 mm. long by 0·015 mm. broad.

Host.—The Wonga Pigeon, *Leucosarcia picata*, North Western New South Wales.

Type specimen in the Australian Museum, No. W. 441.

These specimens were obtained by Dr. T. Harvey Johnston of the University of Queensland, at Moree in north-western New South Wales. They vary a good deal in size, the smallest being 2·75 mm. long by 0·45 mm. broad, while the largest measured 5 mm. long by 0·78 mm. broad, the average length of half a dozen being 4 mm. The form is cylindrical, with the sides of the body parallel except at the ends which are somewhat pointed, especially the posterior end. Spines appear to be completely absent, as I could not find any trace of them either in the whole mounts or sections.

The outline of the suckers is fairly circular and they are approximately equal in size, though sometimes the oral, which is on the ventral aspect of the worm, is a little larger than the ventral, *e.g.*, 0·291 mm. : 0·271 mm. The suckers are a considerable distance apart, for the ventral sucker stands at the beginning of the middle third of the body. The pharynx is conspicuous, measuring, in the same animal on which the two measurements just mentioned were made, 0·135 × 0·155 mm. There is practically no œsophagus, as the two intestinal limbs open directly into the pharynx. The intestinal limbs show the characteristic feature of *Harmostomum* in the shape of the short loop running forwards towards the oral sucker on each side of the pharynx. But instead of running backwards near the edges of the body they course much nearer the middle line, especially in the middle third of the body. They are not straight but thrown into a number of waves.

The genital pore is in the middle line, just in front of the anterior testis, at the junction of the middle and posterior thirds of the body. From the genital opening, the male duct leads at first directly forwards, through the rudimentary cirrus sac, and then bends sharply back and runs towards the testes. This part of the duct is the vesicula seminalis; and, just in the region where the bend occurs, a number of prostate cells are attached to it, with their bodies lying free in the parenchyma; only the anterior end of the vesicula seminalis, where it joins the ejaculatory duct lies within the cirrus sac.

The testes are large and some distance apart, with a distinct space between them and the ovary, which lies between and somewhat to one side of the middle line. The posterior testis is always more elongated than the anterior, measuring, in a specimen 4·75 mm. long, 0·582 mm. $\times$ 0·291 mm., while the latter measures 0·427 $\times$ 0·33 mm. The long axis of the posterior testis lies longitudinally, while that of the anterior is rather oblique. The ovary is also oval in shape, measuring in the same worm 0·291 $\times$ 0·232 mm.

The ascending loop of the uterus is thrown into a number of transverse coils which pass outwards beyond the intestinal limbs into the field in which the yolk glands lie. The latter consist of a large number of small follicles arranged in two elongated fields, extending from the posterior edge of the ventral sucker in front to the posterior edge of the ovary behind. They do not cross over the intestinal limbs, but are confined to the space between these limbs and the lateral edges of the body.

The eggs are very small, narrow and pointed at the ends. The largest measured were 0·032 × 0·016 mm., the smallest 0·027 × 0·013 mm., while the average of a large number measured was 0·028 × 0·015 mm.

This differs from the other species of *Harmostomum* found in birds, *e.g.*, *H. mordens*, *H. fuscata*, *H. caudale*, and *H. centrodes*(10) in the position and extent of the yolk glands fields, the more median position of the intestinal limbs and the crossing of the uterine coils into the lateral fields beyond the intestinal limbs. All these differences are of course correlated with one another.

Subfamily CLINOSTOMINÆ.

Clinostomum australiense, sp. n. (Fig. 17.)

Diagnosis.—Large form, widest in the *region of the gonads*. Oral field well developed. Suckers very large and close together. Intestinal limbs provided with *side branches*. Genital pore in the middle line. Cirrus sac *alongside* the anterior testis. Cirrus spiny.

Host.—*Plotus novæ-hollandiæ*, in the œsophagus.

Type specimen in the Australian Museum, No. W. 442.

Locality, Burnett River, Queensland.

Two specimens of this species of *Clinostomum* were obtained from the œsophagus of the Darter, *Plotus novæ-hollandiæ*, by Dr. Harvey Johnston. One was mounted whole, the other cut into horizontal sections. It is a fairly large form 11 mm, long by 3·25 mm. broad at the widest part, in the region of the gonads. It is fairly thick. The oral field is fairly well marked. The body is constricted at the level of the ventral sucker, and from this point gradually increases in width to the region of the gonads, whence it again becomes narrowed towards the posterior end, which is sharply truncated. The anterior end is also truncated. The cuticle is beset with numerous fine spines which scarcely project on the surface and are only to be seen in sections.

The suckers are large and strong, especially the ventral, which is more than twice as large as the oral. They are both circular in outline, the latter 0·54 mm. in diameter, the former 1·26 mm. They are separated by an interval of 0·75 mm.

Alimentary canal.—There is no pharynx of the usual form found in trematodes, but the wall of the œsophagus, tubular in form, is provided with muscular layers. There is an outer layer of circular and an inner layer of longitudinal fibres. Both these muscular sheets are directly continuous with similarly arranged layers in the oral sucker, though the well marked and thick layer of radial fibres present in the sucker appears to be absent from the œsophagus. MacCallum mentions[34, p. 699] that "the musculature of the (oral) sucker is composed of three layers, meridional, radial, and equatorial or arcuate. The pharynx similarly constructed and provided with a thick cuticular lining," etc. This corresponds pretty closely with what I find in *C. australiense*, except that, in the absence of the usual barrel-shaped pharynx with thick muscular walls, I prefer to call the tubular structure with thin sheets of muscular tissue in its walls "the œsophagus." Braun[8, p. 8] seems to view MacCallum's statement about the muscular layers with some doubt, but my finding them in the form under investigation here may be looked upon as confirmation of MacCallum's observations.

From the œsophagus the intestinal limbs are directed at first laterally, and reach a point halfway between the middle line and the side of the body. Here a sharp turn is made to run backwards more or less parallel to the sides of the body, the two limbs coming nearly together at a point just in front of the excretory vesicle. The two limbs are provided on each side with short diverticula.

Excretory system.—The form of the excretory system is peculiar and highly characteristic. A short V-shaped vesicle, opening by the excretory pore at the posterior end, gives off on each side a very large collecting vessel, which runs forwards, about halfway between the intestinal limbs and the sides of the body, right up into the region of the oral field. Each of these collecting vessels is joined on either side by vessels which form anastomosing loops, that cover the whole dorsal surface of the body. In *Clinostomum marginatum* this part of the excretory system (Osborn, figs. 3 and 4) lies ventral to the intestinal limbs, but in my form they are undoubtedly dorsal. These anastomosing loops communicate with a very extensive system of sub-cuticular spaces and channels, as they do also in *C. marginatum.* I have not been able to trace the fine recurrent vessel described by Osborn in *C. marginatum*, but cannot say definitely that it is not present, as I have only one series of horizontal (parallel to the ventral surface) sections, and in such a series its connection with the collecting tubules would be particularly difficult to demonstrate.

Nervous system.—A pair of large cerebral ganglia lie one on each side of the œsophagus, on the dorsal side of which the transverse connecting commissure passes. Besides the thick nerve cords which run back to the posterior end almost in a line with and ventral to the main collecting vessels of the excretory system, a number of pairs of small nerves are given off by the cerebral ganglia to neighbouring parts.

Genital system.—The gonads lie in the posterior third of the body, the anterior testis projecting a little into the middle third. The testes are roughly triangular, with deep indentations along the margins. The anterior measures 0·78 × 0·69 mm., and is almost entirely on the left side of the middle line, the opposite side being occupied by the comparatively large cirrus sac, which lies alongside it. The posterior testis lies with its base anterior and apex posterior, the base being somewhat concave.

The testes are 0·5 mm. apart, and in the space between them is found the ovary (0·33 × 0·252 mm.), on the right side, oval in shape, and with an entire outline and some coils of the oviduct including the ootype etc. There is a short Laurer's canal opening near the middle line on the dorsal surface, but no receptaculum seminalis. The gland of Mehlis surrounds the ootype. The comparatively conspicuous vasa deferentia become joined to enter at once the coiled vesicula seminalis, which is completely enclosed within the cirrus sac. This leads to a well-marked genital atrium with a conspicuous opening in the middle line, on a level with the anterior edge of the anterior testis. The terminal part of the duct of the cirrus is lined by a number of chitinous tubercles or blunt spines.

The oviduct, after making a number of coils in the space between the testes, curves round the left border of the anterior testis and just in front of it opens into the uterine sac. The latter is a conspicuous object even in the whole mount, and reaches forwards as far as the junction between the anterior and middle third of the body. The uterine sac opens into the genital atrium some distance behind the point at which it is joined by the oviduct. Neither the uterine sac nor the oviduct, in either specimen, contained any eggs, so that I infer the specimens were not quite sexually mature, though the vesicula seminalis was filled with sperms. The immaturity of the specimen was also shown by the state of the yolk glands, which had only just begun to make their appearance, and occupied a small field behind and to the right of the gonads.

This species of *Clinostomum* seems to be more closely related to *C. marginatum*[44] than to any other species. They are fairly similar in external form but the Australian species is larger, and the ventral sucker is relatively further forward in the body. The position of the cirrus sac is different, being alongside the anterior testis, and not at all in front of it. The cirrus of *C. marginatum* does not appear to be spiny since Osborn makes no mention of this feature.

C. australiense differs from *C. hornum*, Nicoll[39] in size and shape, in the position of the genital pore (it is removed from the middle line in the latter) in having the ventral sucker nearer the anterior end and in having side branches to the intestinal limbs.

Family BILHARZIIDÆ Odhner, (SCHISTOSOMIDÆ).

AUSTROBILHARZIA TERRIGALENSIS, gen. et sp. nov.
(Figs. 18–22.)

Diagnosis.—Male *shorter than the female*, the gynecophoral canal extending from the hinder border of the ventral sucker to the posterior end of the body. Suckers well developed and prominent. Œsophagus ending at or a little in front of the ventral sucker; the paired intestinal limbs running backwards without any connecting commissure to the last quarter of the body where four commissures occur, followed by a short, terminal, unpaired section of gut.

Testes consisting of about *eighteen to twenty rounded follicles* lying one behind the other, symmetrically placed between the intestinal limbs, beginning anteriorly a little behind the ventral sucker and extending backwards to the middle of the body. Genital pore situated towards the left side a little behind the ventral sucker. Cirrus sac present, *enclosing the vesicula seminalis: prostate present.*

Female considerably longer than the male, the anterior part rounded and thread-like, the posterior part, in which the ovary and yolk glands lie, flattened and much broader.

Spines absent, ventral sucker present. Ovary comparatively long, tubular and bent into a series of *five or six waves* or loops. Yolk glands occupying the posterior third of the body.

Type species *A. terrigalensis*, sp. n.

Host.—Larus novæ-hollandiæ.

Type specimens in the Australian Museum, Sydney, No. W. 443.

In a gull, *Larus novæ-hollandiæ*, shot at Terrigal, New South Wales, I found in the intestine a number of small worms each surrounded by a droplet of blood. These proved to be Bilharzia-like forms which probably escaped through a wound from the intestinal blood vessels into the intestine. In most cases the female was found to be occupying the gynecophoral canal of the male. Though fairly closely related to *Ornithobilharzia* they proved to belong to none of the already established genera of this family, so that I propose for their reception a new genus *Austrobilharzia.*

In *Austrobilharzia terrigalensis* the males average 4 mm. in length, while the females are 5 mm. or a little longer. The shortest male measured 3·5 mm., and the female with it 4·5 mm. in length. In many cases it was not possible to measure the length of the female exactly, owing to its anterior thread-like part being bent into a number of waves. Spines were quite absent from the integument of both sexes except on the inner surface of the ventral sucker of the male where very small fine spines occurred. Both the oral and the ventral suckers of the male are well marked off from the surface of the body, the latter especially so, for it is distinctly stalked (fig. 20). The suckers are approximately equal and show very little variation in size, the diameter being 0·175 mm. In all the males the body exhibits a marked antero-posterior curvature towards the ventral side, so that the shape of the body viewed from the side is like an open C (fig. 18 and 19). The average breadth of the male viewed from the side and measured from the lateral border, forming the boundary of the gynecophoral canal, to the middle of the dorsal surface is 0·4 mm. The gynecophoral canal is deep, and is wrapped round the female (fig. 22). The limbs of the intestine, both the paired and unpaired tracts, are beset with numerous short diverticula throughout their whole length. The four commissures form two small loops which are connected by an unpaired piece. Behind the second loop the intestine proceeds to the posterior end as a single unpaired tube.

The *Excretory system* consists of a very short Y-shaped vesicle opening at the extreme posterior end, with two fine ciliated tubes given off from the anterior limbs of the Y. In the female also it has a similar form. The genital opening is placed about 0·125 mm. behind the ventral sucker, about midway between the middle line and the lateral border. The cirrus sac is moderately developed and completely encloses the vesicula seminalis, which is elongated pear-shaped. Comparatively large prostate cells lie in the parenchyma of the cirrus sac. The testes begin 0·2 mm. behind the genital opening and extend backwards throughout the second quarter of the body length, consisting of eighteen to twenty rounded follicles, which lie symmetrically placed, one behind the other, midway between the intestinal limbs.

In the *female* the anterior part of the body has a very even diameter (0·058 mm.) throughout its length, while the posterior flattened part is 0·136 mm. wide. The length of the anterior part is 2·65 mm., that of the posterior 1·85 mm.

The mouth opening is ventral, a little (0·03 mm.) behind the anterior end, and there is no oral sucker. The ventral sucker is, however, well developed (fig. 22), and stalked as in the male. It measures 0·035 mm. in diameter. The œsophagus is 0·2 mm. long, and divides into two intestinal limbs just in front of the ventral sucker. The paired limbs are very narrow and even, without diverticula, running straight through the anterior part of the body. At the junction of the anterior and posterior regions they fuse to form a single much wider tube which runs straight backwards as a single tube to the posterior end, lying in the middle of the body, surrounded on all sides by the yolk glands.

The ovary, measured in a straight line from its anterior to its posterior end is 0·388 mm. long, but, as it is thrown into a number of curves or waves along its whole course its real length is much greater than this. The oviduct runs forwards, placed nearly in the middle of the body; towards its anterior end it widens into a uterus in which was found in each case a single egg, 0·032 × 0·026 mm. in size. The female genital opening lies immediately behind and to one side of the ventral sucker. The yolk glands occupy the whole field of the posterior part of the body up to the extreme posterior end and extending forwards for a length of 1·85 mm.

This form shows, perhaps, closer affinities with *Ornithobilharzia*[42] than with the other genera of this family. The members of that genus are found parasitic in European species of *Larus*. In the males of the two genera the external form, with the suckers is much the same: the configuration of the intestine is very similar. The position and arrangement of the testes are also fairly comparable though the follicles are much less numerous and less extensively distributed in *Austrobilharzia*. The position of the genital pore is practically the same. In the *females* the shape is somewhat similar as is also the arrangement of the ovary and the yolk glands, though the anterior thread-like part of the body is much longer in the Australian form, and the posterior broad part relatively shorter and consequently the extent of the yolk glands much less; the ovary is also shorter. While the female is shorter than the male in *Ornithobilharzia*, it is longer in *Austrobilharzia*. While spines are quite absent in the Australian form, except on the ventral sucker of the male, in *Ornithobilharzia* the gynecophoral canal of the male is thickly lined with small pointed spines, and the female has the posterior flattened part of its body armed with thick spines, which only cease at the extreme posterior end.[42] In the latter, too, the vesicula seminalis lies quite outside the rudimentary cirrus sac and a prostate is absent, but in the former the cirrus sac is well developed and completely encloses the seminal vesicle, and contains well developed prostate cells lying in its parenchyma (fig. 21).

The structural relations between the five genera of this family may be seen at a glance in the following table:—

	Bilharzia.	Bilharziella.	Austro-bilharzia.	Ornitho-bilharzia.	Giganto-bilharzia.
Comparative size of male and female	female longer than male	female shorter than male	female longer than male	female shorter than male	female shorter than male
Suckers	present	present or absent	two in male one in female	present	absent
Spines	numerous in both male and female	only on suckers	only on ventral sucker of male	numerous in both male and female	absent
Genital pore of female	immediately behind the ventral sucker	far behind the ventral sucker	close behind the ventral sucker	behind ventral sucker	near anterior end
Testes	few	numerous	not numerous, occupy small field	numerous follicles	very numerous reaching posterior end
Cirrus sac	absent	well developed but not enclosing vesicula seminalis	well developed and enclosing vesicula seminalis	rudimentary	poorly developed
Prostate	absent	present	present	absent	absent
Eggs in uterus	numerous	one	one	one	one?

Family MONOSTOMIDÆ.

Cyclocœlum taxorchis, sp. n. (Fig. 23.)

Diagnosis.—Middle sized worms, widest a little behind the middle, gradually narrowed towards the anterior end, and widely rounded behind. Pharynx small, *œsophagus long.* Genital pore at posterior end of pharynx. Cirrus sac *long, reaching the intestinal* limbs. Testes *side by side, one on either side of the middle line*, equal in size. Fields of the yolk-glands *extend forwards as far as* the pharynx, separated in the posterior end by a distinct interval. Coils of the uterus only in one or two exceptional cases reach beyond the inner edge of the intestinal limbs.

Host.—Limosa novæ-hollandiæ, in the body cavity.

Type specimen in the Australian Museum, Sydney, No. W. 444.

Ten specimens of this species were obtained from the body cavity of the Godwit, *Limosa novæ-hollandiæ*, by Dr. Harvey Johnston, at Lord Howe Island. They are moderate in size, varying from 8 to 14 mm. in length, and 2·28 to 3·53 mm. in breadth. The cuticle is raised up into a number of prominent ridges arranged in the form of a network, so that a section near and parallel to the surface has the appearance shown in fig. 23*a*. The body is flat dorsoventrally, widest a little behind the middle, gradually reduced to a blunt rounded point at the anterior end, while the posterior extremity ends in a broad, round sweep.

The mouth opening is terminal; the oral cavity funnel-shaped; and the pharynx small 0·25 mm. long by 0·192 mm. broad. The œsophagus is comparatively long, 0·6 mm. The intestinal limbs pass back in a somewhat wavy course parallel to the lateral and posterior edges of the body. The excretory vesicle, almost at the pore, divides into two widely separated branches.

The genital pore is on a level with the posterior end of the pharynx. The cirrus sac, of narrow and tubular form, almost entirely filled by the coiled vesicula seminalis, lies in front of the intestinal fork, sometimes crossing the anterior edge of the latter with its posterior end. The testes are of large size, irregular in shape, and situated side by side at the same level, one on either side of the middle line. They are equal in size, 1·36 × 0·97 mm. The ovary is on the right side just in front of the middle of the right testis. It is spherical in form, 0·446 mm. in diameter. The "shell-gland" is large, situated on the postero-median aspect of the ovary.

The yolk glands, consisting of comparatively large, very numerous oval follicles, 0·059 × 0·064 to 0·08 × 0·064 mm., extend from the posterior end of the pharynx to a level behind the intestine in the posterior end of the body. In some of the individuals the yolk glands extend further forward on one side than the other. They are confined to the lateral fields of the body, lying entirely between the intestine and the sides of the body, and are separated at the posterior end by a distinct interval. The uterus is very long and voluminous, and is arranged in a number of loops in the way that seems to be characteristic of *Cyclocœlum;* the loops for the most part lie between the middle line of the body and the lateral edges, only a few running right across the body. They do not anywhere pass out beyond the intestinal limbs, nor backward behind the testes.

The eggs are large and oval and show the characteristic increase in size as one proceeds along the uterus from the ovary. Each egg contains a miracidium with a pair of black eye-spots fused together. The eggs which are very thin-walled, vary in size from 0·117 × 0·059 to 0·139 × 0·059 mm.

Cyclocœlum taxorchis differs from all the other species of the genus in the arrangement of the testes side by side on either side of the middle line. From each of the species separately it shows a number of characteristic differences, and appears to be most closely related to *C. brasilianum*(23) which is parasitic in the South American bird *Totanus flavipes*, a bird closely related to *Limosa novæ-hollandiæ*, the host of the Australian fluke under consideration. The latter resembles *Cyclocœlum brasilianum*, and differs from the other species in its small pharynx and long œsophagus and in the forward extension of its yolk gland fields.

It differs from it, however, in the cirrus sac reaching the intestine, which it always fails to do in *C. brasilianum;* in the testes being equal in size while they are unequal in the Brazilian form and in the very characteristic arrangement of the testes.

Hæmatotrephus adelphus, sp. n. (Fig. 24.)

Diagnosis.—Moderate sized worms, 8 – 14 mm. long, pointed at the anterior end, rounded at the posterior, with the maximum breadth near the posterior end. Mouth cavity crescentic in transverse section. Œsophagus wanting. Intestinal limbs *half way between* middle line and lateral edge of the body. Genital pore at the posterior end of the pharynx. Cirrus sac projecting a little behind the intestinal fork. Yolk glands confined to the lateral fields, but meeting in the posterior end of the body. Mature eggs *very large*, 0·24 × 0·107 mm.

Host.—*Himantopus leucocephalus*, in the body cavity.

Type specimen in the Australian Museum, Sydney, No. W. 445.

Twelve specimens of this species were obtained from the body cavity of the White-headed Stilt, *Himantopus leucocephalus*, in South Australia, by Dr. J. Burton Cleland of the Government Bureau of Microbiology, Sydney. They are moderate sized worms, elongated and flattened, varying in length from 8·1 to 14·82 mm. and in breadth from 2·4 to 3·7 mm. They reach the maximum breadth some distance behind the middle of the body and become gradually narrower towards the anterior end which is pointed; and bluntly rounded off at the posterior end, which is almost semicircular. Figure 24 is drawn from a specimen which does not show the characteristic shape very well, as it had undergone a good deal of contraction along the long axis and bulging in the transverse in its preservation. But at the time the drawing was made I had only two specimens available for study, and this one exhibited the various structures in the body more clearly than the other.

The mouth opening is terminal; the mouth cavity or rudimentary oral sucker is funnel-shaped and there is practically no prepharynx. The mouth cavity has the characteristic crescentic form in transverse sections owing to the prominence that occurs on its dorsal wall. But the pharynx is strongly muscular and measures 0·35 × 0·31 mm. An œsophagus is practically absent, the forking of the intestine proceeding directly from the posterior end of the pharynx. The intestinal limbs, which are without cæca of any kind, lie some distance from the lateral edges of the body and practically parallel to them.

