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OF

NEW SOUTH WALES

FOR

1900.

(INCORPORATED 1881.)

VOL. XXXIV.

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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 the Queen, it assumed its present title, and was incorporated by Act of the Parliament of New South Wales in 1881.

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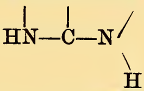
Authors of papers desiring illustrations are advised to consult the editors (Honorary Secretaries) before preparing their drawings. Unless otherwise specially permitted, such drawings should be carefully executed to a large scale on smooth white Bristol board in intensely black Indian ink; so as to admit 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.

CORRIGENDA.

Page 18, line 19 from the top: place the H in this line of the formula on to the next lower line and a little below the line, thus:—



Page 23, line 15 from the top, for 'a,' read '*an*.'
„ 23, line 19 from the top, insert the foot-note number, '[1].'
„ 28, second line from the bottom, for 'Beyerinck,' read '*Bejerinck*.'
„ 29, fifth line from the bottom, for 'years,' read '*years*'.'
„ 38, Formula (3), substitute p for q, as index of the second quantity in brackets, in the B term.
„ 43, Formula (19), the z in Az should be a suffix.
„ 44, Prop. (e), interpolate 'two' between 'the' and 'positive.'
„ 59, Table IX , put A after 7 in the second line of formulæ.
„ 61, Formula (51), the index of k should be r, not p.
„ 64, Table XI., the bracket is omitted before aA.
„ 118, Note on an Obsidian "Bomb" from N.S.W., 'with Plate vi.' omitted.
„ 149, for 'ogui,' read '*ogni*,'
„ 181, for 'toiles,' read '*étoiles*.'
„ 263, insert after 'and,' and before 'camped' on line 2, 'one of us [R. H. Mathews] having.'
„ 289 and 291, for 'E. cneroifolia,' read '*E. cneorifolia*.'

PUBLICATIONS.

Transactions of the Philosophical Society, N.S.W., 1862-5, pp. 374, out of print.

Vol.	I.	Transactions of the Royal Society, N.S.W.,	1867,	pp. 83,	,,
,,	II.	,, ,, ,, ,, ,,	1868,	,, 120,	,,
,,	III.	,, ,, ,, ,, ,,	1869,	,, 173,	,,
,,	IV.	,, ,, ,, ,, ,,	1870,	,, 106,	,,
,,	V.	,, ,, ,, ,, ,,	1871,	,, 72,	,,
,,	VI.	,, ,, ,, ,, ,,	1872,	,, 123,	,,
,,	VII.	,, ,, ,, ,, ,,	1873,	,, 182,	,,
,,	VIII.	,, ,, ,, ,, ,,	1874,	,, 116,	,,
,,	IX.	,, ,, ,, ,, ,,	1875,	,, 235,	,,
,,	X.	Journal and Proceedings ,, ,,	1876,	,, 333,	,,
,,	XI.	,, ,, ,, ,, ,,	1877,	,, 305,	,,
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,,	XXXIV.	,, ,, ,, ,, ,,	1900,	,, 484,	,, 10s. 6d.

CONTENTS.

VOLUME XXXIV.