The genital pore is in the middle line, immediately at the posterior end of the pharynx. The cirrus sac is small and club-shaped and projects a little way behind the intestinal fork.

The testes are very large, irregularly oval in shape and lie obliquely, one in front of the other, in the bay of the posterior commissural circuit of the intestine. The posterior is larger, measuring 1·07 × 0·58 mm., while the anterior measures 0·93 × 0·427 mm.

The ovary, which lies in the middle line on a level immediately in front of the anterior testis, is oval in shape and 0·388 × 0·291 mm. in size. A large "shell-gland" lies behind and to one side of the ovary. The yolk glands are confined to the field outside the intestinal limbs. Anteriorly they extend to the base of the pharynx and posteriorly the two lateral fields become continuous with one another behind the posterior commissural loop of the intestine. They are composed of small oval follicles about 0·08 × 0·053 mm. The uterus is very voluminous and is arranged in numerous transverse loops, many of which stretch right across the body, whilst others only reach from the middle line to the lateral edge. These loops are not directly transverse, but have the backward inclination which seems to be characteristic of the genus, the angle of inclination becoming more marked as we proceed backwards, till at the posterior end the last couple of loops on each side proceed almost directly backwards on either side of the testes, almost reaching the posterior end of the body. The proximal portion is dilated to form a receptaculum seminis uterinum and is filled with sperms. The eggs are very thin-shelled, elliptical, and show an increase in size as one follows the uterus towards the anterior end. The eggs in the end near the ovary measure 0·187 × 0·107 mm.; in the distal part, however, 0·241 × 0·107 mm. Each of the eggs contains a miracidium with a conjoined pair of dark pigmented eye-spots.

This species is very similar in structure to *H. similis*, Stossich, parasitic in the abdominal cavity of *Himantopus atropterus*, and to *H. consimilis*, Nicoll, parasitic in the thoracic cavity of the Spur-winged Plover *Lobivanellus lobatus*. Besides the differences in host and a number of minor structural differences, such as the extension and the position of the yolk-glands, it differs from the two named in having considerably larger eggs, which when mature reach a size of 0·241 × 0·107 mm., while those of *H. consimilis*, Nicoll,[39, p. 125] do not exceed 0·2 × 0·08 mm., and those of *H. similis*, Stoss., 0·202 × 0·083 mm. (Dietz,[13, p. 527]).

Hyptiasmus magnus, sp. n. (Fig. 25.)

Diagnosis.—Large worms, with an elongated, flattened body, widest towards the posterior end. Intestinal limbs separated from the lateral edges of the body by a *wide interval.* Half the cirrus sac lying *behind* the fork of the intestine. Testes *very large.* Three gonads close together. Lateral fields of the yolk glands *not continuous with one another* behind the commissural part of the intestinal limbs. Loops of the uterus *not extending back* behind the anterior border of the posterior testis.

Host.—*Chenopsis atrata*, in the pharynx.

Type specimen in the Australian Museum, Sydney, No. W. 446.

Two specimens of this large fluke were obtained from the pharynx of the Black Swan, *Chenopsis atrata*, in Victoria, by Mr. A. Le Souef, Director of the Zoological Gardens at Sydney. The length of these specimens is 19 mm., and the breadth 4·5 mm. at the widest part in the region of the anterior testis. It tapers fairly gradually to a blunt point in front, but is rounded behind. The integument is made rough by a number of transverse ridges of thickened cuticle that cross the body transversely. The mouth cavity is funnel-shaped, 0·388 mm. long. Between this and the pharynx is interposed a distinct prepharynx 0·29 mm. long. The pharynx is 0·349 mm., and the œsophagus 0·582 mm. long. The large cerebral ganglia lie at the anterior end of the prepharynx, just at its junction with the mouth cavity. The intestinal limbs which are wide, run about halfway between the middle line of the body and the lateral edges, bending inwards a little between the testes.

The genital pore is very far forward, right in front of the pharynx, in the middle line, ventral to the prepharynx. In figure 25 it is shown as lying just to the side of the prepharynx which has become a little displaced to the right in the specimen from which the drawing was made, through pressure. The cirrus sac which is almost completely filled up by the vesicula seminalis is somewhat pear-shaped, with the anterior end elongated. Posteriorly it reaches a level some distance behind the intestinal fork.

The testes are exceedingly large, roughly rounded, with a surface irregular through shallow indentations. The oval ovary, with its long axis transversely placed, lies between them but nearer the posterior, several loops of the uterus intervening between it and the anterior testis. The three gonads are placed in a straight line slightly inclined to the longitudinal axis of the body. The anterior testis, 1·96 × 1·76 mm., is somewhat smaller than the posterior, 2·28 × 1·96 mm., while the ovary, 0·97 × 0·776 mm., is a good deal smaller than either.

The yolk glands are mainly on the outer sides of the intestinal limbs, spreading very little on their dorsal and ventral surfaces. In front they do not reach the level of the intestinal fork, and behind are separated by a wide interval. The follicles are oval in shape and fairly variable in size, from 0·054 – 0·133 mm. long, by 0·043 × 0·085 mm. wide.

The uterus is exceedingly long and voluminous, and the loops run for the most part right across the body, reaching well into the lateral fields between the intestinal limbs and the lateral edges, but some of the loops run from the sides to the middle line only, as in *Cyclocœlum*. None of the loops pass further back than the anterior border of the posterior testis.

The eggs, which are very thin shelled, increase very considerably in size during their passage along the uterus. In the proximal parts, near the ovary, they measure 0·075 × 0·04 mm.; about the middle they vary from 0·081 × 0·043 to 0·091 × 0·053 mm.; and in the distal portion, towards the opening, they attain the size of 0·112 × 0·059 mm.

This species is closely related to a group of species *H. arcuatus*, *H. lævigatus*, and *H. tumidus*, all parasitic in various anseriform birds in Europe. Besides a number of minor points, such as the size and shape of the body and the position of the intestine in regard to the sides and posterior end of the body, it differs from all of these in the cirrus sac projecting back much further behind the intestinal fork; in the much larger testes, and in having the gonads much closer together; and in having the lateral fields of the yolk glands separated from one another at the posterior end. In the three European species some loops of the uterus pass as far back as the hinder border of the posterior testis or beyond it, while in the Australian form they do not pass further back than the anterior border.

PART II.

List of the trematode parasites of Australian birds, together with closely related forms.

OPISTHORCHINÆ.

Opisthorchis obsequens, Nicoll, obtained from the liver of *Hieracidea berigora* in Queensland, is related to *O. interruptus*, Brn., found in the South American bird *Alcedo viridirufa*.

PSILOSTOMINÆ.

Orchipedum sufflavum, Nicoll, parasitic in the œsophagus of the Black Spoonbill *Platalea regia*, in Australia, seems to find its nearest relative in *Orchipedum tracheicola* Brn., parasitic in the European *Anas fusca*.

Coenogoniminæ.

Scaphanocephalus australis, sp. n., from the intestine of the Sea Eagle *Haliaetus leucogaster*, is closely related to *S. expansus*, Jägerskiöld, parasitic in the Sea Eagle *Pandion haliaetus* from the Red Sea.

Echinostominæ.

Including those described in this paper, seventeen members of this group are recorded from Australian birds. Three of these are represented by the same species in European or Asiatic birds, while the others are all more or less closely related to other species of the same family occurring in similar birds in other parts of the world.

Echinostoma acuticauda, Nicoll, parasitic in the Straw-necked Ibis, *Carphibis spinicollis*, in Queensland, is related to *E. revolutum*, found in European Anseriformes, and to *E. mendax*, Dietz, parasitic in certain South American birds belonging to the same family; while *E. revolutum* itself is found in certain Australian Anseriformes.

The related forms *E. elongatum*, Nicoll, and *E. emollitum*, Nicoll, parasitic in *Podargus strigoides* and *Centropus phasianus* respectively, may be looked upon as Australian representatives of *E. uncatum*, Dietz, found in two species of *Crotophaga* in Brazil. *E. hilliferum*, Nicoll, from *Porphyrio melanotus* (Rallidæ), and *E. australasianum*, Nicoll from *Antigone australasiana* (Gruidæ) are related to *E. sarcinum*, Dietz, parasitic in the European *Grus Grus*.

Echinochasmus prosthovitellatus, Nicoll, parasitic in the intestine of the Brown Hawk, *Hieracidea orientalis*, in Queensland, is related to *Echinochasmus euryporus*, Lss., found in several species of hawks belonging to the genus *Milvus* in Egypt. *E. tenuicollis*, sp. n. from the intestine of the shag, *Phalacrocorax melanoleucus* finds its nearest relative in *E. coaxatus*, Dtz., which is also parasitic in a water bird, *Podiceps cristatus*.

Himasthla harrisoni, sp. n. from *Numenius cyanopus* is closely related to *H. rhigedana*, Dtz., parasitic in two species of *Numenius* that inhabit the Sinai peninsula on the Red Sea.

Acanthoparyphium spinulosum, sp. n. from the duodenum of *Charadrius dominicus* seems to be most closely related to *A. phœnicopteri*, Lhe., parasitic in the African *Phoenicopterus roseus.*

Echinoparyphium oxyurum and *E. harveyanum* found in *Herodias timoriensis* and *Micraeca fascinans* respectively are related to *E. elegans.* Lss., *E. aconiatum*, Dtz., and *E. agnatum*, Dtz., found in *Buteo* and *Vanellus.*

Patagifer bilobus, Rud., which occurs in the intestine of several European and South American Ardeiformes is also found in Australia in a number of birds of the same family. *P. acuminatus* and *P. fraternus* are Australian species closely related to the foregoing and found in similar birds, *e.g.*, *Ibis molucca* and *Herodias timoriensis* respectively.

Chaunocephalus ferox, is another Echinostomid having, like *Patagifer bilobus*, a very wide distribution. It is found in Australia in the Black-necked Stork, *Xenorhynchus asiaticus*, a bird which occurs in India, Burmah, the Malay Peninsula, New Guinea, and Northern Australia. The same trematode is also recorded from several species of storks in Europe.

PLAGIORCHIINÆ.

Plagiorchis (Lepoderma) nisbetii, Nicoll, from *Chibia (Dicrura) bracteata* is related to *P. cirratum*, Rud., found in *Corvus monedula* in Europe; and *P. clelandi* from *Petrochelidon ariel* in Australia is closely related to *P. maculosus* parasitic in the European swallow *Hirundo.* All these hosts are passeriform birds. *P. spatulatus*, another Australian form, is also fairly close to *P. maculosus*, but it occurs in one of the Motacillidæ, *Anthus australis.*

MICROPHALLINÆ.

Levinseniella howensis, from the cæcum of *Charadrius dominicus*, finds its nearest relative in *L. brachysoma*, Jägers., which is parasitic in a Scandinavian species of *Charadrius*.

CEPHALOGONIMINÆ.

Prosthogonimus vitellatus, Nicoll, found in *Chibia bracteata* is closely related to *P. cuneatus* found in several European Passeriformes.

DICROCOELIINÆ.

Platynotrema biliosum, Nicoll, and *P. jecoris*, Nicoll, two closely related members of this sub-family are found in the liver of the same species of host, the Stone Curlew, *Burhinus grallarius*, and are related most nearly, perhaps to *Dicrocoelium illiciens*, Brd., which occurs in several Brazilian birds, *e.g.*, *Rhamphastus sp.*, and *Pipra sp.*

Lyperosomum parvum, sp. n., parasitic in one of the Corvidæ, *Strepera versicolor*, is evidently very closely related to an unnamed species of *Lyperosomum* in von Linstow's collection, figured by Braun (Pl. x, fig. 66), which was obtained from the intestine of *Corvus corone*. Two other species, *L. megastomum* and *L. harrisoni* which are probably related to *L. parvum* are found in birds not belonging to the Corvidæ.

HARMOSTOMINÆ.

Harmostomum pulchellum from the Wonga Pigeon, *Leucosarcia picata* is related to *H. mordens*, Brn., which is found in *Rallus* sp., birds fairly closely related to the Columbiformes to which the Wonga Pigeon belongs.

CLINOSTOMINÆ.

Clinostomum australiense, sp. n. from the œsophagus of *Plotus novæ-hollandiæ* is closely related to *C. marginatum* found in various species of Ardea in America; while *C.*

hornum, Nicoll, found in the trachea and œsophagus of the Nankeen Heron, *Nycticorax caledonicus* is also related to *C. marginatum* and to *C. complanatum*, Rud., parasitic in the European Heron, *Ardea cinerea*.

Bilharziidæ.

Austrobilharzia terrigalensis parasitic in the sea-gull, *Larus novæ-hollandiæ* finds its nearest relative in *Ornithobilharzia intermedia*, parasitic in various European species of *Larus*.

Monostomidæ.

Cyclocœlum taxorchis, from the body cavity of *Limosa novæ-hollandiæ* is closely related to *C. brasilianum* parasitic in *Totanus flavipes*. Totanus and Limosa are closely related bird-genera.

Hœmatotrephus consimilis, Nicoll, found in the Spur-winged Plover, *Lobivanellus lobatus* and *H. adelphus* sp. n. parasitic in *Himantopus leucocephalus* are both closely related to *H. similis*, Stossich, found in the abdominal cavity of *Himantopus atropterus* in Egypt. All these birds are members of the family Charadriidæ. *Typhlocoelum reticulare*, mihi, parasitic in *Anseranas semipalmatus* is the Australian representative of *T. cucumerinum*, Rud., found in various species of *Anas* in Europe. *Allopyge antigones*, mihi, parasitic in the great Australian Crane, *Antigone australasiana* is closely related to *Hyptiasmus ominosus*, Stoss. and *H. adolphi*, Stoss., found in several species of European Cranes. *Hyptiasmus magnus*, found in the pharynx of the Black Swan, *Chenopsis atrata* is closely related to *H. arcuatus*, *H. laevigatus* and *H. tumidus* all parasitic in various Anseriform birds in Europe.

Notocotylus attenuatus, Rud., common in European ducks and geese has also been recorded from a considerable number of related birds in Australia.

HOLOSTOMIDÆ.

Strigea promiscua, Nicoll, found in the intestine of two owls in Queensland, *Ninox maculata* and *N. boobook* is nearly related to *S. gracilis*, which occurs in certain anseriformes in Europe. *Strigea flosculus*, Nicoll is a worm of doubtful affinities.

Hemistomum brachyurum, Nicoll, found in the intestine of *Ninox maculata* in Queensland, and *Hem. triangulare* mihi, parasitic in *Dacelo gigas* and *Ninox maculata* in New South Wales may be looked upon as the Australian representatives of the European *Hem. spathula* parasitic, in various members of the Strigiformes.

Hemistomum intermedium, mihi, found in the duodenum of the Black Swan, *Chenopsis atrata*, seems to be a connecting link between Hemistomum and Holostomum. It does not appear to have any near relatives and it must be looked upon as an aberrant or perhaps rather a primitive form.

Holostomum hillii, mihi, found in the duodenum of *Larus novæ-hollandiæ* is nearly related to *H. erraticum* which is found parasitic in several species of Larus in Europe. *Holostomum simplex*, mihi, from the intestine of *Ardea novæ-hollandiæ* is more nearly related to *H. cornu* than to any other form. *H. cornu* is parasitic in various old-world species of herons belonging to the genus Ardea.

Holostomum musculosum found in the duodenum of the Crested Tern, *Sterna bergii*, is most nearly related perhaps to *H. bursigerum* found parasitic in several European Lariiformes.

List of the Trematode Parasites of Australian birds, arranged according to the classification of the birds, together with the nearest relative of the trematode and its host, so that the relationships of the hosts may come into view.

Australian Bird.	Trematode Parasite.	Nearest Relative.	Host of Latter.
Order COLUMBIFORMES			
Leucosarcia picata	*Harmostomum pulchellum*	*H. mordens*	*Rallus sp.*
Order RALLIFORMES			
Porphyrio melanotus	*Echinostomum hilliferum*	*E. sarsinum*	*Grus grus*
Order LARIFORMES			
Sterna bergii	*Lyperosomum megastomum*	?	
	Holostomum musculosum	*H. bursigerum*	Lariformes in Europe
Larus novæ-hollandiæ	*Austrobilharzia terrigalensis*	*Ornithobilharzia intermedia*	*Larus fuscus*
	Holostomum hillii	*Hol. eraticum*	*Larus spp.*
Order CHARADRIFORMES			
Lobivanellus lobatus	*Hæmatotrephus consimilis*	*H. similis*	*Himantopus atropterus*
	Echinostomum ignavum	?	
Charadrius dominicus	*Acanthoparyphium spinulosum*	*A. phœnicopteri*	*Phœnicopterus roseus*
	Levinseniella howensis	*L. brachysoma*	*Charadrius hiaticula* in Scandinavia
Himantopus leucocephalus	*Hæmatotrephus adelphus*	*H. similis*	*Himantopus atropterus*
Numenius cyanopus	*Himasthla harrisoni*	*H. rhigedana*	*Numenius arabicus* and *N. arquatus*
Limosa novæ-hollandiæ	*Cyclocoelum taxorchis*	*C. brasilianum*	*Totanus flavipes* (Charadriformes)
Burhinus grallarius	*Platynotrema biliosum*	*Dicrocœlium illiciens*	*Pipra* (passeriform)
	P. jecoris		
Order GRUIFORMES			
Antigone australasiana	*Allopyge antigones*	*Hyptiasmus ominosus* and *H. adolphi*	in European Gruiformes
	Echinostomum australasianum	*E. sarcinum*	in European *Grus grus*
Order ARDEIFORMES			
Ibis molucca	*Patagifer acuminatus*	*P. bilobus*	several Ardeiformes in Europe
Carphibis spinicollis	*Echinostoma acuticauda*	*E. mendax*	Anseriformes
Platalea regia	*Orchipedum sufflavum*	*O. tracheicola*	*Anas fusca*
	Patagifer bilobus	Same species in Europe	*Platalea leucorodia*
Pelegadis falcinellus	" "	" "	" "
Xenorhynchus asiaticus	*Chaunocephalus ferox*	Same species occurs in Ardeiformes in other parts.	
Herodrias timoriensis	*Patagifer fraternus*	*P. bilobus*	several Ardeiformes in other regions
	Echinoparyphium oxyurum	*E. aconiatum*	*Vanellus vanellus*

LIST OF THE TREMATODE PARASITES—*continued.*

Australian Bird.	Trematode Parasite.	Nearest Relative.	Host of Latter.
Ardea novæ-hollandiæ	*Holostomum simplex*	*H. cornu*	*Ardea sp.*
Nycticorax caledonicus	*Clinostomum hornum*	*C. marginatum* and *C. complanatum*	*Ardea cinerea* in Europe, etc.
Order ANSERIFORMES			
Chenopsis atrata	*Hemistomum intermedium*	?	
	Hyptiasmus magnus	*H. arcuatus* and *H. laevigatus*	European Anseriformes
Anseranas semipalmata	*Typhlocoelum reticulare*	*T. cucumerinum*	*Anas spp.* in Europe
Anas superciliosa	*Echinostomum revolutum*	Same species in Europe	*Anas boschas* and other species of Anseriformes
Nettopus pulchellus	*Notocotylus attenuatus*	Same species	in various species of Anseriformes in Europe
Anas superciliosa	,, ,,	,, ,,	
Chenopsis atrata	,, ,,		
Order PELICANIFORMES			
Phalacrocorax melanoleucus	*Dolichosaccus solecarius*	*D. trypherus*	in frogs
	Echinochasmus tenuicollis	*E. coaxatus*	*Podiceps cristatus*
Plotus novæ-hollandiæ	*Clinostomum australiense*	*C. marginatum*	Ardeiformes
Ord. ACCIPITRIFORMES			
Haliætus leucogaster	*Scaphanocephalus australis*	*S. expansus*	*Pandion haliaetus* (Accipitriformes)
Hieracidea berigora	*Opisthorchis obsequens*	*O. interruptus*	*Alcedo viridirufa* (Kingfisher)
H. orientalis	*Echinochasmus prosthovitellatus*	*E. euryporus*	*Milvus spp.* in Egypt (Accipitriformes)
Order STRIGIFORMES			
Ninox boobook	*Lyperosomum harrisoni*	*L. parvum*	*Strepera versicolor*
	Strigea promiscua	*S. gracilis*	Anseriformes in Europe
N. maculata	*Strigea promiscua*	*S. gracilis*	Anseriformes
	Hemistomum brachyurum	*Hem. spathula*	European Strigiformes
	Hem. triangulare	,, ,,	,, ,,
Order CORACIIFORMES			
Podargus strigoides	*Echinostomum elongatum*	*E. uncatum*	*Crotophaga spp.* (Picarine Bird)
Dacelo gigas	*Hem. triangulare*	*Hem. spathula*	Strigiformes
	Strigea flosculus	?	
Order COCCYGES			
Centropus phasianus	*Echinostomum emollitum*	*E. uncatum*	*Crotophaga spp.*
Order PASSERIFORMES			
Petrochelidon ariel	*Plagiorchis clelandi*	*P. maculosus*	*Hirundo spp.* (Passeriformes)
Micrœca fascinans	*Echinoparyphium harveyanum*	*E. aconiatum*	*Vanellus spp.* (Charadriformes)
Anthus australis	*Plagiorchis spatulatus*	*P. maculosus*	Passeriformes in Europe
Chibia bracteata	*Plagiorchis nisbetii*	*P. cirratum*	*Corvus monedula* (Passeriformes)
	Prosthogonimus vitellatus	*P. cuneatus*	Several European Passeriformes
Strepera versicolor	*Lyperosomum parvum*	*Lyperosomum sp.* (of von Linstow)	*Corvus corone* in Europe

Of all the trematodes known from Australian birds only four have been referred to new genera, viz., *Platynotrema biliosum* Nicoll, *P. jecoris* Nicoll, *Allopyge antigones* mihi and *Austrobilharzia terrigalensis* mihi. The remainder have not only been referred to known genera, but are, for the most part, pretty closely related to known species occurring in other parts of the world. In some of the birds which are migratory or have a very wide range the same trematode has been recorded as occurring in them both in Australia and in Asia, Europe or other parts; for instance the Echinostomid *Chaunocephalus ferox* Rud. has been recorded both from Asia and Australia as parasitic in the Jabiru, *Xenorhynchus asiaticus*, a stork that ranges from India through Southern Asia and the East Indies to Northern Australia. *Patagifer bilobus* Rud. has been recorded several times in Australia from *Platalea regia* and *Pelegadis falcinellus* and was originally described in Europe as a parasite of the European *Platalea leucorodia*. With one exception, all the trematodes known from Australian birds are either identical with, or more or less closely related to parasites of birds in other parts of the world.

It is a remarkable and significant fact that all these relatives of the Australian forms should find birds as their hosts. And further than this, the bird-hosts of similar forms are almost in every case birds of a similar kind.

Of the fifty-one trematodes of Australian birds mentioned in the foregoing table, thirty find their nearest relatives in trematodes parasitic in birds of the same family, ten in birds of a closely related family, and seven in birds which cannot be considered closely related to the Australian bird-hosts, while three are so constituted that they do not seem to have any near relatives amongst known trematodes.

In the case of the first group and perhaps also of the second, it may be considered that the pairs of related trematodes have been derived from common ancestors, and also that their hosts have been derived from common ancestors, and that the ancestors of the trematodes were parasitic in those of the birds. For instance, *Holostomum hillii* and *H. eraticum*, two closely related species of *Holostomum*, are parasitic in various species of *Larus*. These sea-gulls are apparently derived from common ancestors in which the species of trematode that gave rise to *H. hillii* and *H. eraticum* was parasitic. As the original *Larus* spread over the earth till, in the course of time, it attained the present very wide distribution of the genus, by the acquisition of different characters it became split up into a number of species. Evolutionary agencies were at the same time working on the trematodes which accompanied the birds, and one group eventually became separable from another as a distinct species.

The want of relationship between the hosts in the case of the seven pairs in the third group, may be explained on the supposition that in the one case or the other the parasite has been acquired by the bird much more recently.

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EXPLANATION OF PLATES.

The drawings which were made by Mr. W. F. Atkins of the Technical High School, Sydney, were all done with the help of the camera lucida.

REFERENCE LETTERS.

c. g. Cerebral ganglion
c. s. Cirrus sac.
c. Cirrus
Ej. d. Ejaculatory duct
E. Excretory vessel
Ex. p. Excretory pore
Ex. v. Excretory vesicle
F. C. Flame cell
G. p. Genital pore
G. S. Genital sinus
Int. Intestinal limbs
L. c. Laurer's canal
L. t. Lateral nerve-trunk
M. O. Mouth-opening
N. Nervous system
N. t. Nerve trunk
Œs. Œsophagus
O. S. Oral Sucker
O. Ovary
O. d. Oviduct
P. Penis
Ph. Pharynx
Pr. Prostate
R. s. Receptaculum seminis
R. s. u. Receptaculum seminis uterinum
S. g. "Shell-gland"
T. Testis
Ut. Uterus
Vag. Vagina or metraterm
v. d. Vas deferens
v. s. Vesicula seminalis
v. sk. Ventral sucker
y. d. Yolk-duct
y. g. Yolk-glands
y. r. Yolk-reservoir

Plate IX.

Fig. 1.—General view of *Scaphanocephalus australis* from a whole mount. *G. cx.* genital sucker. × 45.

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Fig. 15.—*L. megastoma*, whole mount. × 44.

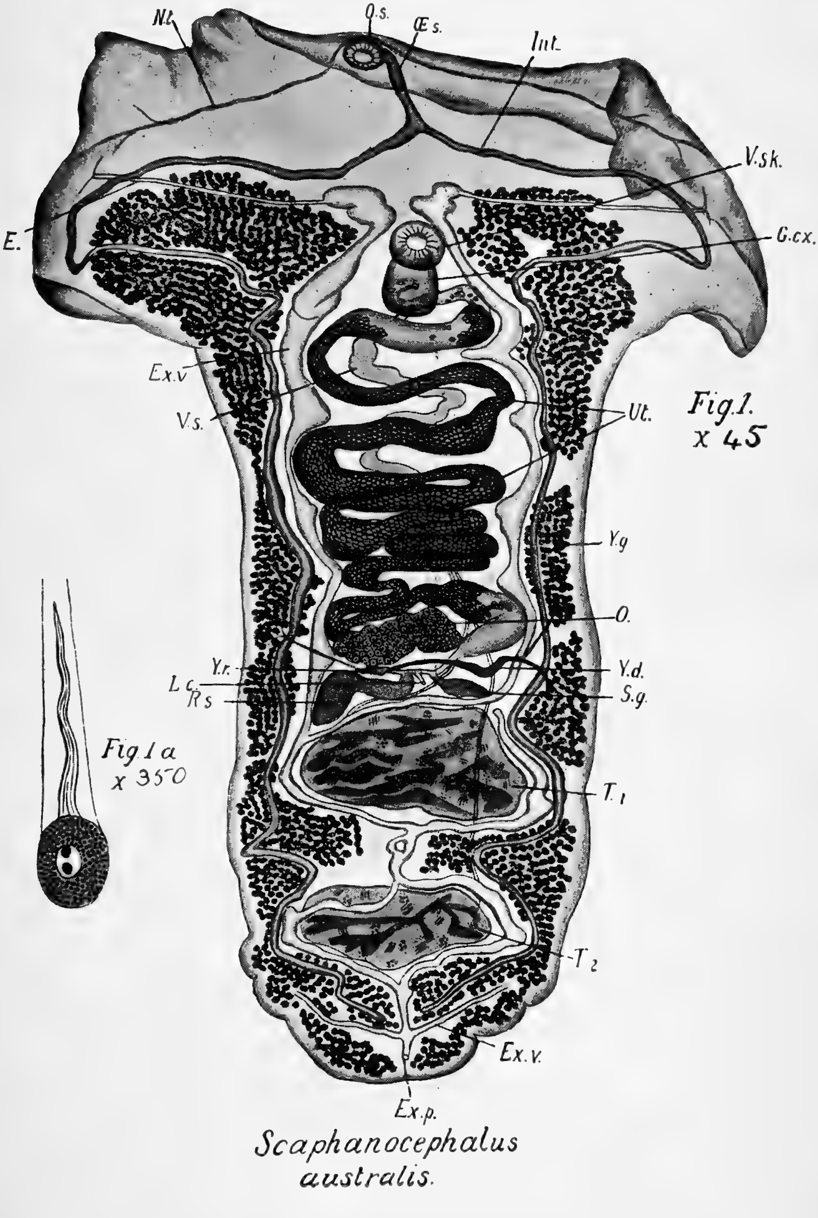
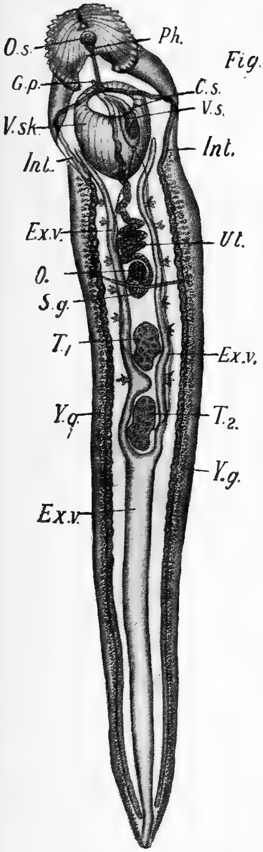


Fig. 1. x 45

Fig. 1a x 350

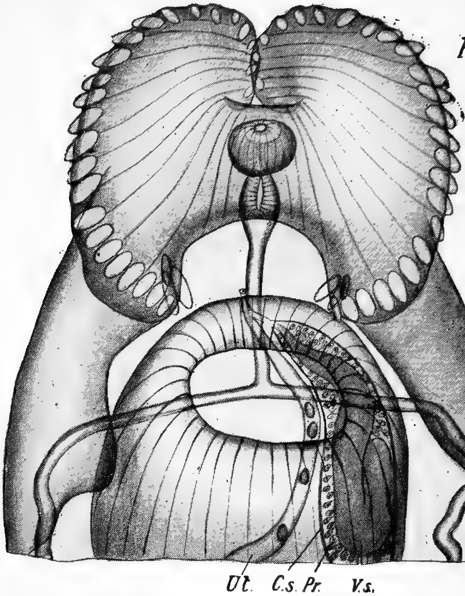
Scaphanocephalus australis.

Fig. 2.



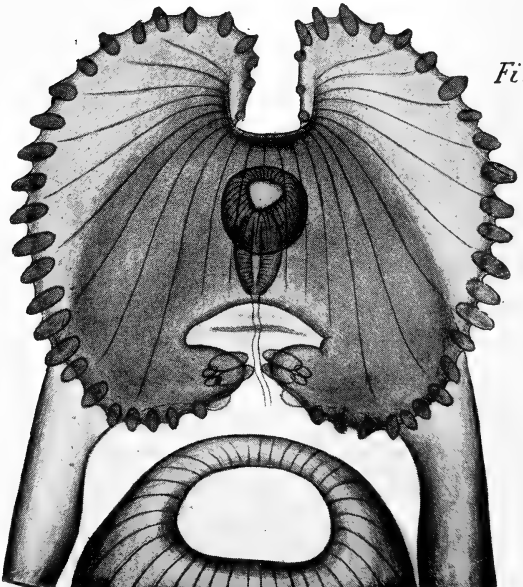
Patagifer acuminatus.

Fig. 3.

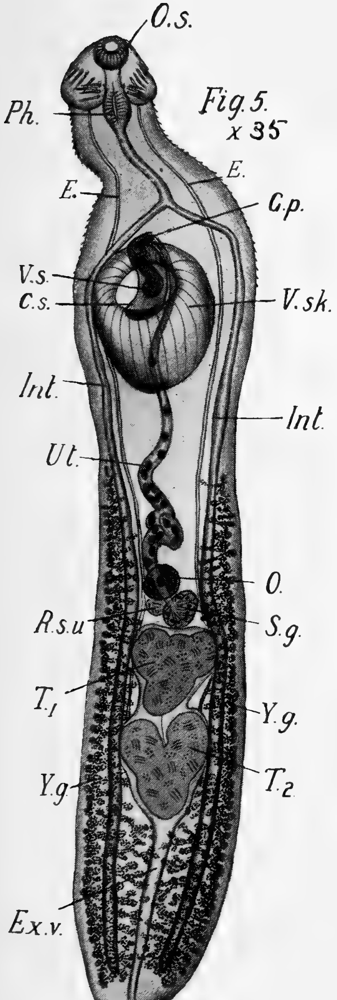


Patagifer acuminatus.

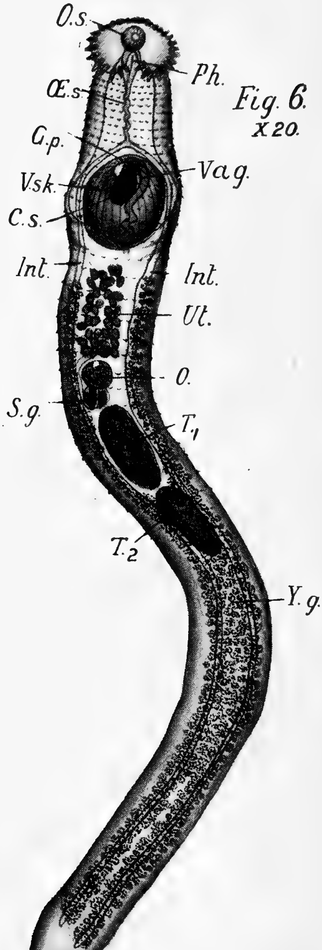
Fig. 4.



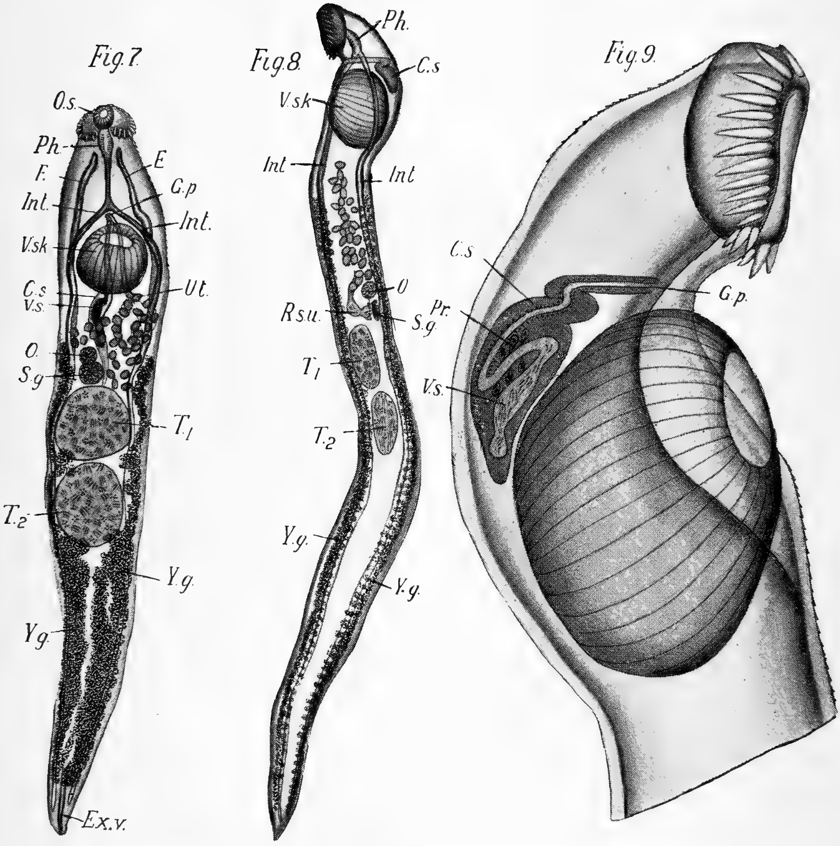
Patagifer fraternus



Echinochasmus tenuicollis.

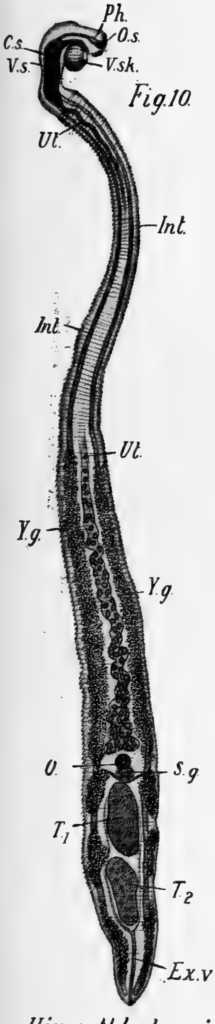


Echinoparyphium oxyurum.

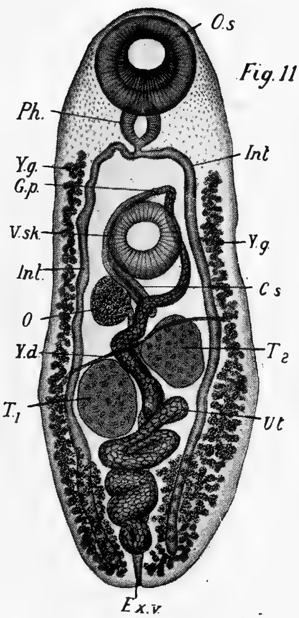


Acanthoparyphium spinulosum.

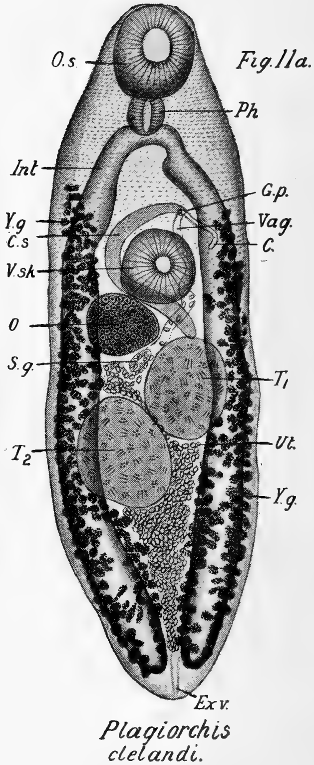
Echinoparyphium harveyanum.



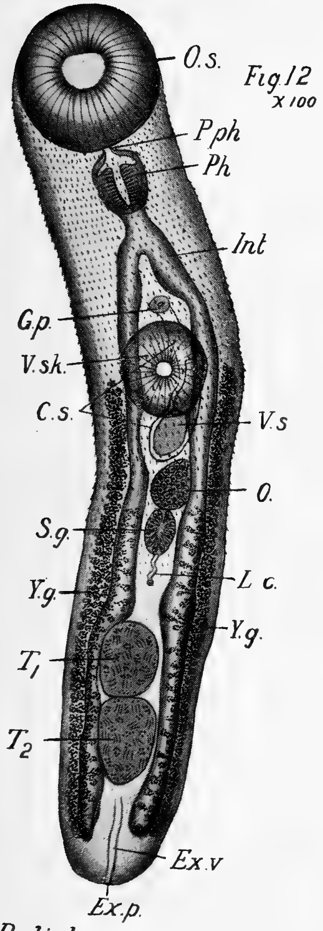
Himasthla harrisoni



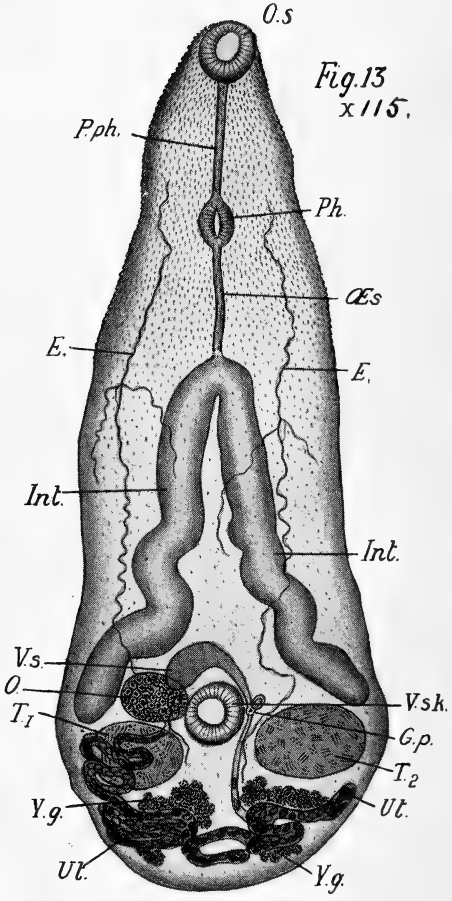
Plagiorchis spatulatus



Plagiorchis clelandi.



Dolichosaccus solecarius



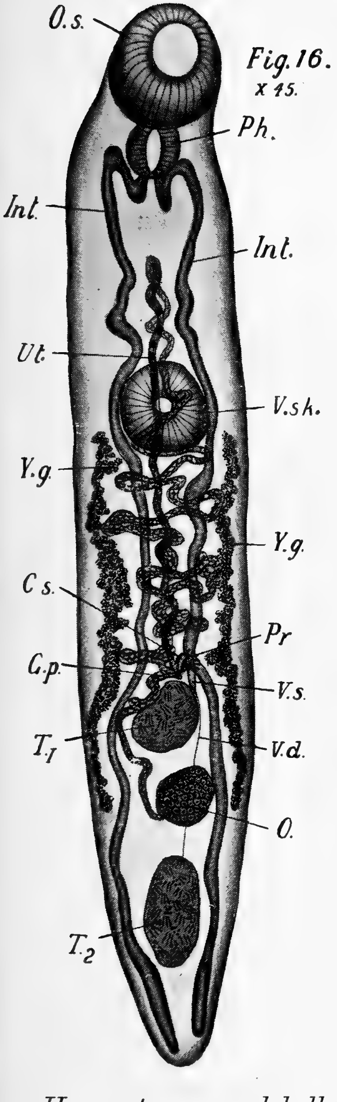
Levinseniella howensis.

Fig. 14.
x 50.

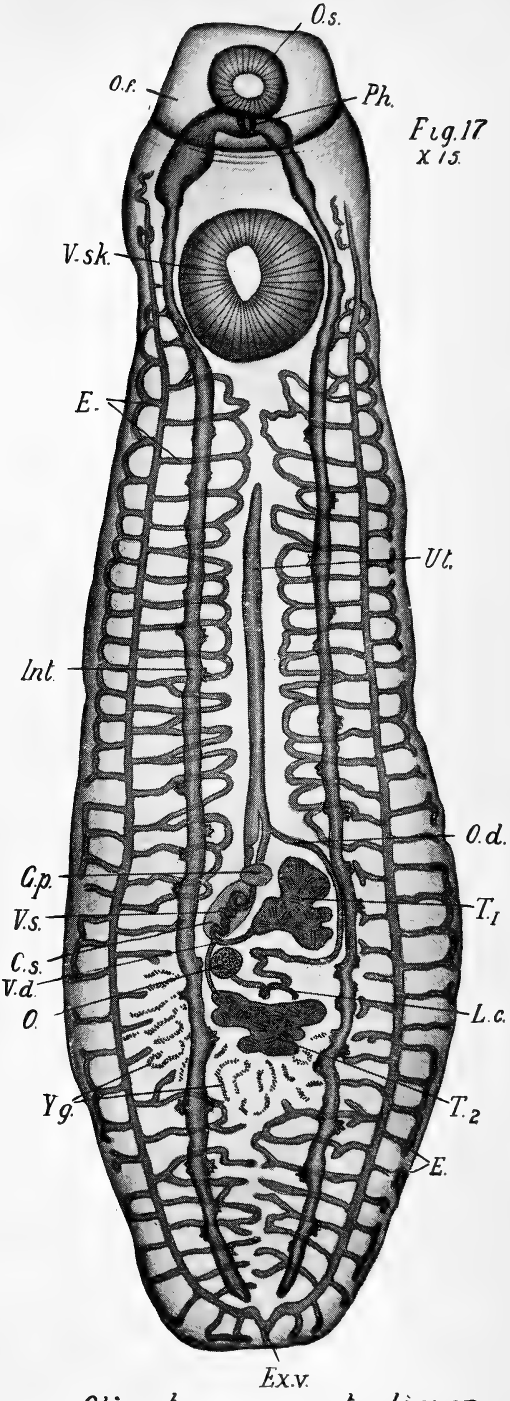
Lyperosomum parvum.

Fig. 15.
x 44.