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1891	P 1	How, William F., M. Inst. C.E., M. I. Mech. E., Wh. Sc., Mutual Life Buildings, George-street.
1877		Hume, J. K., 'Beulah,' Campbelltown.
1894	P 2	Hunt, Henry A., F. R. Met. Soc., Second Meteorological Assistant, Sydney Observatory.
1891		Jamieson, Sydney, B.A., M.B., M.R.C.S., L.R.C.P., 198 Liverpool-street, Hyde Park.
1900		Jarman, Arthur, A.R.S.M., Demonstrator, University of Sydney.
1884		Jenkins, Edward Johnstone, M.A., M.D. *Oxon.*, M.R.C.P., M.R.C.S., L.S.A. *Lond.*, 213 Macquarie-street, North.
1887		Jones, George Mander, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 'Viwa,' Burlington Road, Homebush.
1884		Jones, Llewellyn Charles Russell, Solicitor, Sydney Chambers, 130 Pitt-street.
1867		Jones, P. Sydney, M.D. *Lond.*, F.R.C.S. *Eng.*, 16 College-street, Hyde Park; p.r. 'Llandilo,' Boulevard, Strathfield.
1876		Jones, Richard Theophilus, M.D. *Syd.*, L.R.C.P. *Edin.*, 'Cader Idris,' Ashfield.
1875	P 2	Josephson, J. Percy, Assoc. M. Inst. C.E., 'Moppity,' George-street, Dulwich Hill.
1878		Joubert, Numa, Hunter's Hill.
1883		Kater, The Hon. H. E., J.P., M.L.C., Australian Club.
1873		Keele, Thomas William, M. Inst. C.E., Harbours and Rivers Branch Public Works Department.
1877		Keep, John, Broughton Hall, Leichhardt.
1894		Kelly, Walter MacDonnell, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 265 Elizabeth-street.
1887		Kent, Harry C., M.A., Bell's Chambers, 129 Pitt-street.
1898		Kerry, Charles H., J.P., 310 George-street.
1892	P 3	Kiddle, Hugh Charles, F. R. Met. Soc., Public School, Seven Oaks, Smithtown, Macleay River.
1891		King, Christopher Watkins, Assoc. M. Inst. C.E., L.S., Assistant Engineer, Harbours and Rivers Department, Newcastle.
1874		King, The Hon. Phillip G., M.L.C., 'Banksia,' William-street, Double Bay.
1896		King, Kelso, 120 Pitt-street.
1892		Kirkcaldie, David, Commissioner, New South Wales Government Railways, Sydney.
1878		Knaggs, Samuel T., M.D. *Aberdeen*, F.R.C.S. *Irel.*, 5 Lyons' Terrace, Hyde Park.
1881	P 13	Knibbs, G. H., F.R.A.S., Lecturer in Surveying, University of Sydney; p.r. 'Avoca House,' Denison Road, Petersham. *Hon. Secretary.*
1877		Knox, Edward W., 'Rona,' Bellevue Hill, Rose Bay.
1878		Kyngdon, F. B., F.R.M.S., *Lond.*, Deanery Cottage, Bowral.

Elected		
1874		Lenehan, Henry Alfred, F.R.A.S., Sydney Observatory.
1883		Lingen, J. T., M.A. *Cantab.*, 167 Phillip-street.
1901		Little, Robert, 'The Hermitage,' Double Bay.
1872	P 50	Liversidge, Archibald, M.A. *Cantab.*, LL.D., F.R.S., Hon. F.R.S. *Edin.*; Assoc. Roy. Sch. Mines, *Lond.;* F.C.S., F.G.S., F.R.G.S.; Fel. Inst. Chem. of Gt. Brit. and Irel.; Hon. Fel. Roy. Historical Soc. *Lond.*; Mem. Phy. Soc., *Lond.;* Mineralogical Society, *Lond*; Edin. Geol. Soc.; Mineralogical Society, *France;* Corr. Mem. Edin. Geol. Soc.; New York Acad. of Sciences; Roy. Soc., *Tas.;* Roy. Soc., *Queensland;* Senckenberg Institute, *Frankfurt;* Society d' Acclimat., *Mauritius;* Foreign Corr. Indiana Acad. of Sciences; Hon. Mem. Roy. Soc., *Vict.;* N. Z. Institute; K. Leop. Carol. Acad., *Halle a/s;* Professor of Chemistry in the University of Sydney, The University, Glebe; p.r. 'The Octagon,' St. Mark's Road, Darling Point. *President.*
1878		Low, Hamilton, 'Lillington,' Cambridge-street, Stanmore.
1892		MacCarthy, Charles W., M.D., F.R.C.S. *Irel.*; 223 Elizabeth-street, Hyde Park.
1884		MacCormick, Alexander, M.D., C.M. *Edin.*, M.R.C.S. *Eng.*, 125 Macquarie-street, North.
1887		MacCulloch, Stanhope H., M.B., C.M. *Edin.*, 24 College-street.
1874		M'Cutcheon, John Warner, Assayer to the Sydney Branch of the Royal Mint.
1892		McDonagh, John M., B.A., M.D., M.R.C.P. *Lond.*, F.R.C.S. *Irel.*, 173 Macquarie-street. North.
1897		MacDonald, C. A., C.E., 63 Pitt-street.
1878		MacDonald, Ebenezer, J.P., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1868		MacDonnell, William J., F.R.A.S., 114A Pitt-street.
1877		McDouall, Herbert Chrichton, M.R.C.S. *Eng.*, L.R.C.P. *Lond.*, D.P.H. *Camb.*, Hospital for Insane, Callan Park, Rozelle.
1900		McKay, G. A., Chief Mining Surveyor, Department of Mines, Sydney.
1891		McKay, R. T., L.S., Sewerage Construction Branch, Public Works Department.
1893		McKay, William J. Stewart, B.Sc., M.B., Ch.M., Cambridge-street, Stanmore.
1876		Mackellar, The Hon. Charles Kinnaird, M.L.C., M.B., C.M. *Glas.*, Equitable Building, George-street.
1876		Mackenzie, Rev. P. F., The Manse, Johnston-st., Annandale.
1880	P 6	M'Kinney, Hugh Giffin, M.E. Roy. Univ. *Irel.*, M. Inst. C.E., 'Dilkhusha,' Fuller's Road, Chatswood.
1876		MacLaurin, The Hon. Henry Norman, M.L.C., M.A., M.D. *Edin.*, L.R.C.S. *Edin.*, LL.D. Univ. *St. Andrews*, 155 Macquarie-st.
1894		McMillan, Sir William, 'Logan Brae,' Waverley.
1900		MacTaggart, A. H., D.D.S., *Phil.* U.S.A., King and Phillip-sts.
1900		MacTaggart, J. N. C., B.E. *Syd.*, 16 Lugar-street, Waverley.
1882	P 1	Madsen, Hans. F., 'Hesselmed House,' Queen-st., Newtown.
1883	P 6	Maiden, J. Henry, J.P., F.L.S., Corr. Memb. Pharm. Soc. Gt. Brit.; of the National Agric. Soc., Chili; Hon. Memb. Royal Netherlands Soc. (Haarlem); of the Philadelphia Coll. of Pharmacy; of the Royal Soc. of S.A.; of the Mueller Botanic Soc. of W.A.&c.; Government Botanist and Director, Botanic Gardens, Sydney. *Hon. Secretary.*