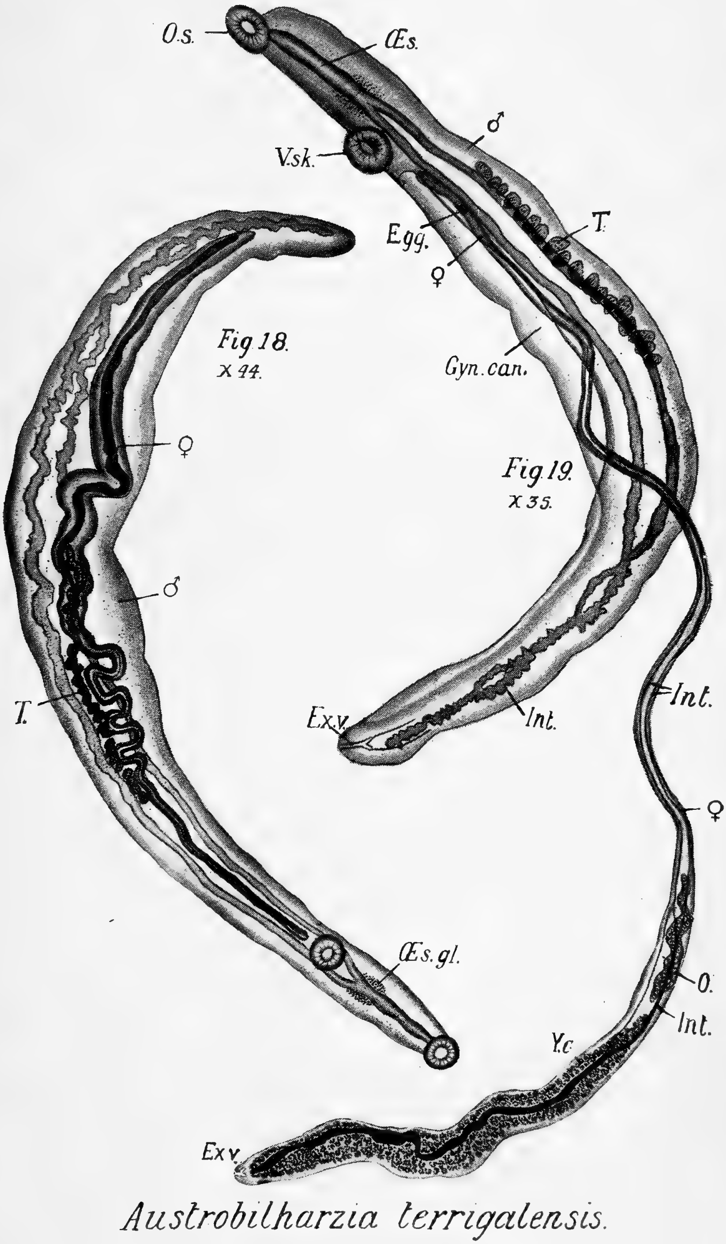
L. megastoma.



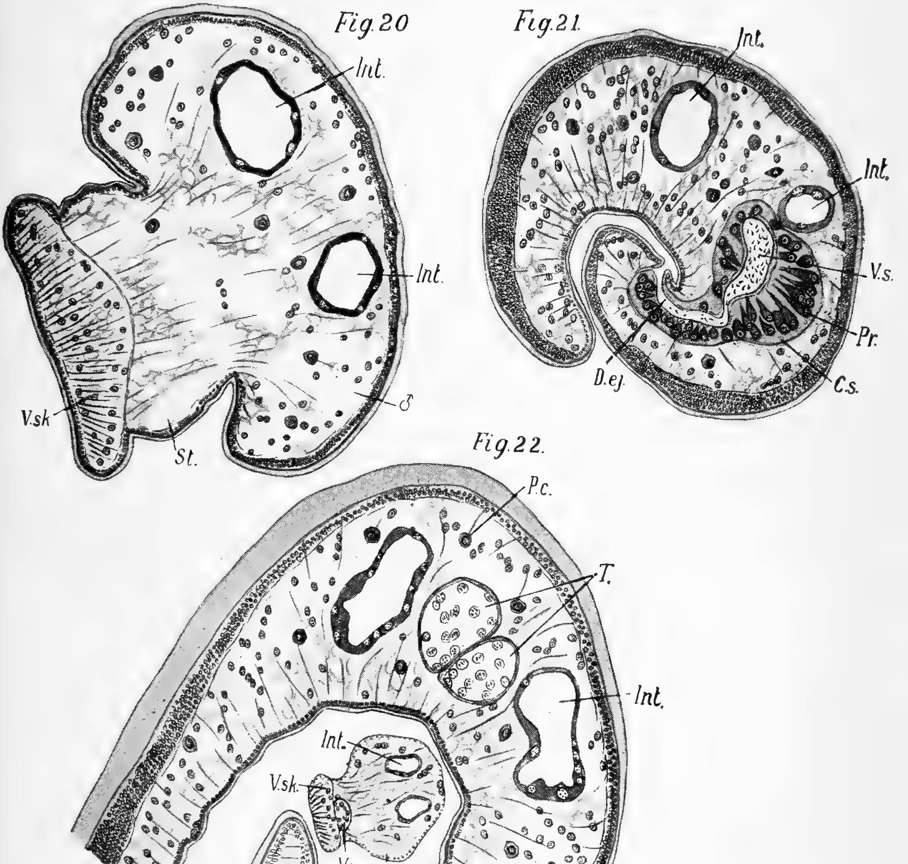
Harmostomum pulchellum.



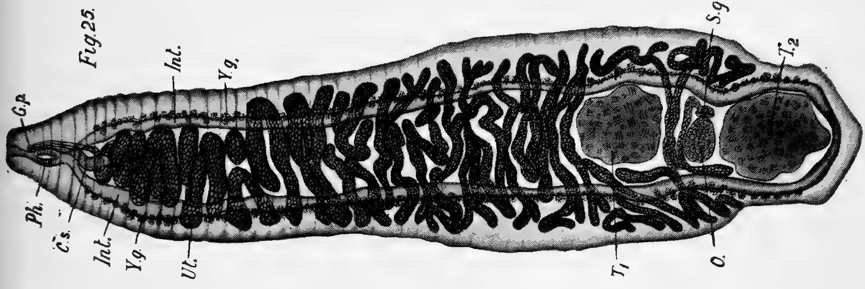
Clinostomum australiense.



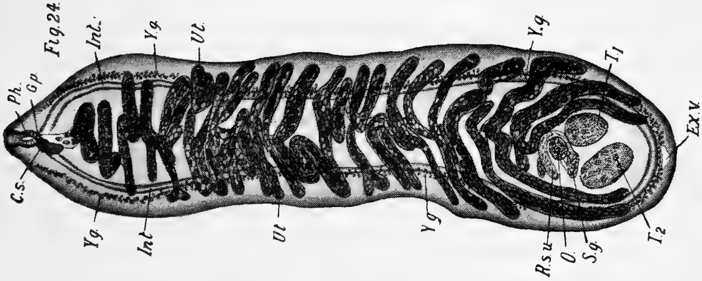
Austrobilharzia terrigalensis.



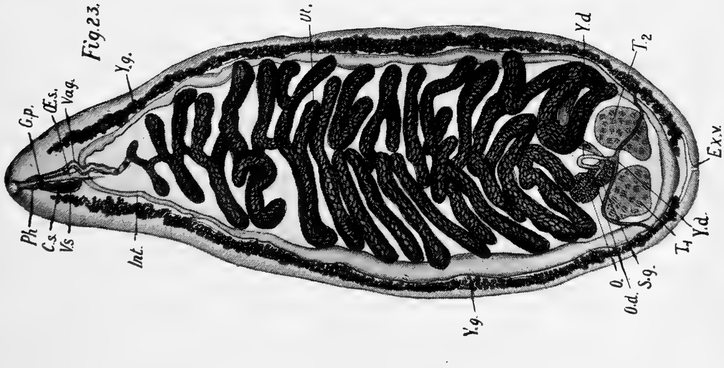
Austrobilharzia terrigalensis.



Hyptiasmus magnus.



Haematotrephus adelphus.



Cyclocœlum taxorchis.

Plate XVI.

Fig. 16.—*Harmostomum pulchellum*, whole mount. × 45.

Fig. 17.—*Clinostomum australiense*, whole mount. × 15.

Plate XVII.

Fig. 18.—*Austrobilharzia terrigalensis*, whole mount with the female lying in the gynecophoral canal of the male. × 44.

Fig. 19.—The same species. showing the female almost completely freed from the gynecophoral canal of the male. × 35.

Plate XVIII.

Fig. 20.—*Austrobilharzia terrigalensis*, transverse section through the male in the region of the ventral sucker. St., stalk of the sucker. × 205.

Fig. 21.—T.S. through the cirrus sac and male opening. × 222.

Fig. 22.—T.S. through a pair at the level of the ventral sucker of the female. × 240.

Plate XIX.

Fig. 23.—*Cyclocœlum taxorchis*, whole mount. × 10.

Fig. 24.—*Hœmatotrepus adelphus*, whole mount. × 10.

Fig. 25.—*Hyptiasmus magnus*, whole mount. × 6.

A PHOTOGRAPHIC FOUCAULT-PENDULUM.

By Rev. E. F. PIGOT, S.J., B.A., M.B.

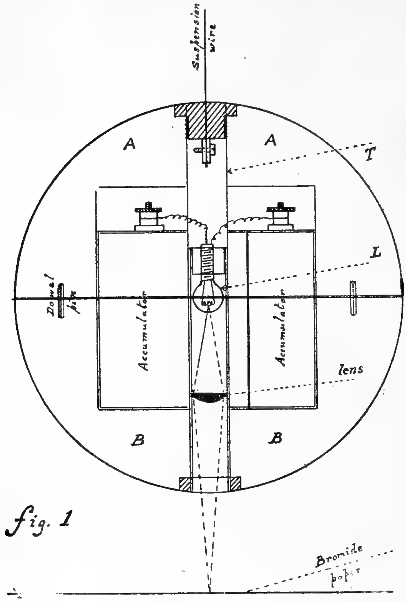
[*Read before the Royal Society of N. S. Wales, December 6, 1916.*]

THE following notes have unavoidably been put together somewhat hastily, but I thought nevertheless that a brief account of some trial experiments with a new apparatus might be of interest to the Society, even before more precise results were obtained.

It was in the small hours of the morning of January 8th, 1851, in Paris, that Leon Foucault obtained the first successful result of his classical pendulum-experiment, demonstrating the rotation of our planet on its axis. The progressive apparent change in azimuth of the plane of vibration of a long heavy pendulum had, without his knowledge, been observed two centuries before by Viviani, at Florence; but the honour rests with Foucault of having discovered, from theory, the physical law governing this movement (as a close approximation at least), and of having verified it by actual experiment.

In order to thoroughly investigate the truth of his now well-known "sine-law," his pendulum experiment was repeated, especially in 1851 and 1852, in many countries of the world,—in France (5 cities), England and Ireland (5), Holland (4), Germany (3), Switzerland (2), Italy, Denmark, Canada, United States, Ceylon, and Brazil (1 each), and in many cases with extreme care. Of course I am not to be understood as referring now to the experiment as doubtless frequently performed merely for lecture-demonstration purposes, but as carried out with the rigorous attention to detail demanded by scientific research. In all these various places, the investigation was carried out by a visual method of some kind or other, which in certain cases at least, lays itself open to criticism.

During November of last year, while planning details for a quantitative repetition in Sydney, with all the precision possible, of Foucault's experiment, with a view to the verification of his law in the Southern Hemisphere (the observations at Rio Janeiro in 1851 having given unsatisfactory results), it occurred to me that it would be interesting to endeavour to obtain also a photographic record of the apparent variation in azimuth of the oscillation-plane of the pendulum. This appeared to have certain advantages from several points of view, not as supplanting, but as supplementing the time-honoured visual method, which alone I intended following in the first instance. It appeared to me that a small glow-lamp and short-focus lens could be enclosed within the heavy leaden "bob" of the pendulum, and thus a well-defined spot of light could be made to record the change of azimuth of the latter on a sheet of bromide-paper placed below. Professor Pollock, F.R.S., to whom I spoke about the idea, encouraged me to attempt to realise it, which I did. The results so far are, I hope, such as to justify further experiments, to be begun soon. Various difficulties of course soon presented themselves, but they were eventually overcome. Among them was the question of feeding the glow-lamp. Several alternative plans were considered, but finally I decided to adopt an 8-volt supply, derived from four storage-cells symmetrically disposed within the bob itself. The latter was originally designed as a pair of brass hemispheres with bayonet-joint coupling, and filled with lead, except for a cubical space in the centre for the cells and lamp, and two vertical cylindrical spaces, one below, for a draw-tube holding the lens, the other above, to maintain symmetry of mass. This plan was afterwards partially modified, and the whole weight of the bob is carried by the tube T (fig. 1), which also serves to contain the lamp and draw-tube for the lens,—the enveloping brass hemispheres being thus rendered unnecessary. This modification was suggested to me by Mr. T. J. Murday, to whom I am also indebted for several other improvements which I have much pleasure in acknowledging. He has, at my request, supplied the following details of the method adopted in making the large heavy hemispheres. These are made of stereo-metal, instead of lead, so as to be workable in the lathe.



Vertical Section of Pendulum-bob: *A, A,* upper hemisphere; *B, B,* lower hemisphere; *T,* central supporting tube; *L,* glow-lamp.

"The production of a true sphere of relatively small size is a fairly easy task in the hands of a skilled mechanic equipped with proper tools; but when the mass weighs 60 lbs. and measures about 7½ inches in diameter, other methods are called for, and the following brief details of the means adopted in this particular case may not be out of place. From a hemispherical wood pattern two castings in stereo metal were obtained, with the recess for the accumulators cast in. Each section was carefully centred and drilled and afterwards mounted on a rigid steel mandrel, and the face turned flat. The hemispheres were then mounted together on the mandrel,—dowel pins having been inserted to keep them from turning independently,—and the globe thus formed roughed into shape.

"To carry the cutting tool, one end of an L-shaped lever was bolted and pivotted to the bed of the lathe centrally beneath the equator of the ball, the other end carrying the cutting tool at the exact height necessary to sweep out a meridian accurately from the poles. With the ball slowly revolving, this tool was used until the rough surface was removed, and the ball became an approximately true sphere. The final shaping was given by the use of a piece of five inch diameter tube, having the end ground sharp, pressed against the revolving ball until the edge was in contact with the ball surface at all points, and in all positions. A template cut out of flat brass to the exact radius was used to verify the work from time to time.

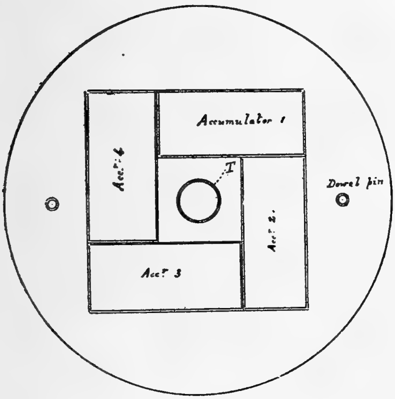


fig. 2

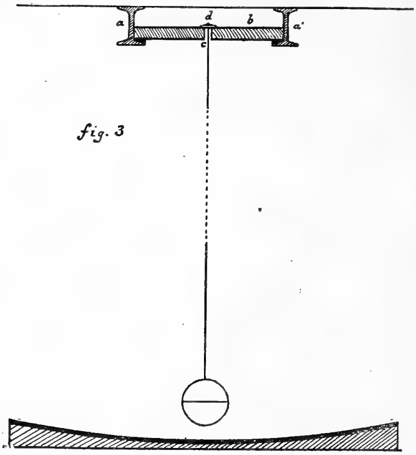
Plan of Pendulum-bob (through equator).

"With the accumulators and central tube in position, the geometrical centre of the ball was determined, and a disc with a conical depression in its centre, was fixed at this point in the tube. A long steel rod fixed to a pedestal and pointed at the top was introduced into the tube, and the ball was balanced on this point, holes being drilled in the heaviest sides, from the interior, until the ball hung on the point without tendency to tilt or rock in any way."[1]

The ball and its contents, as well as the knife-edge suspension for the whole pendulum, have been carefully prepared under Mr. Murday's supervision, and some of the more delicate electrical connections for the glow-lamp

[1] As an additional precaution, with the kind assistance of Professor Vonwiller, the ball was floated in a basin of mercury, at the Physics Laboratory, University of Sydney, and further trimmed till equilibrium was obtained.

have been made by himself. The lamp-circuit is capable of being closed or opened at will, by a screw-switch placed near the upper pole of the ball. The lens (plano-convex) is stopped down to a very small aperture, and its focussing-tube, when the pendulum is in position, can be easily adjusted from the lower end of the supporting tube in which it slides. The sustaining wire is of phosphor-bronze (diam. 1·5 mm.) attached above to a specially constructed knife-edge suspension of the Cardan type, (fig. 4, and Plate XX, B), permitting the pendulum to continue oscillating for many hours. This Cardan suspension is fixed on a stout beam supported (as shown in Fig. 3) on two heavy steel girders at the top of the main staircase at Riverview College,—



General arrangement of experiment: *a, a,* steel girders; *b,* wooden beam, rigidly wedged between girders; *c,* hole for suspending wire; *d,* Cardan suspension; *f,* platform for bromide-paper.

a spot well suited for a Foucault-pendulum, and where I had for many years contemplated erecting one, as suggested to me as far back as 1891 by the late Father Charles O'Connell, S.J. These girders are two out of a series, about 1 metre apart, designed to support a very large water-tank above the staircase. They measure 36 centimetres vertically, and 14·5 centimetres horizontally at base. The length of the whole pendulum is 13·7 metres, the ball having a diameter of 18·5 centimetres, and weighing 27 kilograms. The photographic paper is attached to a curved platform, very rigidly fixed, the curved surface corresponding to the pendulum-length, so as to secure uniform definition in the photograph (Fig. 3).

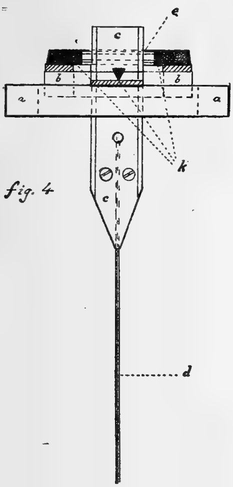


fig. 4

Cardan suspension: *a*, outer ring, screwed on *b*, (fig. 3); *b*, inner ring, on knife-edges; *c*, clamp for suspending wire (*d*), on knife-edges; *k*, knife-edges.

By the end of January last the apparatus was ready, and some trial photographs were obtained, one of which is reproduced in Plate XX, (A). Each of the experiments was made during the quietest portion of the night, some time between 1 a.m. and 4·30 a.m., and of course using red light. One of the two observers, while making the exposures (in pairs, North and South, or East and West) every five minutes, gave a signal of the instant of maximum excursion of the spot of light, the other observer noting the time with a half-second chronometer. In Plate XX, the alteration in azimuth during the five-minute intervals between the exposures is evident, and agrees fairly well with the theoretical value for the latitude of Sydney, 8° 21′ per siderial hour. But several slight perturbing influences were present, and are now to be eliminated. The elliptical path sooner or later always followed by the bob is also clearly visible, and capable of quantitative measurement. Obviously it is quite too rapidly generated, in this trial photograph; but in the next series of exposures, now about to be undertaken, I have reason to hope it will be greatly reduced, as well as some minor defects, with the introduction of a number of refinements in the apparatus and in the *modus operandi*.

Thus, as I have endeavoured to show, the main feature of this "photographic Foucault-pendulum," (which for convenience I have ventured to name "geogyrograph,"—not a very euphonious term, I admit, especially if the second "g" is pronounced soft, but sufficiently expressive—) is the substitution of photography for the traditional visual observations, thus to a large extent eliminating the element of "personal equation." By this means actual records (geo-gyrograms) of the Earth's rotation can be measured at leisure by a number of persons, each a check on the others, and quantitative determinations obtained, I believe, of a degree of accuracy at least equal to that obtainable by the visual methods hitherto employed.

These somewhat hurriedly-prepared notes do not allow at present of describing various other details of the method of procedure adopted to ensure precision, *e.g.*, the method of releasing the bob, removal of residual torsional oscillation in the bob, protection from air currents, etc.

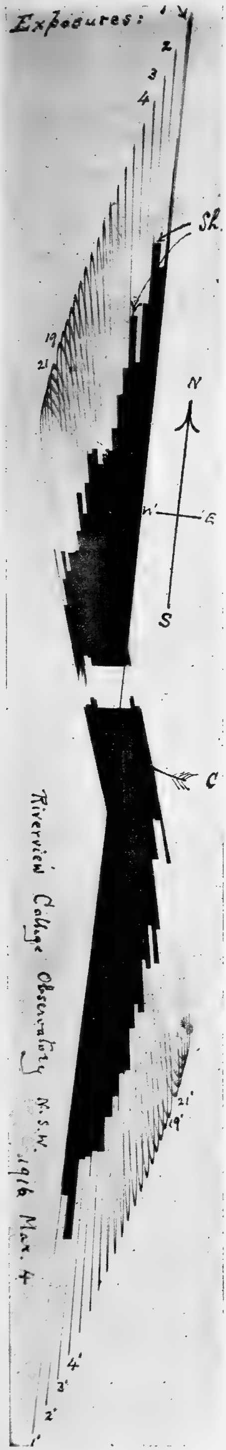
I also postpone for the present giving any quantitative results of these experiments, (as well as of a second series also in progress, in the dome of the Queen Victoria Markets, Sydney, with a pendulum no less than 26 metres long) until the above mentioned improvements have been carried out, both series having been somewhat of a tentative character. In a subsequent paper, I hope to give the full results of all the experiments.

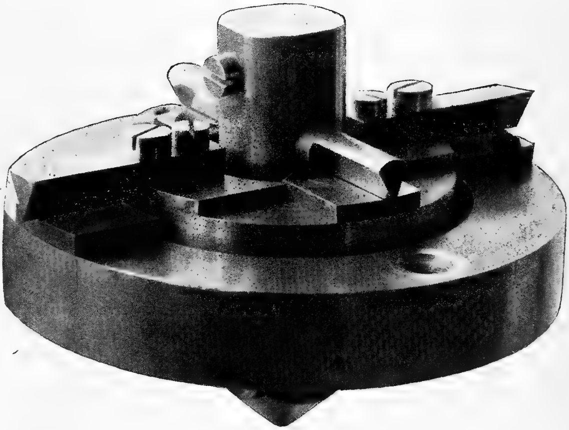
In conclusion, I wish to express my sincere thanks to Prof. Pollock, D.Sc., F.R.S., Prof. Vonwiller, B.Sc., Prof. Cotton, M.A., F.G.S., Messrs. Ranclaud, B.Sc., J. Lane Mullins, J.P., Murday and Breden, for valuable suggestions and kindly help; to the Surveyor-General and Mr. R. H. Cambage, F.L.S., for the loan of instruments for the new visual method I have adopted at the Queen Victoria Markets; and to the Lord Mayor, for having been so good as to grant me the use of this fine building for the research.