Elected		
1880	P 1	Manfred, Edmund C., Montague-street, Goulburn.
1877		Mann, John F., 'Kerepunu,' Neutral Bay.
1879		Manning, Frederic Norton, M.D. Univ. *St. And.*, M.R.C.S. *Eng.*, L.S.A. *Lond.*, Australian Club.
1869		Mansfield, G. Allen, Martin Chambers, Moore-street.
1897		Marden, John, B.A., M.A., LL.B., Univ. *Melb.*, LL.D. Univ. *Syd.*, Principal, Presbyterian Ladies' College, Sydney.
1875	P 10	Mathews, Robert Hamilton, L.S., Assoc. Mem. Soc. d'Anthrop. de Paris; Cor. Mem. Anthrop. Soc., Washington, U.S.A.; Cor. Mem, Roy. Geog. Soc. Aust., Queensland; 'Carcuron,' Hassall-street, Parramatta.
1888		Megginson, A. M., M.B., C.M. *Edin*,, 147 Elizabeth-street.
1896	P 5	Merfield, Charles J., F.R.A.S., Railway Construction Branch, Public Works Department; p.r. 'Branville,' Green Bank-street, Marrickville.
1887		Miles, George E., L.R.C.P. *Lond*, M.R.C.S. *Eng.*, The Hospital, Rydalmere, Near Parramatta.
1873		Milford, F., M.D. *Heidelberg*, M.R.C.S. *Eng.*, 231 Elizabeth-st.
1882		Milson, James, 'Elamang,' North Shore.
1889	P 3	Mingaye, John C. H., F.C.S., F.I.C., Assayer and Analyst to the Department of Mines, Government Metallurgical Works, Clyde; p.r. Campbell-street, Parramatta.
1856	P 7	Moore, Charles, F.L.S., Australian Club; p.r. 6 Queen-street, Woollahra. *Vice-President.*
1879		Moore, Frederick H., Illawarra Coal Co., Gresham-street.
1875		Moir, James, 58 Margaret-street.
1877	P 1	Morris, William, Fel. Fac. Phys. and Surg. *Glas.*, F.R.M.S. *Lond.*, c/o Mrs. C. H. Humphrey, 'Luscombe,' Livingstone-street, Burwood.
1882		Moss, Sydney, 'Kaloola,' Kiribilli Point, North Shore.
1877		‡Mullens, Josiah, F.R.G.S., 'Tenilba,' Burwood.
1879		Mullins, John Francis Lane, M.A. *Syd*,, 'Killountan,' Challis Avenue, Pott's Point.
1887		Munro, William John, M.B., C.M., M.D. *Edin.*, M.R.C.S. *Eng.*, 213 Macquarie-street; p.r. Forest House, 182 Pyrmont Bridge Road, Forest Lodge.
1898		Murray, Lee, M.C.E. *Melb.*, Assoc. M. Inst. C.E., 16 O'Connell-street.
1876		Myles, Charles Henry, 'Dingadee,' Burwood.
1893		Nangle, James, Architect, Australia-street, Newtown.
1891		‡Noble, Edwald George, 21 Norfolk-street, Paddington.
1873		Norton, The Hon. James, M.L.C., LL.D, Solicitor, 2 O'Connell-street; p.r. 'Ecclesbourne,' Double Bay.
1893		Noyes, Edward, C.E., c/o Messrs. Noyes Bros., 310 O'Connell-st.
1888		O'Neill, G. Lamb, M.B., C.M. *Edin.*, 221 Elizabeth-street.
1896		Onslow, Lt. Col. James William Macarthur, Camden Park, Menangle.
1875		O'Reilly, W. W. J., M.D., M.Ch. Q. Univ. *Irel.*, M.R.C.S. *Eng.*, 197 Liverpool-street.