Journal Royal Society of N.S.W., Vol. L., 1916.

Plate XX.

A





B

Explanation of Plate XX.

(A.)—Reproduction (reduced one-fifth) of Foucault-pendulum photograph (geogyrogram) taken 1916, March 4, from 2 h. 37 m. 54 s. a.m. to 4 h. 37 m. 55 s. a.m., (Sydney standard time). The exposures (in pairs) were made every five minutes, and the change of azimuth in the intervals is clearly seen. The twentieth pair of exposures was missed, owing to an accidental interruption.

Sh. indicates the edge of the occulting shutter or screen during the five-minute intervals.

C. is the zero-point of the oscillations.

(B.)—Cardan Suspension (see text-figure 4).

(N.B.—Text figures not strictly to scale.)

WIRELESS TIME SIGNALS—SOME SUGGESTED IMPROVEMENTS.

By W. E. and F. B. Cooke.

[*Read before the Royal Society of N. S. Wales, December 6, 1916.*]

Anticipating a re-determination of Australian longitudes by means of trans-Pacific radio signals, some experimental work has been recently undertaken at the Sydney Observatory, with a view of eliminating certain sources of error.

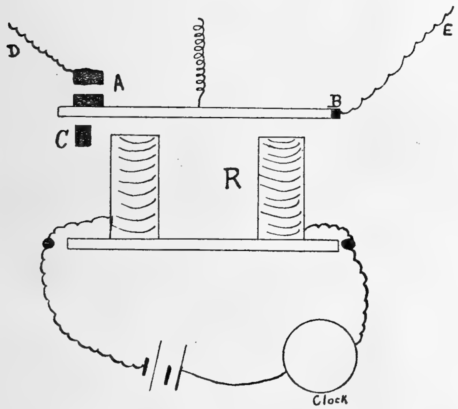
Prior to the war great and rapid progress was made with the new methods, culminating in the determination of the difference of longitude between Paris and Washington by means of radio signals across the Atlantic. In the course of this work every possible precaution to ensure great accuracy was taken. The results were undoubtedly good, but one gathers from the remarks of M. Baillaud (Director of the Paris Observatory) and others that there are still some outstanding difficulties which will have to be met and overcome.

With those of a purely astronomical character we are not here concerned. The object of this present paper is to indicate a method whereby two clocks or chronometers separated by some 5,000 miles or so may be compared with an error not exceeding one-hundredth of a second, and with entire elimination of personal equation.

In order that our remarks may be followed it will be advisable to briefly indicate the general features of the whole operation, and the special difficulties to be attacked.

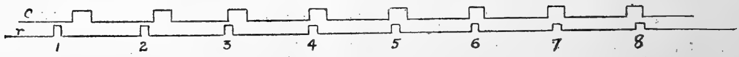
Three, or perhaps four, stations are concerned. Let us call the two astronomical stations (or those which contain the clocks to be compared) A and B. A third station C (the transmitting or signalling station) contains some piece of apparatus which radiates a series of "dots" regularly spaced at intervals of *nearly*, but not quite, one second apart. This station should preferably be about midway between A and B, but if this is impracticable, we shall probably have two stations C_1 and C_2 close to A and B respectively, and each acting alternately as a transmitting station. For definiteness we shall suppose a single station C. For example, if A and B were the Sydney and Lick Observatories, C might be at Honolulu: or with A and B at Sydney and Honolulu C might be at Nauru (near the equator).

All we expect from C is a series of regularly spaced "dots" at nearly a second interval. The exact times of the dots are quite immaterial. It is the object of the observers at A and B to receive this series of arbitrary signals and compare them with the beats of their respective clocks, and this is accomplished by the well known method of coincidences. Our problem now resolves itself into this—to determine the exact seconds at which the *C* signals coincide with the beats of our *A* (or *B*) clock. The principal difficulty seems to be this—that a very short sharp "dot" cannot be radiated and received over long distances, and that if the dot is of an appreciable length different observers take different parts of it to form their coincidences with their clock beats. The personal element also arises from the fact that the sound of the radio signal generally differs greatly from the sound of the clock beat, however it is introduced. We propose to avoid both these difficulties and eliminate the personal element by means of the following simple mechanical device.



The clock circuit, as usual, passes from the clock contacts through a battery to the relay *R*, and for all practical purposes *R* is the clock. The armature of the relay is pivoted at *B* and normally rests against the stop at *A*. When the seconds-impulse comes from the clock the contact *A* is broken and the armature rests against the stop *C*. Let us now interpose the contact *A* in the path of the incoming signals. That is, let *D A B E* be in series with the aerial. THAT IS ALL. Let us follow the sequence, supposing that the period of the radio dots is 0·99s, thus giving a coincidence, with a gain of one second upon the local clock, in every hundred seconds.

With relay open, as shown in the above diagram, the radio-dots come through uninterruptedly, but with relay closed, the radio circuit is broken and we hear nothing. For brevity, let us call the clock circuit *c* and the radio circuit *r*, and note that it is essential that the duration of the periodic closing of *c* shall be greater than the duration of the *r* signal. *E.g.* if the *r* signal occupies 0·1s, then the *c* must close every second for 0·15s or any period longer than this. There need practically be no limitation to the length of the *r* signal, provided that the *c* impulse is a trifle longer. There will thus occasionally occur a condition when *r* tries to come through but finds *c* closed and consequently no path available, and we shall then cease to hear the *r* signals for a time. Taking the above figures, this overlap will be 0·05s, and with *r* gaining about 0·01s per second the *r* signals will find their path blocked for five consecutive seconds, and we shall have silence for that period. In addition, the few *r* signals immediately preceding this silence will be cut short. They will commence to pass but almost immediately their path will be blocked by the closing of *c* and we shall notice a gradual diminution until they finally cease. The coincidence may be taken either as the last audible signal or a second later. Theoretically it never occurs at any exact second, and we must adopt either the one immediately preceding or following. Practically it makes no difference which we adopt, provided we act systematically; and then even the third place of decimals will in the long run be just about correct. To those accustomed to chronographs the following diagram may help to make the matter clear. The whole sequence is purposely exaggerated.



These two irregular lines show the records as they would appear if one could transfer them to a chronograph.

At 1 and 2 the signals come through without interruption. At 3 the signal starts but is broken when *c* closes. At 4 the same thing happens, but the making and breaking of *r* is almost simultaneous, and we hear a very short sharp dot. At 5, 6, and 7 *r* cannot get through and we hear nothing. Real coincidence occurs between 4 and 5, and we may make a rule to take either, provided we adopt the same rule at both *A* and *B*. It may perhaps be as well to point out that the shortening of the *r* signals in this way is quite different from the (unsuccessful) attempt to *send* short sharp dots by shortening the duration of key-closing at the transmitter. In our case the signal may normally be of any duration, and we do not interfere with it until it actually begins to sing. *Then* our clock automatically cuts it out. In practice we have not yet had an opportunity of testing the method over any great distance. We have, however, taken advantage of some signals sent by the Riefler clock at Adelaide (about 700 miles). The determination of coincidence was found to be a very simple matter and quite free from strain. It is far more easy to concentrate the attention upon one series of signal dots, and ascertain when they cease, than to determine the moment of coincidence of two series, and requires no special training. We occasionally obtained the assistance of friends who had no experience of time observations, and their determinations of the exact moments of coincidence always agreed with our own.

Incidentally a few side issues may be worth glancing at.

(1) It is obvious that *one* transmitting station, where possible midway between *A* and *B*, is preferable to two. We may then feel pretty certain that the arbitrary signals reach *A* and *B* practically simultaneously.

(2) In Australia the spark and crystal system still holds sway, and we understand that it is also in use in England and France. Through the courtesy of Mr. Ormiston, an American operator, we have been introduced to the arc system, and have been so fortunate as to obtain one of

the latest forms of oscillating Audion receivers. In our opinion this combination is greatly superior, for several reasons. In the spark system no current passes until the key is closed, and then some little time must elapse before radiations actually commence. In the arc system the current is flowing through the aerial continuously, and the action of pressing the key simply shorts a few turns of wire in the inductance and thus alters the wave length. It is quite probable, though we have not yet had the opportunity of testing the question, that very short sharp dots can be sent by this method, if required.

Then again, the tuning of the arc can be made far sharper than the spark, and the Audion is very much more sensitive than the crystal. *E.g.*, with our little aerial at the Observatory we have no difficulty in hearing Tuckerton (New Jersey) at a distance of about 10,000 miles. It would be a simple matter to choose some wave length sufficiently distinct to be free from interference, and to tune sharply, so that we should hear nothing except the time signals and the atmospherics.

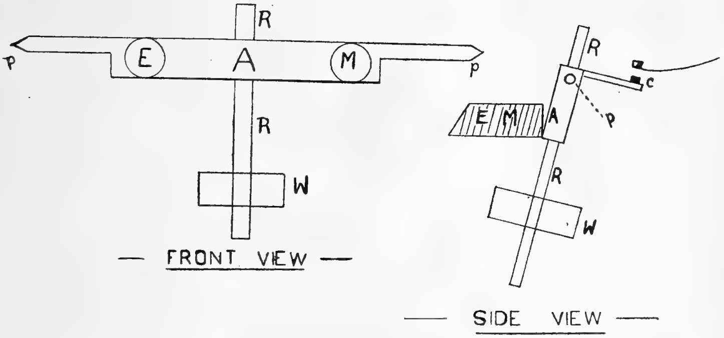
Finally the receiving observer makes his own "tune." That is, he can control the oscillation of his Audion so as to bring the signals to any musical pitch he desires, and by raising this sufficiently he can cause such a difference between the sound of the dots and the lower growl of the atmospherics, as to very considerably reduce the annoyance from the latter.

(3) The main principle can easily be used for the comparison of local clocks or chronometers, in particular for comparing mean and sidereal times. In this case the mean time clock takes the place of *c*, and the sidereal of *r*, and the latter instead of being in series with the aerial, is placed in series with a battery and high-pitch buzzer. With this arrangement not only can coincidences be obtained

with the greatest ease and certainty, but the slightest want of beat (irregularity of seconds) can be immediately and obtrusively detected.

(4) Alternatively, the radio signals can be made to *lose*, instead of gain, about one second in one hundred, and this appears to us to be rather better. In this case coincidence occurs at the *first* perceptible tick after the silence, instead of the last heard. It seemed to us to be easier to describe the gaining arrangement, but our own personal feeling is in favour of the losing ticks.

(5) It is an essential point that the duration of the closing of *c* should be slightly longer than the length of the *r* ticks: and to ensure the practicability of always obtaining this adjustment it is advisable to have some form of slow-acting relay. There are several on the market, but amongst those which we have seen, nothing appears to be quite suitable, so the following form was adopted.



In the above, *E M* are the electro magnets; *A* the armature, pivoted at *p p*; *R* a light rod passing through the armature and carrying a weight *W*; *c* the contact between the armature and a light spring.

Normally the clock circuit is closed, and broken momentarily every second. Therefore as a rule the armature rests against the magnets, but when the current is broken it acts as a pendulum, swinging away and forming contact at c for a period that is determined by the position of the weight *W*. This arrangement has been in use for another purpose at the Sydney Observatory for several months and works very satisfactorily.

CONTENTS.

FINAL PART OF VOL. L.

ISSUED MAY 2nd, 1917.

Vol. L. Part III.

JOURNAL AND PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

NEW SOUTH WALES

FOR

1916.

PART III., (pp. (i.)-(xxii.), i.-lxiv.)

COMPLETING VOL. L.

Containing Abstract of Proceedings, Title Page, Contents, List of Publications, List of Members, etc., and Index.

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1916.

F. W. WHITE, Typ., 344 Kent Street, Sydney.

ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

MAY 3rd, 1916.

The Annual Meeting, being the three hundred and eightieth General Monthly Meeting of the Society, was held at the Society's House, 5 Elizabeth Street, Sydney, at 8 p.m.

Dr. R. GREIG-SMITH, President, in the Chair.

Forty members were present.

The minutes of the General Monthly Meeting of the 1st December, 1915, were read and confirmed.

The certificates of four candidates for admission as ordinary members were read: two for the second and two for the first time.

Mr. J. E. CARNE and Dr. HARKER were appointed Scrutineers, and Mr. W. S. DUN deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

EDMUND MILNE, Assistant Commissioner, N.S.W. Tramways, Public Works Building, Bridge-st., Sydney.

WALTER GEORGE STONE, Assistant Analyst, Department of Mines, Sydney.

A framed list of members who have volunteered for Active Service at the front was exhibited.

The President announced that a framed portrait of Professor HERDMAN, D.Sc., F.R.S., Professor of Natural History in the University of Liverpool, who visited Australia as a General Secretary of the British Association for the Advancement of Science in August 1914, had been presented to this Society by Mr. J. H. MAIDEN.

The President conveyed the congratulations of the Society to Mr. MAIDEN and Professor POLLOCK on their election as Fellows of the Royal Society of London.

The Annual Financial Statement for the year ended 31st March, 1916, was submitted to members, and, on the motion of the Honorary Treasurer, Dr. H. G. CHAPMAN, was unanimously adopted:—

GENERAL ACCOUNT.

RECEIPTS.	£ s. d.	£ s. d.	£ s. d.
To Cash at Bank and on hand at 1st April, 1915			69 10 6
,, Subscriptions		420 0 0	
,, Rents—			
Offices	324 5 6		
Hall and Library	142 5 6		
		466 11 0	
,, Sundry Receipts		36 6 4	
			922 17 4
,, Government Subsidy for 1915 ...			399 19 10
,, Clarke Memorial Fund—Advances for the year... ...			290 0 0
			£1682 7 8

PAYMENTS.	£ s. d.	£ s. d.
By Salaries and Wages—		
Office Salaries and Accountancy Fees ...	184 3 4	
Assistant Librarian...	166 6 8	
Caretaker	121 4 0	
		471 14 0
,, Printing, Stationery, Advertising, Stamps, etc.—		
Stamps and Telegrams	35 0 0	
Office Sundries, Stationery, etc	4 19 10	
Advertising	10 17 7	
		50 17 5
Carried forward		522 11 5

Payments—*continued.*	£ s. d.	£ s. d.
Brought forward		522 11 5
By Rates, Taxes and Services—		
Electric Light	24 6 11	
Gas	5 16 1	
Insurance	21 13 9	
Rates	85 10 0	
Telephone	5 17 10	
		143 4 7
,, Printing and Publishing Society's Volume—		
Printing, etc...		257 7 3
,, Library—		
Books and Periodicals	85 2 8	
Book-binding	59 19 8	
		145 2 4
,, Sundry Expenses—		
Bank Charges and Exchange	2 13 1	
Repairs	18 3 0	
Lantern Operator	12 0 0	
Sundries	45 15 0	
		78 11 1
,, Interest—		
On Mortgage	115 0 0	
Clarke Memorial Fund	5 0 0	
		120 0 0
,, Clarke Memorial Fund—		
Refund of Loan		340 0 0
,, Balance—		
Credit Balance, Union Bank of Australia Ltd.	68 9 5	
On Hand	7 1 7	
		75 11 0
		£1682 7 8

Compiled from the books and accounts of the Royal Society of New South Wales and certified to be in accordance therewith.

HENRY G. CHAPMAN, M.D., *Honorary Treasurer.*

W. PERCIVAL MINELL, F.C.P.A.
Auditor.

SYDNEY, 18TH APRIL, 1916.

BUILDING AND INVESTMENT FUND.

Receipts.	£ s. d.
To Loan on Mortgage owing to the Australasian Association Advancement of Science—	
Balance as at 31st March, 1915	2300 0 0
,, General Fund—	
Amount received to date...	115 0 0
	£2415 0 0

Payments.	£ s. d.
By Interest—	
Amount paid to Australasian Association Advancement of Science	115 0 0
„ Balance owing at this date	2300 0 0
	2415 0 0

CLARKE MEMORIAL FUND.

Balance Sheet, 31st March, 1916.

Liabilities.	£ s. d.	£ s. d.
Accumulation Fund—		
Balance as at 31st March, 1915		585 16 6
Additions during the year—		
Interest Savings Bank of N.S.W. ...	6 17 10	
„ Government Savings Bank ...	6 5 0	
„ Commonwealth Savings Bank	2 7 5	
„ General Fund	5 0 0	
		20 10 3
		£606 6 9

Assets.	£ s. d.	£ s. d.
Royal Society of New South Wales, General Fund		
Amount invested in Commonwealth War Loan		180 0 0
Cash deposited in Savings Bank of N.S.W. ...	194 6 3	
„ Government Savings Bank ...	194 2 3	
„ Commonwealth Savings Bank...	37 18 3	
		426 6 9
		£606 6 9

Statement of Receipts and Payments, 31st March, 1916.

Receipts.	£ s. d.	£ s. d.
To Balance 31st March, 1915—		
Savings Bank of N.S.W.	197 8 5	
Government Savings Bank	187 17 3	
Commonwealth Savings Bank	150 10 10	
		535 16 6
„ Interest to date—		
Savings Bank of N.S.W.	6 17 10	
Government Savings Bank	6 5 0	
Commonwealth Savings Bank	2 7 5	
General Fund on Advances	5 0 0	
		20 10 3
„ General Fund—		
Amount refunded to date		340 0 0
		£896 6 9

PAYMENTS.	£ s. d.	£ s. d.
By General Fund—		
Advances to date		290 0 0
Amount Invested in War Loan		180 0 0
„ Balance at this date—		
Savings Bank of N.S.W.	194 6 3	
Government Savings Bank	194 2 3	
Commonwealth Savings Bank	37 18 3	
		426 6 9
		£896 6 9

A report on the state of the Society's property and the annual report of the Council were read as follows:—

ANNUAL REPORT OF THE COUNCIL FOR THE YEAR 1915-16. (1st May to 26th April).

The Council regrets to report that we have lost by death seven ordinary members, and one Clarke Medallist. Fourteen members have resigned. On the other hand, six ordinary and two Honorary members have been elected during the year.

To day (26th April, 1916) the roll of members stands at 300.

The Clarke Memorial Medal was awarded to Professor W. A. HASWELL, of the Sydney University.

During the Society's year there have been eight monthly meetings and ten Council meetings.

The holding of the Annual Dinner has been dispensed with owing to the continuance of the War.

In order to do honour to their colleagues, Major Professor DAVID and Captain Professor POLLOCK, prior to leaving for the front, the Council entertained them at Sargent's Café on Thursday, 3rd February, 1916.

A Section of Public Health and Kindred Sciences was established during the year.

Scientific Assistance.—In view of the war the Council offered its services to the Government in an advisory capacity on scientific matters of which they had special knowledge.

There have been two resignations from the Council namely, Professor POLLOCK and Professor ROBINSON.

A special lecture to members was delivered by Colonel HUBERT FOSTER, R.E., on the 19th of August, 1915, on "The Strategy of the War in Europe."

Three Popular Science Lectures were given, namely:—

June 17—"*Whales and Whaling in Australian Seas,*" by D. G. STEAD, F.L.S.

July 15—"*Diamonds,*" by C. ANDERSON, M.A., D.Sc.

September 16—"*Plant Life in the Sea,*" by Professor A. ANSTRUTHER LAWSON, D.Sc., F.R.S.E.

Twenty-two papers were read at the monthly meetings, and these, with a good number of exhibits, afforded much instruction and interest to members of the Society.

The President, Dr. R. GREIG-SMITH, then delivered his Presidential Address.

On the motion of Mr. HAMLET, seconded by Mr. MAIDEN, a hearty vote of thanks was accorded to the retiring President for his valuable address.

Dr. GREIG-SMITH briefly acknowledged the compliment.

There being no other nominations, the President declared the following gentlemen to be Officers and Council for the coming year:—

President:

T. H. HOUGHTON, M. INST. C.E.

Vice-Presidents:

F. H. QUAIFE, M.A., M.D. | C. HEDLEY, F.L.S.

HENRY G. SMITH, F.C.S. | R. GREIG-SMITH, D.S

Hon. Treasurer:

H. G. CHAPMAN, M.D.

Hon. Secretaries:

R. H. CAMBAGE, L.S., F.L.S.	J. H. MAIDEN, F.R.S., F.L.S.

Members of Council:

E. C. ANDREWS, B.A., F.G.S.	Prof. C. E. FAWSITT, D.Sc., Ph.D.
D. CARMENT, F.I.A., F.F.A.	J. NANGLE, F.R.A.S.
Prof. H. S. CARSLAW, M.A., Sc. D.	C. A. SUSSMILCH, F.G.S.
J. B. CLELAND, M.D., Ch. M.	H. D. WALSH, B.A.I., M. INST. C.E.
W. S. DUN.	Prof. W. H. WARREN, LL.D., Wh. Sc.

Dr. Greig-Smith, the outgoing President, then installed Mr. Houghton as President for the ensuing year, and the latter briefly returned thanks.

JUNE 7th, 1916.

The three hundred and eighty-first General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. Houghton, President, in the Chair.

Thirty-one members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of four candidates for admission as ordinary members were read; two for the second, and two for the first time.

Mr. J. E. Carne and Mr. G. Hooper were appointed Scrutineers, and Mr. C. Hedley deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Walter John Enright, B.A., Solicitor, High Street, West Maitland, N.S.W.

Cecil Edgar Tilley, Demonstrator in Geology, The University, Sydney.

On the motion of Mr. R. T. Baker, seconded by Dr. Greig-Smith, Mr. W. P. Minell was elected Auditor for the current year.

The congratulations of the Society were conveyed by the President to Mr. J. H. MAIDEN who had recently been honoured by His Majesty the KING in being made a Companion of the Imperial Service Order.

The President announced that two Popular Science Lectures would be delivered this session, namely:—

1. "The Chemistry of Nitrogen and its value for Food-Stuffs and Explosives," by R. K. MURPHY, Dr. Ing. Chem. Eng.

2. "The Debt of Agriculture to Science," by Professor R. D. WATT, M.A., D.Sc.

Three volumes, 61 parts, and 5 reports were laid upon the table.

THE FOLLOWING PAPERS WERE READ:

1. "Some Amphipoda and Isopoda from Barrington Tops," by CHARLES CHILTON, M.A., D.Sc. (Communicated by Mr. C. HEDLEY).

2. "The Analysis of Toluene and Benzene in Coal Tar Oils," by GEORGE HARKER, D.Sc.

Remarks were made by Mr. HAMLET, Mr. CHALLINOR, Dr. MURPHY and Dr. COOKSEY.

3. "Notes on Australian Fungi, No. 3," by J. BURTON CLELAND, M.D., and E. CHEEL.

Remarks were made by Mr. R. T. BAKER.

JULY 5th, 1916.

The three hundred and eighty-second General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, Sydney, at 8 p.m.

Mr. T. H. HOUGHTON, President, in the Chair.

Forty members and fifty-five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of eight candidates for admission as ordinary members were read: two for the second, and six for the first time.

Dr. C. ANDERSON and Mr. OLLÉ were appointed Scrutineers, and Mr. H. G. SMITH deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

HAROLD G. MCQUIGGIN, B.Sc., Demonstrator in Physiology, The University, Sydney.

JOHN READ, M.A., Ph.D., B.Sc., Professor of Organic Chemistry in the University, Sydney.

The meeting then proceeded to discuss that portion of Dr. GREIG-SMITH'S Presidential Address which relates to Science and Industry.

The discussion was opened by Dr. R. GREIG-SMITH who said that Science and Industry have existed so long, each largely going its own way, that probably many of the accustomed habits of thought may have to be given up before a perfect and happy union can be achieved: but what he would specially like to hear spoken about are the means whereby industry can be brought into closer contact with science. He considered the time opportune for industrialists and scientists themselves to consider how industry may be benefited, and believed that the elucidation could be found in forming an Industrial Section of this Society. In such a section industrialists and scientists could meet together and informally discuss the recent advances in industry and science: matters brought forward by scientists could be discussed by manufacturers, who would be able to show the direction in which industry could be benefited, and matters brought forward by manufacturers could be discussed by the scientists. The utilisation of trade waste would be an excellent theme for the conjoint discussion, as it opens up a large field of enquiry, and can only be treated satisfactorily by a conference between the manufacturers who consider the matter from an economic point of view, and the scientists, who understand the possibilities of the utilisation.

The matter was then very fully discussed by the following gentlemen:—J. H. MAIDEN, T. U. WALTON, H. G. SMITH, A. B. HECTOR, Dr. J. B. CLELAND, F. A. COOMBS, and WALLACE NELSON.

The discussion was then adjourned.

JULY 18th, 1916.

Special Meeting of the Royal Society held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. HOUGHTON, President, in the Chair.

The business of this meeting was to continue the discussion on the subject of Science and Industry, to which the following gentlemen spoke at some length:—F. B. GUTHRIE, G. P. DARNELL-SMITH, L. MEGGITT, B. J. SMART, J. HENDERSON, and W. M. HAMLET.

At the close of the discussion it was resolved:—That it is desirable to ask the Council of this Society to establish a Section of Industry.

AUGUST 2nd, 1916.

The three hundred and eighty-third General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. HOUGHTON, President, in the Chair.

Twenty-eight members and one visitor were present.

The minutes of the General Monthly Meeting of 5th July, 1916, were read and confirmed.

The certificates of eleven candidates for admission as ordinary members were read: six for the second, and five for the first time.

Mr. G. HOOPER and Mr. A. J. SACH were appointed Scrutineers, and Mr. C. A. SUSSMILCH deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

WILLIAM JOHN ALLEN, Government Fruit Expert and Irrigationist, 'Oriel,' The Boulevard, Strathfield.

STEPHEN JASON JOHNSTON, B.A., D.Sc., Lecturer and Demonstrator in Zoology, The University, Sydney.

PAUL RENÈ LOUBÈT, M.D., B.Sc., 17 Castlereagh Street.

ROBIN JOHN TILLYARD, M.A., B.Sc., F.E.S., Macleay Research Fellow Linnean Society of N.S.W., 'Kuranda,' Mount Errington, Hornsby, N.S.W.

GEORGE VALDER, J.P., Under Secretary and Director, Department of Agriculture, Sydney.

ROBERT ALEXANDER WARDEN, President, Government Savings Bank of New South Wales, Moore Street.

The President announced that a Popular Science Lecture entitled "The Debt of Agriculture to Science," would be delivered by Professor R. D. WATT, on 17th of August.

Eight volumes, one hundred and two parts and eleven reports were laid upon the table.

THE FOLLOWING PAPERS WERE READ:

1. "Acacia Seedlings," Part II, by R. H. CAMBAGE, F.L.S.

Remarks were made by Mr. MAIDEN, Mr. ANDREWS, Dr. HARKER and Mr. CHEEL.

2. "Napier's Logarithms: Remarks supplementary to previous paper, entitled 'The Discovery of Logarithms by Napier of Merchiston'," by Professor H. S. CARSLAW.

EXHIBITS:

1. Mr. J. H. MAIDEN exhibited six large tropical plants displaying culture and interesting morphological points.

2. Mr. C. A. SUSSMILCH exhibited a frog (species undetermined) said to have been obtained from the inside of a hollow ironstone concretion. This concretion was obtained in quarrying in the Tamworth district, at a depth of eight feet below the surface. The concretion had no visible opening, and the frog is alleged to have been inside, alive, and lived for two minutes after the concretion was broken open. The walls of the hollow concretion have a thickness of three-eighths of an inch, and there was sufficient space within for the frog to turn around only. The circumstances of the finding are vouched for by two quarrymen who obtained it. One half of the hollow concretion was also exhibited.

3. Mr. JOHN BARLING exhibited a large Rainfall Chart, 10 × 14 feet, showing the Sydney rainfall for the last fifty-eight years, and gave the following note:—

SUMMARY OF SIXTY-ONE YEARS' RECORDS OF SYDNEY RAINFALL.

Their	average	for the	first	six months	being	29	inches.
,,	,,	,,	second	,,	,,	19	,,
					Yearly	48	,,

These are supplementary to his paper of 2nd December, 1908.

It would seem that when the rainfall for the first six months of any year is less than 20 inches, the total for the year is less than 48 inches. The years 1846-49-56-62, 65-72-80-86-88-1902-3-6-8-9—fourteen years in all—each had less than 20 inches in their first six months, and each had less than 48 inches in the year.

1916 has also had less than 20 inches (17·20) for its first half year. It seems reasonable to suppose that it will have less than 48 inches for the year, that is, it will be an under-average year.[1]

[1] Mr. Barling subsequently reported that the rainfall for the year 1916 amounted to 44·88 inches.—[Eds.]

But even so, it by no means follows that there will be any shortage of rain during its second half. The years 1846-86-1902-3-8, all with less than 20 inches of rain in their first half—each had abundant rains during their second half. It is interesting to note the Sydney rainfall in connection with Cataract Dam and other sources of our Water Supply. From the official figures courteously supplied to Mr. Barling, it is evident that the rainfall over the Catchment Area is greater than the Sydney rainfall. So that it is safe to compare the Water Supply with the Sydney records.

It is found that Cataract Dam was full early in September, 1915. Since that time there has been no material addition to its storage. From the end of August, 1915 to 28th July, 1916, say eleven months, the rainfall in Sydney has amounted to 24 inches, and this quantity has been insufficient to maintain a full dam, in fact the stored water is seriously low down.

It is found from the chart that the last six months of 1875 and the first three months of 1876—nine months in all—had the low rainfall of but 10¾ inches. This is the lowest record for any similar period. At that time abundant rains had fallen immediately before and also immediately following the dry spell. Again, the last five months of 1884, and the first five months of 1885, gave but 16¾ inches of rain, almost useless for water supply, and this dry spell was followed by great rain in June and July, and also the previous four months to August had abundant rain. If similar dry periods occur again, there may be no shortage in our water supply.

But there seems to be no reason to anticipate such favourable conditions as occurred then before and after the dry time. Without such rains the Sydney water supply would be in "parlous case." This shows the urgent need of increased storage. If eleven months of only moderately dry weather has so diminished the water in Cataract Dam, what would be its condition in a prolonged drought?

It seems safe to assume that all those years (26 out of 61) in which not less than 30 inches of rain had fallen in *any six months*, would have given a super-abundant water supply with our present storage. And that with increased storage, the present Catchment Area would provide an ample supply for a much larger city than Sydney is now, or is likely to be for many years to come.

Table showing in inches and points the rain which has fallen in each year since 1857 in Sydney, and also their totals for each quarter of the year.

Year.	First Quarter.	Second Quarter.	Total for First Half.	Third Quarter.	Total for first 9 mths.	Fourth Quarter.	Total for Year.	Remarks.
1846	...	...	**19·00**	...	...	...	**44·00**	
1849	...	...	**11·00**	...	...	...	**21·50**	Average for first six months approx. 29 inches.
1856	...	...	**16·00**	...	...	...	**24·00**	Ditto for second ditto, 19 inches.
1858	621	2237	2858	226	3084	830	39·14	
1859	1521	574	2095	1587	3682	523	42·05	
1860	2265	2299	4564	2398	6962	1319	**82·81**	**Maximum year.**
1861	1126	2789	3915	1525	5440	496	58·36	
1862	1036	618	**1654**	268	1922	474	**23·96**	second half of year *below normal.*
1863	1838	1254	3092	1104	4196	512	47·08	
1864	1996	2687	4683	1219	5902	1010	69·12	
1865	994	875	**1869**	590	2459	1155	**36·14**	second half of year *below normal.*
1866	1073	1325	2398	563	2961	728	36·89	,, ,, ,, ,,
1867	1747	3394	5141	689	5830	**138**	59·68	lowest fourth quarter.
1868	2067	817	2884	941	3825	480	43·05	second half of year *below normal.*
1869	1342	1983	3325	558	3883	936	48·19	,, ,, ,, ,,
1870	2296	1750	4046	627	4673	**1749**	64·22	highest fourth quarter.
1871	1755	2723	4478	134	4612	615	52·27	second half of year *below normal.*
1872	1297	535	**1832**	623	2455	1258	**37·13**	second half of year normal.
1873	26·50	1547	4197	1545	5742	1598	73·40	
1874	1873	2700	4573	972	5545	815	63 60	
1875	1346	2515	3861	383	4244	381	46·25	second half of year *below normal.*
1876	320	2283	2603	1153	3756	813	45·69	second half of year normal.
1877	949	1705	2654	2061	4715	1251	59·66	
1878	1935	976	2911	1265	4176	801	49·77	
1879	950	1987	2937	**2547**	5484	835	63·19	highest third quarter.
1880	1086	543	**1629**	749	2378	571	**29·49**	second half of year *below normal.*
1881	938	1302	2240	889	3129	980	41·09	
1882	626	2036	2662	382	3044	1176	42·20	second half of year *below normal.*
1883	1790	1079	2869	1185	4054	638	46·92	
1884	**290**	2636	2926	898	3824	578	44·04	lowest first quarter—second half of year *below normal.*
1885	742	1791	2533	816	3349	642	39·91	second half of year *below normal.*
1886	895	774	**1669**	848	2517	1426	**39·43**	second half of year *exceeds* normal.
1887	1358	2184	3542	1254	4796	1220	60·16	
1888	476	**184**	**660**	715	1375	926	**23·01**	lowest second quarter, also lowest first 6 and 9 months.
1889	590	2556	3146	1734	4880	836	57·16	
1890	**3910**	2151	**6061**	1233	**7294**	848	**81·42**	**second highest year,** also highest first quarter and first 6 and 9 mouths.
1891	1319	2206	3525	1326	4851	679	55·30	
1892	2931	918	3849	1628	5477	1449	69·26	
1893	1775	1480	3255	813	4068	922	49·90	
1894	1825	663	2488	710	3198	624	38·22	second half of year *below normal.*
1895	1620	511	2131	441	2572	614	31·86	,, ,, ,, ,,
1896	997	1870	2867	480	3347	893	42·40	,, ,, ,, ,,
1897	594	1770	2364	1180	3544	708	42·52	second half of year normal.
1898	1161	1753	2914	915	3829	488	43·17	second half of year *below normal.*
1899	485	2073	2558	2074	4632	958	55·90	
1900	935	3015	3950	1622	5572	1072	66·44	
1901	1223	1315	2538	1110	3648	362	40·10	[10 consecutive years below average] second half of year *below normal.*
1902	449	451	900	1766	2666	1641	43·07	second half of year *exceeds normal*
1903	707	670	**1377**	1483	2860	1002	**38·62**	,, ,, ,, ,,
1904	1090	1799	2889	1336	4225	368	45·93	,, ,, *below normal.*
1905	1260	1326	2586	352	2938	565	35·03	,, ,, ,, ,,
1906	682	1008	**1690**	720	2410	779	**31·89**	,, ,, ,, ,,
1907	1367	1234	2601	**93**	2694	438	31·32	lowest third quar., sec. half *below normal.*
1908	1117	643	**1760**	**2420**	4180	385	**45 65**	very high third quart.
1909	807	730	**1537**	890	2427	815	**32·42**	second half *below normal.*
1910	1360	970	2330	1120	3450	1240	46 90	second half of year *exceeds normal*
1911	2170	580	2750	1740	4490	530	50·20	
1912	1690	1220	2910	1270	4180	570	47·50	
1913	1085	**3800**	4885	690	5575	205	57·80	highest second quarter. **Cataract Dam filled in May.** Second half *below normal.*
1914	1360	1030	2390	1520	3910	**1732**	56·42	second highest 4th quar., see 1870.
1915	670	1640	2310	830	3140	339	34·79	second half *below normal.*
1916	660	1060	**17·20**					

First Quarters = **763** in. Second Quarters = **924**. Third Quarters = **620**. Fourth Quarters = **478**. It would seem that if the rainfall for the first Six months is less than **20** inches; the total for the year will *be less than the average of* **48** *inches,* nor does it follow that an excess of even the average of **29** inches for the first six months will give a total for the year of the average of **48** inches.

SEPTEMBER 6th, 1916.

The three hundred and eighty-fourth General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. Houghton, President, in the Chair.

Thirty-four members and five visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of fourteen candidates for admission as ordinary members were read: five for the second, and nine for the first time.

Mr. G. H. Halligan and Mr. A. G. Hamilton were appointed Scrutineers, and Mr. J. Nangle deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

Forbes Burn, National Diploma in Agriculture, Goorianawa Station, Gular, N.S.W.

Edmund James Coote, Manufacturing Jeweller, 492 George Street, Sydney.

Jacob Robert Lucas Dixon, M.R.C.S., L.R.C.P., The University, Sydney.

Richard Tycho Dalrymple-Hay, Director of Forests, N.S.W., Goodchap Road, Chatswood.

John Gibson Youll, Editor, "Irrigation Record," Perpetual Trustee Chambers, Hunter Street, Sydney.

Fifty-eight parts, four volumes and three reports were laid upon the table.

THE FOLLOWING PAPER WAS READ:

"Shoreline Studies at Botany Bay," by E. C. Andrews, B.A., F.G.S.

Remarks were made by His Excellency Sir Gerald Strickland, and by His Honor Judge Docker.

EXHIBITS :

1. Mr. J. H. MAIDEN exhibited some acorns of a dwarf oak collected at Gallipoli, by Dr. A. ASPINALL, and which appears to be *Quercus Libani*. Also a photograph of Sir ALFRED ROBERTS, M.R.C.S., E. (1823–1898), who was Hon. Secretary of the Philosophical Society of New South Wales in 1862, and President of the Royal Society of New South Wales in 1888.

2. Mr. G. H. HALLIGAN exhibited a part of the flange of a 10 inch cast iron pipe eroded by a water jet charged with sand. The pipe was used in connection with the Grafton Water Supply, and was laid on the bed of the Clarence River, where it became embedded in sand. Owing to an imperfect joint, a minute jet of water, under a head of 327 feet, emerged from the pipe, and impinging upon the sand, caused the grains to fall within the influence of the jet, and thus provided an efficient scouring agent. The pipe joint finally collapsed twenty-two months after it was laid, about one half of the flange, which was $1\frac{1}{2}$ inches in diameter, having been more than half eaten away.

3. Mr. J. NANGLE exhibited samples of leather and other work prepared by students of the Sydney Technical College.

4. Dr. H. G. CHAPMAN exhibited a method for determining the average composition of ten samples of alveolar air by means of one analysis.

OCTOBER 4th, 1916.

The three hundred and eighty-fifth General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. HOUGHTON, President, in the Chair.

About twenty members were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of twelve candidates for admission as ordinary members were read; nine for the second and three for the first time.

Mr. A. B. HECTOR and Mr. J. E. BISHOP were appointed Scrutineers, and Mr. D. CARMENT deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

JAMES MACLEAN ALEXANDER, M. Inst. C.E., 25 O'Connell St.

SEPTIMUS BIRRELL, Chemist and Bacteriologist, Marrickville Margarine Co., "Florella," Dunslaffnace St., Hurlstone Park.

VICTOR HERBERT GREEN, Manager, George Shirley Ltd., 7 Bent Street, Sydney.

ARTHUR ANDREW HAMILTON, Botanical Assistant, Botanic Gardens, Sydney.

VICTOR LAWSON HARDY, Merchant, "Grey Lynn," 117 Cavendish Street, Stanmore.

JAMES HENDERSON, Manufacturer, "Dunsfold," Clanalpine Street, Mosman.

PHILIP à MORLEY PARKER, M. Inst. C.E., M. Am. Soc. C.E., B.C.E., B.A., Rawson Chambers, Pitt and Eddy Streets, Sydney.

STEPHEN HENRY SMITH, Inspector of Continuation Schools, Department of Education, Sydney.

ALFRED ERNEST STEPHEN, Manager, Nitrate Propaganda, Culwulla Chambers, 67 Castlereagh Street, Sydney.

The death was announced of Mr. WILLIAM HENRY WEBB, Assistant Librarian, who from 1877 to 1911 was Assistant Secretary of this Society, and from the latter date until the time of his death, on 29th August, 1916, was Assistant Librarian, also that the Council had directed that a letter of sympathy be sent to his daughters, and that the great appreciation of the Society for his long, faithful, and excellent service, be recorded in the minutes.

Letters were read from Miss L. WEBB, Mr. W. A. TURNER, and Mrs. J. W. JUDD, in which the writers thanked the Society for sympathy in their bereavements.

The Government Statistician of Western Australia wrote drawing attention to the approaching Tercentenary of the first landing in Australia (Western) by the Dutch on 25th October, 1616, and asking that the event might be recognised in some way. It was decided to bring the matter under the notice of the Press.

One hundred and twenty-one parts, fifteen volumes, twelve reports and one calendar were laid upon the table.

THE FOLLOWING PAPER WAS READ:

"On the Essential Oil from the bark of *Eucalyptus Macarthuri*," by H. G. SMITH, F.C.S.

Remarks were made by Mr. MEGGITT, Dr. CHAPMAN, Mr. OLLÉ, Dr. GREIG-SMITH, Mr. CHEEL, and Mr. DARNELL-SMITH.

EXHIBITS:

1. Mr. E. CHEEL exhibited some ripe nuts of *Hicksbeachia pinnatifolia* F.v.M., from Murwillumbah near the Queensland border. The kernels are of a fine flavour and seem equal to the "Popple Nut," or so-called "Queensland Nut" *(Macadamia ternifolia)*. As the putamen or shell is not so thick and hard as that of the "Popple Nut," it is considered well worth cultivating.

2. Mr. G. P. DARNELL-SMITH exhibited eight specimens of the destructive root parasite *Armillaria mellea*, namely: i. Sporophores of the fungus in various stages of development. ii. Roots of a peach tree showing the fungal hyphæ forming a network in the region of the cambium. iii. Roots of a nectarine tree showing the rhizomorphs ramifying over the surface. iv. Bole of an aged apple tree showing the manner in which the rhizomorphs

may interlace at the base of the stem. v. Roots of citrus trees showing the rhizomorphs buried in the cortex. vi. Base of the stem of a Burbank plum tree, showing dead and living areas, with fungal hyphæ beneath the bark. vii. Potatoes showing the fungus ramifying over the external surface and penetrating the tissues. viii. Orange twigs in process of decay from a tree, the roots of which were attacked by *Armillaria.*

3. Mr. E. C. Andrews exhibited two fine specimens of crystallised molybdenite from a large chamber of rich ore in the Allies' Mine, six miles east of Deepwater. The mineral occurs associated with prisms and pyramids of quartz in a "pipe" of altered granite, and at a depth of 160 feet from the surface measured along the underlie.

4. Mr. J. E. Carne exhibited a small polished specimen of brownish-grey marble, prettily marked with irregular veins and splashes of white calcite from a large deposit at Molong.

NOVEMBER 1st, 1916.

The three hundred and eighty-sixth General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. Houghton, President, in the Chair.

Thirty-four members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of five candidates for admission as ordinary members were read: three for the second, and two for the first time.

Mr. R. W. Challinor and Mr. A. J. Sach were appointed Scrutineers, and Dr. Cleland deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

James Wood Bragg, B.A., Engineer, c/o Gibson, Battle & Co., Ltd., Kent Street, Sydney.

Henry James Hoggan, Consulting Engineer, 'Lincluden,' Frederick Street, Rockdale.

Gilbert Wright, Lecturer and Demonstrator in Agricultural Chemistry, Department of Agriculture, The University, Sydney.

Two volumes and forty-six parts were laid upon the table.

THE FOLLOWING PAPER WAS READ:

"Maize Improvement in N.S. Wales," by H. Wenholz, B.Sc., Communicated by J. H. Maiden, F.R.S. (not published.)

Mr. E. C. Andrews' paper, "Shoreline Studies at Botany Bay," was then discussed by the following members:— Messrs. G. H. Halligan, C. A. Sussmilch, A. A. Hamilton, A. G. Hamilton, Dr. Harker, the President, and Mr. Andrews.

EXHIBITS:

Dr. J. B. Cleland and Mr. E. Cheel exhibited specimens or coloured drawings of the following fungi:—

Paxillus awicus, under fallen log, Wiseman's Ferry, August 1915, spores rod-shaped and pale yellowish? $3{\cdot}5 \times 1{\cdot}5\mu$ (identified by C. G. Lloyd; Somersby Falls, Gosford, May 1915, spores pale yellowish? 4 to $4{\cdot}8 \times 3\mu$.

Colus hirudinosus, Cav. and Sec., Milson Island, Hawkesbury River, March and June, 1916.

Catastoma hyalothrix, (Cooke) Milson Island, Hawkesbury River, February 1916, spores 4μ (identified by C. G. Lloyd).

Leotia lubrica, Pers., Lane Cove River, June 1916 (J.B.C.) and Somersby Falls near Gosford, June 1916 (G. P. Darnell-Smith).

Phillipsia polyporoides, Berk.? on fallen log, Kurrajong Heights, August, 1912 (identified by C. S. Lloyd).

Lenzites repanda, Mont. The largest from Eumundi, Queensland measuring 40 × 29 c.m., while others from Atherton Scrub, Queensland and from Goat Island near Broadwater, Richmond River, N.S.W., agree with the measurements given in Cooke's Handbook, Australian Fungi, *i.e.*, 6 – 10 c.m.

DECEMBER 6th, 1916.

The three hundred and eighty-seventh General Monthly Meeting of the Royal Society of New South Wales was held at the Society's House, 5 Elizabeth Street, at 8 p.m.

Mr. T. H. HOUGHTON, President, in the Chair.

Fifty-four members and two visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of five candidates for admission as ordinary members were read; three for the second, and two for the first time.

Mr. R. T. BAKER and Mr. G. H. HALLIGAN were appointed Scrutineers and Mr. E. C. ANDREWS deputed to preside at the Ballot Box.

The following gentlemen were duly elected ordinary members of the Society:—

JAMES DARNELL GRANGER, PH.D., Manager and Chemist, Chiswick Polish Co. of Australia Ltd., Mitchell Road, Alexandria.

WALTER WILLIAM L'ESTRANGE, Operative Brewer, "Orrville," The Avenue, Strathfield.

Eight volumes, two hundred and nineteen parts and seven reports were laid upon the table.

THE FOLLOWING PAPERS WERE READ:

1. "On an undescribed Darwinia and its Essential Oil," by R. T. BAKER, F.L.S. and H. G. SMITH, F.C.S.

Remarks were made by Mr. MAIDEN and Mr. CHALLINOR.

2. "On the Trematodes of Australian Birds," by S. J. Johnston, D.Sc.

3. "The Action of Pancreatic Juice upon Milk," by H. G. Chapman, M.D., and A. H. Moseley, M.B.[1]

4. "A Photographic Foucault-Pendulum," by Rev. E. F. Pigot, B.A., M.B.

Remarks were made by Mr. Nangle, Professor Cooke, Acting Professor Vonwiller and Professor Cotton.

5. "Wireless Time-Signals—Some suggested Improvements," by W. E. and F. B. Cooke.

EXHIBITS:

1. Mr. E. Cheel exhibited three seedling plants of *Eucalyptus Smithii* to show the rate of growth in certain soil in its native district as against a check plant in richer soil in the Sydney district. The seed from which the plants were raised was collected from a very large tree near Mount Jellore in October, 1915. Twenty-three seedlings were raised altogether, all of which with the exception of one, were planted in a shallow gully at Hill Top in February, 1916. A check plant was kept in a pot of rich black soil at Ashfield near Sydney. The plants when planted out at Hill Top were about $1\frac{1}{2}$ inches high with three pairs of opposite leaves. The smallest and the largest of the plants at Hill Top were lifted and repotted again a fortnight ago (November 18th) and are exhibited to show the comparative growth with the check plant at Ashfield. The growths of the plants are as follows:—Smallest plant from Hill Top $1\frac{1}{4}$ inches high; largest plant from Hill Top $4\frac{1}{2}$ inches high; check plant at Ashfield 1 ft. $9\frac{1}{2}$ inches high. It will be seen from the above that the rate of growth in the ordinary

[1] Published in Medical Journal of Australia, Vol. I, pp. 223, 243, 1917.

soil at Hill Top is very poor indeed, and although the species is a native of Hill Top and the surrounding district, that it will only thrive in rich patches of soil such as is found at Mr. D. CHALKER'S at Box Knob, and in the deep gullies with rich soil, as well as at Colo about six and a half miles from Hill Top and near Mount Jellore, where there are patches of fairly rich soil, probably of volcanic origin.

2. Dr. J. B. CLELAND and Mr. E. CHEEL recorded the following species of fungi for New South Wales :—

Collybia radicata, Relh. (Syn. *C. olivaceo-alba*, Cooke and Massee, a form), Bulli Pass, Mosman, Lisarow, Terrigal, Tuggerah.

,, *striatulata*, Lloyd, Sydney.

,, *stripitaria*, Fries, Milson Island.

,, *ingrata*, Schum, Mosman.

Marasmius lanaripes, Cooke and Massee, Sydney.

Pleurotus ostreatus, Jasq., Hawkesbury River.

Pholiota disrupta, Cooke and Massee, Milson Island.

,, *pumila*, Fr., Sydney.

,, *unicolor*, Fl. Dan., Mount Wilson, Leura, Lisarow.

,, *marginata*, Batsch, Milson Island.

Tubaria inquilina, Orange.

Naucoria semiflexa, B. and Br., near Bumberry.

,, *abstruza*, Fr., Milson Island, Sydney.

Galera tenera, Schaeff., Milson Island, Sydney, Orange.

,, *campanulata*, Massee, Hawkesbury River, Sydney, Adelaide

,, *hypnorum*, Batsch, Sydney, Lisarow.

,, *rubiginosa*, Pers., Sydney.

Crepidotus globigera, Berk., Tuggerah, Narrabeen, National Park.

Hebeloma mesoptœum, Fr., Mount Wilson.

Hebeloma subcollariatum, B. and Br., Sydney, Manildra, Narrabri.

Flammula californica, Earle, Lane Cove.

Stropharia umbonatescens, Peck, Sydney.

,, *melasperma*, Bull., Sydney.

Hypholoma sublateritium, Schaeff., Mount Wilson.
,, *perplexum*, Peck, Mount Wilson.
,, *capnoides*, Fr., Leura.
Boletus romanus, Ottav., Sydney.
Psalliota arvensis, Schaeff., var. *villaticus*, Brind., Botanic Gardens.

GEOLOGICAL SECTION.

ABSTRACT

OF

PROCEEDINGS OF THE GEOLOGICAL SECTION.

Monthly Meeting, 12 April, 1916.

Mr. R. H. Cambage in the Chair.

Nine members and one visitor were present.

Mr. J. E. Carne and Mr. W. S. Dun were proposed and elected as Chairman and Honorary Secretary respectively.

EXHIBITS:

1. Dr. Anderson exhibited, (*a*) pseudomorph of silica after azurite from the Dorothy Mine, Chillagoe, Queensland; (*b*) wolfram replacing quartz and showing banded structure, from Torrington, Nav.

2. Mr. W. S. Dun, (*a*) section of Favosites from Loombera, collected by Dr. W. N. Benson, showing *multitabulata* structure succeeding on *gothlandica;* (*b*) specimens of *Glossopteris* showing leaf structure from Richmond Vale.

Dr. Benson gave notes on the physiography of the Cradle Mountain area, Tasmania, devoting particular attention to glacial effects on the topography.

Monthly Meeting, 10th May, 1916.

Mr. J. E. Carne in the Chair.

Seven members were present.

EXHIBITS:

1. Mr. W. R. Browne exhibited opalescent quartz in granite from Victor Harbour, S.A., now being described by Messrs. Browne and Tilley. Mr. Tilley suggested that

the opalescence may be due to the occurrence of fine inclusions rather than cracks.

2. Mr. G. W. CARD exhibited from the Mining Museum, (*a*) light oil from Papua; (*b*) chrysotile from Beaconsfield, Tasmania; (*c*) native bismuth from Kingsgate; (*d*) bismuth telluride and native bismuth from Whipstick; (*e*) chalcopyrite from North Mount Lyell; (*f*) ores from the Boss Mine, Nevada, yielding 100 ozs. Pt., 131 ozs. Pall., 81 ozs. Au. per ton; (*g*) chrome mica from New Caledonia.

Mr. L. A. COTTON gave an account of pendulum experiments at Burrinjuck.

Monthly Meeting, 14th June, 1916.

Mr. J. E. CARNE in the Chair.

Nine members and one visitor were present.

EXHIBITS:

1. Mr. C. A. SUSSMILCH exhibited (*a*) spherulitic rhyolite of Carboniferous age from the Dungog Road; (*b*) *Lepidodendron australe* from Carboniferous (?) conglomerate on Hudson Peak–Elderslie Road, a coarse conglomerate interstratified in tuffs; (*c*) Devonian sandstone from conglomerate at Elderslie Bridge, near Branxton; (*d*) Radiolarian cherts, aplitic types of granite and slates of the Jenolan area from Branxton.

2. Dr. W. N. BENSON exhibited gold-bearing silicified Permo-Carboniferous mudstone from Port Cygnet, and porphyry in dolerite and tertiary alkaline rocks collected by Professor SKEATS.

Mr. C. A. SUSSMILCH described the physiography of the Barrington Tops and Lower Hunter:—

Some notes on the Physiography of the Hunter River Valley.

The valley of the Lower Hunter River has been cut out of a tableland which has a general altitude of about 1,300 feet. The original surface of this tableland was a peneplain cut out of Triassic Permo-Carboniferous and Carboniferous strata; this peneplain is a part of the great Australian Tertiary Peneplain, and was elevated to its present position at the end of the Tertiary Period; this tableland may be referred to as the Hunter River tableland. In this region it has been almost completely dissected and the main valleys are thoroughly mature. Followed southwards from the Hunter River the altitude of the tableland gradually decreases, and in the neighbourhood of Gosford it is 900 feet high, while still further south at Hornsby it is under 700 feet in altitude. Followed northwards from the Hunter River it maintains a general altitude of 1,300 to 1,400 feet, until it reaches the foot of the great southern scarp of the Barrington Tableland a few miles north of Dungog. The Barrington Tableland is a great fault-block, bounded by great fault escarpments on its southern and western sides. At its south-western corner it reaches an altitude of 5,000 feet, but has a decided tilt to the north-east. The southern escarpment of this fault-block is the result of a series of step-faults with a vertical throw to the south of over 3,000 feet; these step-faults strike almost due east and west. The Barrington Tableland is capped by Tertiary basalt and this basalt has participated in the faulting; the faulting itself would appear to have taken place at the end of the Tertiary Period and during the uplifting of the tableland. Small cappings of Tertiary basalt also occur on the Hunter River Tableland, notably at Martin's Creek and at Mount Warrawolong, these appear to be remnants of extensive Tertiary flows. The greater part of the Barrington Tableland belongs to the watershed of the Manning River, but its southern and western margins are drained by the Hunter River and its tributaries. Those draining the southern side, viz, the Allyn, Paterson, Williams, etc., following very definitely the strike of the Carboniferous strata over which they flow.

Monthly Meeting, 9th August, 1916.

Mr. R. H. Cambage in the Chair.

Eleven members were present.

EXHIBITS:

1. Mr. C. A. SUSSMILCH exhibited *Cladochonus sp.* indet., from Wallis Head.

2. Professor COTTON, Pelé's Hair from Hawaii.

3. Dr. ANDERSON, (*a*) Iceland spar from the Garibaldi Mine, Lionsville; (*b*) molybdenite and native bismuth from Kingsgate; (*c*) beryl from Torrington showing naturally etched figures.

4. Mr. W. S. DUN, *Semionotus* from near Geurie, Lower Mesozoic.

5. Mr. G. W. CARD, exhibits from the Mining and Geological Museum.

6. Mr. C. A. SUSSMILCH also exhibited in connection with Dr. BENSON's note, (*a*) Intrusive tuffs in Radiolarian rocks; (*b*) Pillow lavas and examples of epidotisation from Bundook; (*c*) Permo-Carboniferous fossils—*Deltopecten illawarrensis*, *Spirifera*, *Martiniopsis*, *Polypora (?)* from Georgetown, Manning River, a horizon comparable with that of Comerford's, near West Maitland.

Mr. SUSSMILCH communicated Dr. BENSON'S notes on their joint observations on the general geology of the Gloucester District:—

The General Geology of the Gloucester District.

W. N. BENSON, D.Sc., F.G.S.

The section studied extends from Bulliac Railway Station to Mount George on the Manning River, a distance of eleven miles, and runs in a roughly E.N.E. direction, nearly perpendicular to the main direction. From such information as could be gathered from the train-window, it seemed that from Gloucester to Bulliac, once the Gloucester infaulted Permo-Carboniferous series has been passed, the strata consist of rhyolite, Burindi (Marine) Lower Carboniferous mudstones with rare limestones, and Barraba Upper Devonian mudstones and tuffs, with perhaps the upper portion of the Tamworth Middle Devonian Series. The section from Bulliac onward, shows features identical with those in the middle and lower parts of the Tamworth Series as exhibited in the Tamworth District. The rocks consist chiefly of coarse to medium grained breccias and tuffs, associated with a small amount of banded radiolarian claystone, which near Bulliac occur in masses from thirty to a hundred feet thick, but are much thicker further to the N.E. Excellent instances of intrusive tuff are visible, the clearest example being about a mile from Bulliac. About four miles further to the N.E. a small mass of intrusive albitised dolerite occurs. The dip of the claystone near Bulliac is W. 40° S. at 65°, which follows about the average strike (from memory), further to the N.E. the dip is often steeper, and rarely reversed, the strike also fluctuates somewhat. This must be a region of frequent strike faulting, traces of which can be seen in the cuttings.

After a considerable thickness of claystone, pillow lavas appear about a quarter of a mile west of Bundook, apparently running back to the confluence of the Barrington and Manning Rivers, and continue for the next two miles along the railway. They are extremely decomposed at first, the pillow outlines appearing but faintly, but east of Bundook Station the structure is more obvious, and in the short deep cutting immediately beyond Baker's Creek, they are very dense, hard, fresh-looking rocks, which are subvariolitic spilites, with well preserved pyroxenes, but albitic felspars. A very striking feature in these rocks is the very great amount of alteration they have undergone, the occurrence of bands of shattering, with abundant introduction of quartz and of epidote. Vesicules are not very abundant.

This last spur of spilite is the north-western extremity of the Kangat Range. Kangat itself is over 2,000 feet in height, and very steep, densely covered with brush, and is exclusively composed of very massive pillow lavas, the ellipsoidal partings being traceable on the crags exposed every here and there, particularly on the southern slope. Only rare and narrow zones of radiolarian chert intercalated (by faulting?) in the igneous rocks break their continuity. So far as we know, so great an apparent thickness of pillow lavas has not been elsewhere described and raises very interesting problems as to the depth of the sea and other conditions under which they were formed.

The northern face of the Kangat range slopes steeply down to a small lowland in the abnormally wide valley of the Manning River, and is evidently due to differential erosion and soft rocks in the river valley which are bounded by a line of faulting, as has been observed by one of us in the neighbourhood of Bowling Alley Point on the Peel River. Crushed and steeply dipping clayshales and phyllites lie north-east of the broad zone of spilites, and the low land in the river bottom consists on the south bank of a soft pinkish claystone, which dips so steeply where it comes into contact with the Devonian rocks (by the small bridge over the railway cutting just beyond the sharp bend west of Somerset Station) that it becomes very difficult to see the line of fault. This pink claystone contains a few Permo-Carboniferous Lamellibranchs. North of the Manning River the first cutting exposes a series of conglomerates with a steep dip varying from N. 50° W. at 40° W. to N. 20° W. at 70°, very like the Comerford conglomerate in the Lower Marine Series, and in which the following forms were seen: *Deltopecten illawarrensis*, *Spirifera*, *Martiniopsis subradiata*, and *Polypora(?)*, and more than a mile further east beyond Mount George Station, the railway cutting lies in marine micaceous mudstone dipping from N. 25° E. at 70° to N. at 30°, which traced into the north contain *Fenestella*, a small *Productus* and indeterminable casts, and occasional erratics of quartzite and granite, one-eighth of an inch in diameter, and rise into hills composed of a type of tuffaceous sandstone with a few boulders. These all seem to be Permo-Carboniferous. Immediately north of the railway at Mount George, however, lies the northern boundary fault of this small infaulted Permo-Carboniferous area, and north of this lies two masses of very schistose serpentine, the one at Mount George Station a quarter of a mile wide, and the other in Woolshed Creek half a mile to the west. Between these outcrops lie

Middle Devonian breccias and agglomerates with interbedded mudstones dipping E. 30 N. at 80°.

Local information revealed that serpentine also occurred five miles north of Mount George, near Glen Lewis in Dingo Creek (Western Branch), and specimens of serpentine have been received by Mr. CARD from Bow Bow near Tinonee, south of the Manning River, and approximately twelve miles south-east of the last mentioned occurrence of serpentine.

Thus we have in this region a series of formations and geological structures completely analogous to those of the great serpentine belt on the upper Peel River, but striking rather more west of north, and lying some twenty miles east of the line which would continue the strike of the Great Serpentine Belt southwards from Nundle, and therefore in a position where only the highly crushed phyllites and jaspers of the eastern series would be anticipated, instead of the normal Middle Devonian rocks passing into Upper Devonian and Carboniferous rocks, that actually do occur. Future research must be directed to discovering whether this whole region is a faulted repetition of the serpentine line or its deflected southern extremity. Further, the presence of the north-westerly strike so near the coast renders improbable the suggestion that the N.N.E. strike of the Devonian rocks at Port Macquarie is connected by a curve sweeping through an E.W. direction with the N.N.W. strike of the western slopes of New England, but that the N.N.E. strike is more probably a virgation, passing off from the main N.N.W. line of strike, such virgations having been noticed in several areas between Bingara and Nundle.

Monthly Meeting, 13th September, 1916.

Mr. J. E. CARNE in the Chair.

Nine members were present.

EXHIBITS:

1. Mr. E. C. ANDREWS, Photographs of beach forms at Lady Robinson's Beach, in illustration of his paper read before the Society.

2. Dr. C. Anderson, (*a*) Dreikanter from Wanganui, N.Z.; (*b*) etched beryl from Torrington; (*c*) photographs of earth pillar, Wolgan Valley, Dry Gully at Tenterfield, and restoration of Parramatta River.

3. Mr. G. W. Card, (*a*) wood opal from Tingha; (*b*) Molybdenite and bismuth from Bow Creek, Deepwater.

4. Professor Cotton, photographs of land forms prepared by the U.S. Geological Survey.

5. Mr. W. R. Browne, specimens of Glendonites from Wollongong and Singleton covered with crystals of sulphate of lime.

6. Mr. J. E. Carne, gold-bearing specimens from Hill End.

Monthly Meeting, 8th November, 1916.

Mr. R. H. Cambage in the Chair.

Ten members and one visitor were present.

EXHIBITS:

1. Mr. E. C. Andrews exhibited (*a*) slates from Chatsbury; (*b*) molybdenite from Deepwater and Yetholme; (*c*) zincblende from Deepwater.

2. Dr. C. Anderson, (*a*) azurite from Iodide and Melrose; (*b*) quartz crystals from Kingsgate and Torrington.

3. Mr. C. F. Laseron exhibited a series of new and rare Permo-Carboniferous fossils from the Maitland District. These included the following species from the Lower Marine Series, just west of Farley Railway Station :—

Ptycomphalina sp. nov., a form distinct from *P. Morrisiana* McCoy, the common Upper Marine species.

Straparollus sp. nov., a small new form associated with the above.

Hyolithes lanceolatus Morris, several specimens of the opercula.

Mytilus sp., a small shell resembling a species found in the Upper Marine Series of the Shoalhaven River.

Astartila or *Pachydomus* sp., possibly a new species.

In addition to these the following were collected from the railway cutting near Allandale:—

Mœonia sp. nov., a highly carinated form, quite distinct from *M. carinata* Morris, the only species it at all resembles.

Straparollus ammonitiformis Eth. fil., a very fine specimen of this very rare shell.

Aviculopecten or *Deltopecten*, a small species which may be new.

Keeneia platyschismoides Eth. fil., a fine specimen.

Keeneia sp., a fine specimen of a distinct species from the above.

4. Dr W. N. Benson, Foraminifera from the Nemingha Limestone (Devonian), *Ammodiscus* and *Endothyra*.[1]

5. Mr. W. S. Dun, *Lepidodendron australe* from Stewart's Brook, and *Austrospongia* (gen. et sp. nov.) from the Tamworth Limestone.

6. Mr. G. W. Card, (*a*) silica-coated leaves from Papua; (*b*) phosphate rock from Wellington; (*c*) chrysolite from Beaconsfield.

Mr. E. C. Andrews gave further notes on the Beach Formations of Botany Bay in amplication of his paper. [*Vide* this Journal, pp. 165 - 176]:—

Further notes on the Shoreline Topography of Botany Bay.

E. C. Andrews, B.A., F.G.S.

The discussion on "Shoreline Studies at Botany Bay," published in this year's journal of the Society, was continued from the general meeting in October. It was stated by Mr. Andrews that there had been no consensus of opinion upon the idea expressed by various observers, namely, that the shoreline of New South Wales had emerged recently to the extent of a few feet.

Mr. Andrews considered that Lady Robinson's Beach was an emergent feature, and moreover that it was merely a type which was to be found along the whole of the eastern Australian shoreline. The evidence consisted of:—

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[1] Descriptions will probably be published in P.L.S., N.S.W., for 1917.

1. The fact that marine erosion on a headland consisted in the first place, of a direct attack of the storm wave unarmed or armed, with rock fragments, and in the second place, of the scouring action of the rock load below and beyond the direct wave attack. This action produced a simple profile in ordinary rock structures, steeper near the land and flattening gradually towards the sea.

2. The topography of Lady Robinson's Beach and the land surface immediately behind the beach were due, apparently, to two activities, the one not coming into operation until the completion of the other. Thus the broad rolling surface of sand covered by forest growths, subhorizontal when viewed from above, and rising about fifteen feet above high water mark was explained as an emergent feature, whereas the overlying belt of sand dunes behind the beach was due to the later action of the wind.

3. The fact that along the whole south-eastern and eastern side of Australia rock platforms and lines or zones of marine erosion occur at and above high-water mark.

These rock platforms have been formed by marine erosion. They may be wide or narrow, they may occur in rock masses of igneous origin or in those possessing gentle dips, or they may occur in rocks showing strong contortion. The platforms, however, in nearly every instance transgress the bedding planes.

The surfaces of the platforms lie but a few feet above high water mark, but they may occur one above the other, separated by low escarpments.

The main attack of the storm waves to day appears to be on the edge of the lowest platform, in the cases where more than one exists, and there is thus evidence of two or more lines or zones of marine cutting vertically above the other. This in itself is in direct contradistinction to the idea that the sea has cut the platforms at the same time, inasmuch as the tendency of the sea wave is to establish a simple profile of erosion on a stable shore line.

The surfaces of the platforms themselves are deeply pitted and scored with holes, due to subaërial action, aided in a minŏr degree only by marine action. The lowest portions of the headland cliffs themselves also exhibit the characteristic marks of subaërial weathering. Many of the cliffs themselves are protected by great fallen blocks which litter their bases. These are deeply pitted with holes of subaërial weathering, and the greatest storm waves of the past 20 or 30 years have not been observed to have moved such large blocks. Many of the cliffs also are of the form known as *well-subdued*, and are covered with forest growths, indicating that effective sapping has ceased for very many years.

Great sand flats also occur from five to twenty feet above high water mark in the vicinity of the platforms. Right along the east side of Australia, both these sand flats and the rock platforms have been trenched deeply, the former by subaërial influences, the other mainly by wave action.

Various observers have recorded the existence of horizontal zones of dead barnacle colonies *in situ* a few feet above the highest limit of massed barnacle growths to day. These emerged features occur on exposed rock faces with deep water immediately below.

Various observers also, such as Wilkinson, David, and Harper, have recorded the existence of marine "blowholes" behind the platforms in positions such that they are high above the influence of the greatest storms of the present time.

All this evidence tends to demonstrate that the present shore-line of eastern Australia is a feature of emergence of very recent origin, probably not exceeding a few hundred years. Lady Robinson's Beach, being considered merely as a type of such features, appears to be also one of very recent emergence.

It cannot be emphasised too strongly that these slight movements of recent emergence have been imposed upon a recent but much greater movement of submergence which drowned the whole eastern side of Australia to the extent apparently of 200 feet.

Many observers of the Sydney and eastern Australian shoreline profess to see only the features due primarily to submergence, such as bay bars, lagoons, silted water ways, and cliffed headlands.

If the activities consequent upon subsidence be evaluated, such subsidence being possibly as much as 10,000 or 20,000 years old, it will be seen that the features described above would be unexplained in their entirety Marine and subaërial action, however, on emerged features, formed after submergence, afford a sufficient explanation.

SECTION OF PUBLIC HEALTH AND KINDRED SCIENCES.

ABSTRACT OF PROCEEDINGS

OF THE

SECTION OF PUBLIC HEALTH AND KINDRED SCIENCES.

Abstract of the work of the Section for the year 1916, the second year of its existence.

Contrary to expectations, the Section of Public Health and Kindred Sciences has had a fairly successful year. The meetings were well attended, and papers of considerable value were read and discussed. The discussions in every case brought forward much additional information of value.

During the year, meetings were held and papers read, as follows:—

13th June, 1916, Papers Read and Discussed.

1. "Some Hints on the Construction of Healthy Dwellings," by J. NANGLE, F.R.A.S., Superintendent of Technical Education, N.S. Wales.

2. "The Effect of Holding the Breath on the Composition of Alveolar Air," by H. S. HALCROW WARDLAW, D.Sc., Sydney University.

3. "Some Notes on the Deterioration of Condensed Milks," by T. COOKSEY, Ph.D., B.Sc., F.I.C., Government Analyst.

11th July. 1916, Paper Read and Discussed.

"Light and Air in Dwellings and Factories," by JOHN L. BRUCE, Department of Sanitation, Technical College, Sydney.

12th September, 1916, Paper Read and Discussed.

A discussion on "Labour Saving Devices in the House." This discussion was opened by Mr. J. NANGLE, F.R.A.S. In addition, the following members and visitors took part in the discussion:—The Chairman, Sir THOMAS ANDERSON STUART, Drs. SAVILL WILLIS, GREIG-SMITH and FITZHARDINGE, Rev. Father PIGOT, and Messrs. OLLÉ and HECTOR.

14th November, 1916, Paper Read and Discussed.

"Humidity and Temperature of Air in Relation to Comfort and Health," by JOHN L. BRUCE, Department of Sanitation, Technical College, Sydney.

Some of the above-mentioned papers, notably those by Messrs. NANGLE and BRUCE, were illustrated by lantern slides and models.

As it was understood the Society's funds were not too flourishing, no recommendations were made with regard to the publication of the above papers in the Proceedings of the Royal Society. The papers were, however, published in one or other of the scientific journals printed in the State.

At the November meeting, an election of Officers for the year 1917 was held.

The Chairman and Secretary having signified their inability to continue in office, the following Officers were elected:—

Chairman—Dr. CECIL PURSER.

Hon. Secretary—Dr. F. GUY GRIFFITHS.

Recommendation Committee—Drs. J. B. CLELAND and C. SAVILL WILLIS, and Mr. ALGERNON PEAKE.

SECTION OF AGRICULTURE.

ABSTRACT OF THE PROCEEDINGS

OF THE

SECTION OF AGRICULTURE.

As the Council of the Royal Society had decided that the time was opportune to form a Section of Agriculture, a meeting was called for the 12th of July, 1916, at 4 o'clock p.m.

The members who responded consisted of the President Mr. T. H. HOUGHTON, M. Inst. C.E., Dr. H. G. CHAPMAN, Dr. J. B. CLELAND, Prof. R. WATT, M.A., Messrs. R. H. CAMBAGE, F.L.S., J. H. MAIDEN, I.S.O., F.R.S., F. B. GUTHRIE, F.I.C., E. CHEEL, and A. J. SACH. Messrs. H. C. L. ANDERSON, M.A., VICTOR GREEN, YOULL, and WRIGHT accepted the invitation to attend. Dr. R. GREIG-SMITH acted as Hon. Sec. *pro tem.*

Mr. T. H. HOUGHTON, the President of the Society took the chair and initiated a discussion by referring to the attitude of the Council in the matter. Dr. GREIG-SMITH spoke of the advantage that would be given to members in having a section specially devoted to Agriculture. Dr. CLELAND emphasised the convenience of having a common meeting ground for those interested in scientific agriculture.

The President asked the members to nominate a chairman of the Section, and on the motion of Prof. WATT, seconded by Dr. CHAPMAN, Mr. F. B. GUTHRIE was nominated and unanimously elected. Dr. GREIG-SMITH was elected Honorary Secretary.

It was proposed and carried, that the following gentlemen be elected a Committee with power to add to their number.

Dr. H. G. Chapman, Dr. J. B. Cleland, Mr. G. P. Darnell Smith, B.Sc., Mr. J. H. Maiden, I.S.O., F.R.S., Mr. H. W. Potts, F.C.S., Prof. Douglas Stewart, B.V.Sc., Prof. R. Watt, M.A., and the Chairman and the Hon. Sec. *ex officio.*

The Inaugural Meeting of the Section was held on Tuesday, July 25th, 1916, at 8 p.m., when a large number of members and visitors were present.

Mr. F. B. Guthrie, F.I.C., the Chairman of the Section, declared the Section formed and hoped that it would have a long and prosperous career. He trusted that the watchword of the Section would be "Informality," as the formal reading of papers was not proposed. The idea was to discuss all subjects bearing upon Agriculture in the most free and informal manner. Any notes of interest communicated by members would make profitable subjects for discussion, and the same would apply to any experiences met with by agriculturalists, orchardists, horticulturalists and others. The chief benefits would arise from the broad, open untrammelled discussion of any matter of interest. The Section might have short lecturettes given by anyone specially interested in any particular subject, and these might afford opportunities for discussion. Certain subjects might be put forward as ideas rather than as being part of a programme. These include Education, Forestry, Soil-surveys, Prices of Food, and the formation of a Federal Bureau of Agriculture. Each or all of these might be discussed in a purely scientific and non-party spirit.

The Chairman's remarks led to a discussion, in which the following gentlemen took part:—Messrs. J. H. Maiden, A. J. Sach, A. Yates, Rumsey, E. Cheel, Saunders, A. B.

HECTOR, A. A. HAMILTON, A. G. HAMILTON, P. G. GILDER, R. SPENCER WATTS, and Dr. J. B. CLELAND.

Second Meeting, Tuesday, August 29th, 1916.

Mr. F. B. GUTHRIE, F.I.C., in the Chair.

A letter was read from Mr. E. BREAKWELL upon the cross-breeding and cultivation of Native Grasses.

Mr. G. P. DARNELL SMITH, B.Sc., opened a discussion upon Green-manuring in semi-dry districts. Messrs. A. J. SACH, A. E. STEPHEN, MATTHEWS, E. CHEEL, OSBORNE, Dr. J. B. CLELAND, and the Chairman joined in the discussion.

Mr. GILDER introduced the subject of the Fat Standard of Milk, and this was discussed by Messrs. DEIGHTON, MATTHEWS, A. B. HECTOR, J. M. HATTRICK, A. E. STEPHEN, J. BISHOP, E. CHEEL, Dr. J. B. CLELAND, and the Chairman.

Dr. J. B. CLELAND exhibited and described *Tetragonia expansa* or Native Spinach, which is common to the shores of Port Jackson.

Third Meeting, Tuesday, September 26th, 1916.

Mr. F. B. GUTHRIE, F.I.C., in the Chair.

A letter was read from Mr. E. BREAKWELL describing the work that was being done by him as State Agrostologist in the improvement and cultivation of the Native Grasses and Pastures.

The letter led to a discussion in which Messrs. GEORGE VALDER, G. P. DARNELL SMITH, A. B. HECTOR, J. M. HATTRICK, J. S. STENING, Dr. J. B. CLELAND, the Chairman and the Hon. Secretary took part.

As an outcome of the discussion the Hon. Secretary was instructed to consult with Mr. E. BREAKWELL, and if it were considered advisable, to write to the Minister for Education, suggesting that complete instructions should be sent to the country school-masters to enable them to get the children to gather the seeds of the kangaroo grass or one other native grass, and sow them in the school gardens with the object of increasing our knowledge regarding the habits, etc. of the native grasses.

Mr. G. P. Darnell Smith referred to the previous discussion upon green-manuring and amplified his former remarks. Messrs. Geo. Valder, J. M. Hattrick, A. B. Hector, Dr. J. B. Cleland, the Chairman and the Hon. Secretary joined in the discussion.

Mr. J. B. Hector spoke about radio-activity in agricultural and horticultural practice.

Fourth Meeting, Tuesday, October 31st, 1916.

Mr. F. B. Guthrie, F.I.C., in the Chair.

Mr. G. W. Norris read a note upon Macaroni Wheats, in which he described the properties of the plants and of the semolina, and the flour obtained from them. He also dealt with the nature of the bread made with and without the addition of the flour of ordinary wheat.

Messrs. G. S. Stening, A. D. Ollè, Gosche, A. E. Stephen, Dr. J. B. Cleland, the Chairman and the Hon. Secretary took part in the discussion.

The Hon. Secretary, Dr. Greig-Smith, called attention to the work that had recently been done in Utah, U.S.A., in manufacturing potassium sulphate from alunite. The work of the Australian Alum Co. was noted, and the importance of a commercial source of potash at the present time was emphasised.

Mr. Dixon of the Australian Alum Co. spoke about the work of his company, and Messrs. A. B. Hector, A. E. Stephen, Dr. J. B. Cleland and the Chairman took part in the discussion.

Mr. E. CHEEL showed five specimens of wild clovers, and pointed out their importance in improving poor soils.

Mr. A. E. STEPHEN exhibited a specimen of Humogen or bacterised peat. Dr. GREIG-SMITH described its preparation and properties.

Fifth Meeting, Tuesday, December 12th, 1916.

Mr. F. B. GUTHRIE, F.I.C., in the Chair.

A letter was read from the Under Secretary for Education in which he said that in some schools a start would be made in getting the pupils to grow native grasses, especially kangaroo grass.

Mr. E. BREAKWELL discussed the study of the native grasses, the most extensively grown crop in New South Wales. He considered that the vitality of kangaroo grass seed was too low to justify its being grown by school pupils who should work with a grass that would yield positive results. Messrs. A. J. SACH, A. A. HAMILTON and H. W. POTTS contributed to the discussion.

The Hon. Secretary was instructed to lay the views of the Section before the Under Secretary for Education.

Mr. E. CHEEL exhibited specimens of kangaroo grasses which had been cultivated for cross-breeding purposes.

Mr. W. W. L'ESTRANGE contributed a note upon brewing barleys, in which he called attention to some progress that had been made in correlating the structure of the grain with the germinating power and the diastatic content. There was great need for selecting and improving local barleys from a brewing point of view. Imported barleys deteriorated under cultivation.

In the discussion Mr. H. W. POTTS described a visit to the Guelph College, Canada, and the work of its barley selector in improving the barleys of Canada.

Mr. G. W. WALKER discussed barley-growing from a feeding standpoint. He did not think that horse owners paid enough attention to the value of barley for feeding horses. He advocated a more extensive use of barley as a rotation crop with wheat.

Mr. H. W. POTTS emphasised the value of barley for fattening stock.

The Hon. Secretary was instructed to approach the Department of Agriculture regarding the advisability of experimenting with varieties of barley grown in New South Wales with the view to their improvement.

Mr. G. W. WALKER spoke about the tendency of farmers in taking up stock-raising as against wheat growing at the present time, owing to financial stress and the uncertainty of the world's markets. After some discussion, the Hon. Secretary was instructed to suggest to the Federal Government that it should approach the Home Authorities with the view of fixing a reasonable guaranteed price for all shipping wheat grown next year in the Commonwealth. He was also instructed to suggest to the State Government the advisability of guaranteeing an extra sixpence per bushel for all wheat grown upon new land in this State.

Mr. A. A. HAMILTON exhibited specimens of plants which had appeared in a paddock where American hay had been fed to stock.

Mr. A. J. SACH suggested that the Section should have excursions to places of agricultural interest, and Mr. H. W. POTTS invited the section to visit the Hawkesbury Agricultural College.

The Section took advantage of Mr. POTTS' invitation on Friday, February 23rd, 1917, when thirteen members were conducted over the College, and had the general working explained by him.

SECTION OF INDUSTRY.

ABSTRACT OF THE PROCEEDINGS

OF THE

SECTION OF INDUSTRY.

As a sequel to the address of the retiring President, Dr. GREIG-SMITH, several meetings of the Society were, during June and July, devoted to discussing the relations between Science and Industry.

It was made clear during the discussion that the Society considered the time to be opportune for forming a Section of Industry, and the Council accordingly decided that this should be done. The Hon. Secretaries summoned the members to attend an inaugural meeting.

Inaugural Meeting held on Wednesday, August 23rd, 1916.

Mr. T. H. HOUGHTON, President, in the Chair.

Nominations were called for the office bearers of the Section, and Mr. LOXLEY MEGGITT, F.I.C., was proposed by Dr. H. G. CHAPMAN, seconded by Mr. A. D. OLLÉ, and duly elected chairman.

Dr. R. GREIG-SMITH was proposed by Mr. A. B. HECTOR, seconded by Dr. J. BURTON CLELAND, and elected Hon. Secretary.

The President congratulated Mr. MEGGITT and installed him in the Chair.

Mr. FRANK LEVERRIER, B.A., B.Sc., K.C., described the formation of the Commonwealth Advisory Council in Science and Industry, of the Executive Council and of the State Committees. The appointment of Special Committees for the investigation of special problems in industrial matters was alluded to, and the formation of a Special Bureau for the collection and dissemination of industrial information was commented upon.

Prof. W. H. WARREN, LL.D., emphasised the advantages that would accrue to a large portion of the community by the formation of a Section in which the purely scientific could exchange views with the practical man. He also laid stress upon the necessity for the more liberal teaching of the fundamental sciences of chemistry and physics in the schools and technical colleges.

Prof. R. D. WATT, M.A., B.Sc., showed that the Institute of Science and Industry, as proposed, would not be a building but a council which would have for its aim the better utilisation of existing laboratories. It had at present the power of assisting these financially, and of similarly assisting any movements which would be of advantage to the primary and secondary industries of the Commonwealth.

Mr. G. H. KNIBBS, C.M.G., Commonwealth Statistician, suggested a scheme for teaching science in elementary schools, and showed that, in Germany, all education had a scientific foundation.

Meeting held on Thursday, September 21st, 1916.

Mr. LOXLEY MEGGITT in the Chair.

The Chairman read a letter from Mr. FORBES MACKAY, Electrician to the City Council, in which he advocated the technical training of a greater number of apprentices in the technical schools and colleges.

Mr. W. T. WILLINGTON, President of the Chamber of Manufacturers, in opening a discussion upon the co-operation of science with industry, said that *post bellum* conditions would create a state of affairs that would take some time to adjust, and during this time the assistance of science would be of the greatest use to manufacturers. A higher state of efficiency and skill would be requisite in the future.

Mr. A. B. HECTOR considered that the co-ordination of scientific facts that were already known was the main desideratum of the moment. Along with this, there were the unification of standards, and the simplification of our complicated weights and measures. The scientific education of the rising generation was a matter of urgency. Popular industrial lectures might be given by the Section.

Mr. A. D. WALKER believed that the Section could help the smaller firms which could not afford a scientific staff. He thought that science improves an industry after it has been established by the tariff.

Mr. JAMES HENDERSON said that science could best assist industry by considering the scientific education of the young and of the budding worker. Lecturettes upon industrial subjects should be given by scientific men. He considered that we should think and act more as a community than as individuals.

His Excellency Sir GERALD STRICKLAND, G.C.M.G., Governor of the State, said that the education of the rising generation in science was full of promise, and he suggested that a Government department should be inaugurated or the University system extended to allow of thoroughly competent scientific advice being given when desired by manufacturers.

Mr. T. H. HOUGHTON, President of the Society, appealed to manufacturers to allow their young men to go to the technical schools during the afternoon.

Mr. THOS. POOLE gave an instance of the benefit of co-operation in several small firms combining to employ a chemist.

Mr. B. J. SMART thought that scientists were not quite seized with the problems confronting manufacturers and suggested the classification or grouping of the industries.

Mr. CLAUDE READING also spoke.

Meeting held Thursday, October 19th, 1916.

Mr. LOXLEY MEGGITT in the Chair.

Prof. O. U. VONWILLER gave a lecturette upon Physics in the Industries, in which he gave instances of many useful industrial applications of ideas which had been derived from purely theoretical work. He showed that it would pay industrial concerns to employ scientists to study the theory of their industrial processes. He suggested that the Section should pay periodic visits to the scientific laboratories of the University.

Mr. JAMES HENDERSON, the Chairman, and the Hon. Secretary also spoke.

Prof. J. READ gave a lecturette upon the Hydrogenation of Liquid Fats. He showed the differences between the liquid and solid fats and described the earlier experiments that led to the industrial application of the action of hydrogen upon liquid fats in the presence of a catalyst such as reduced nickel oxide.

Dr. R. K. MURPHY described the steps taken by an American firm which dealt in Cotton Seed Oil, to convert the oil into a solid fat. He also spoke about the manufacture of synthetic lard by mixing the oil with 5% of the hardened product. The treatment and utilisation of chemical engineers by industrial firms was incidentally dealt with.

Messrs. A. D. OLLÉ, F. A. COOMBS, S. E. SIBLEY, J. STEDMAN, and the Chairman also spoke.

Meeting held on Thursday, November 16th, 1916.

Mr. Loxley Meggitt in the Chair.

Mr. C. J. White, B.Sc., Teachers' College, opened a discussion upon "Science in the Schools." The teaching of science in the primary schools was unnecessary, as its place was taken by a system of instruction in nature study which began when the pupil was six years of age. The course had for its object the building up of a habit of enquiry, and the method of teaching rather than the matter was of importance. From the developing of his powers of observation as in differences of form, the scholar was gradually led up to the study of natural phenomena associated with the growth of plants. At the age of thirteen or fourteen he began to receive some instruction in elementary physics by means of simple experiments in the action of heat, water, pressure, and so on.

Mr. F. W. Carpenter, M.A., Sydney Grammar School, dealt with the science education of boys from fourteen years in the secondary schools. He would like to see a greater latitude in the school curriculum, so that useful training might not be set aside for work that will pay in examinations. Too much attention is paid to examination work in which 5% of the bright boys are specially catered for, while the remaining 95% suffer more or less. The schools should develop a scientific way of thinking and give a good all-round knowledge of fundamental facts. This would be greatly enhanced were the fundamental sciences of physics and chemistry made compulsory in the matriculation examinations of the University. The tendency at present is to demand more science in the schools, and to meet this more good teachers must be forthcoming. This however, will be impossible, unless the "plums" of teaching are open to men with good scientific ability. The head masters of our schools are chosen for their classical rather than for their scientific attainments.

Mr. J. Nangle, Superintendent of Technical Education, pointed out that from the time the boy left the primary school at fourteen, until he became an apprentice at sixteen there was a hiatus of two years, during which he had lost much of what he had learnt at school, but, worse than that, he had lost the habit of study. He suggested a compulsory partial school attendance from fourteen to sixteen years.

The discussion was continued by Messrs. A. J. Sach, A. B. Hector, C. C. Tucker, Prof. Cooke, Dr. J. B. Cleland, Dr. G. Harker and Dr. R. K. Murphy.

Meeting held on Thursday, December 14th, 1916.

Mr. Loxley Meggitt in the Chair.

Mr. S. H. Smith, Inspector of Continuation Schools, described the departmental methods for scholars in continuation schools.

Dr. Greig-Smith spoke of the value of science in benefiting the industries, and of its importance in our daily lives. But science had not the status which it should have and this was largely due to the University, our highest educational authority, classing the fundamental sciences of physics and chemistry as optional subjects for the matriculation examination, while less important subjects, such as Latin, had the definite status of being compulsory.

The discussion was continued by Messrs. G. P. Darnell-Smith, R. W. Challinor, A. B. Hector, A. J. Sach, F. W. Carpenter and A. D. Ollè.

As a result of the discussion, the Section recommended that the Council of the Society should consider the advisability of communicating with the Senate of the University with the object of making the fundamental sciences of physics and chemistry compulsory subjects in the matriculation examinations.

Mr. James Nangle read a paper upon the Technical Training of Apprentices, in which he showed how the instruction at the Technical College was adapted to make the apprentice a more efficient craftsman. He was watched and tested throughout his course and his work had always a technical bearing as regards his own particular trade. The craftsman could in time work up to the University standard.

Following some remarks by Mr. G. P. Darnell-Smith, a committee was appointed to consider the question of suggesting to the Government the advisability of making attendance at the evening school on one or more evenings a week, compulsory for boys between the ages of fourteen and sixteen years.

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