Elected		
1883		Osborne, Ben. M., J.P., 'Hopewood,' Bowral.
1891		Osborn, A F., Assoc. M. Inst. C.E., Public Works Department, Cowra.
1883		Palmer, Joseph, 133 Pitt-st.; p.r. Kenneth-st., Willoughby.
1878		Paterson, Hugh, 197 Liverpool-street, Hyde Park.
1899		Pearce, W., Union Club; p.r. 'Waiwera,' Cecil-st., Ashfield.
1877		Pedley, Perceval R., 227 Macquarie-street.
1899		Perkins, E. W., 122 Pitt-street.
1877		Perkins, Henry A., c/o Perpetual Trustee Co. Ld., 2 Spring-st.
1899		Petersen, T. T., Associate Sydney Institute of Public Accountants, 85 Womerah Avenue.
1876		Pickburn, Thomas, M.D., C.M. *Aberdeen*, M.R.C.S. *Eng.*, 22 College-street.
1879	P 5	Pittman, Edward F., Assoc. R S.M., L.S., Government Geologist, Department of Mines.
1899		Plummer, John, Northwood, Lane Cove River.
1881		Poate, Frederick, District Surveyor, Moree.
1879		Pockley, Thomas F. G., Commercial Bank, Singleton.
1887		Pollock, James Arthur, B.E. Roy. Univ. *Irel*, B.Sc., *Syd.*, Professor of Physics, Sydney University.
1891		Poole, William Junr., Assoc. M. Inst. C.E, 87 Pitt-street, Redfern, or Palace Hotel, Broken Hill.
1896		Pope, Roland James, B.A. *Syd.*, M.D., C.M., F.R.C.S. *Edin.*, Ophthalmic Surgeon, 235 Macquarie-street.
1897	P 1	Portus, A. B., Assoc. M. Inst. C.E., Superintendent of Dredges, Public Works Department.
1893		Purser, Cecil, B.A., M.B., Ch.M. *Syd.*, 'Valdemar,' Boulevard, Petersham.
1876		Quaife, Frederick H., M.A., M.D., Master of Snrgery *Glas.*, 'Hughenden,' 14 Queen-street, Woollahra.
1899	P 1	Rae, J. L. C., Manager Sydney Harbour Collieries Ltd.; p.r. 'Strathmore,' Ewenton-street, Balmain.
1900		Ralston, J. T., Solicitor, 86 Pitt-street.
1865	P 1	‡Ramsay, Edward P., LL.D. Univ. St. And., F.R.S.E., F.L.S., 8 Palace-street, Petersham.
1881	P 3	Rennie, Edward H., M.A. *Syd.*, D. Sc. *Lond.*, Professor of Chemistry, University, Adelaide.
1890		Rennie, George E., B.A. *Syd.*, M.D. *Lond.*, M.R.C.S. *Eng.*, 40 College-street, Hyde Park.
1870		Renwick, The Hon. Sir Arthur, Knt., M.L.C., B.A. *Syd.*, M.A., F.R.C.S. *Edin.*, 295 Elizabeth-street.
1893	P 1	Roberts, W. S. de Lisle, C.E., Sewerage Branch, Public Works Department, Phillip-street.
1885		Rolleston, John C., Assoc. M. Inst. C.E., Harbours and Rivers Branch, Public Works Department.
1897		Ronaldson, James Henry, Mining Engineer, 32 Macleay-st., Pott's Point.

Elected		
1892		Rossbach, William, Assoc. M. Inst. C.E., Chief Draftsman, Harbours and Rivers Branch, Public Works Department.
1884		Ross, Chisholm, M.D. *Syd.*, M.B., C.M. *Edin.*, Hospital for the Insane, Callan Park, Rozelle.
1895		Ross, Colin John, B.Sc., B.E., Assoc. M. Inst. C.E., Borough Engineer, Town Hall, North Sydney.
1895	P 1	Ross, Herbert E., Consulting Mining Engineer, Equitable Buildings, George-street.
1882		Rothe, W. H., Colonial Sugar Co., O'Connell-st., and Union Club
1894		Rowney, George Henry, Assoc. M. Inst. C.E., Water and Sewerage Board, Pitt-street; p.r. 'Maryville,' Ben Boyd Road, Neutral Bay.
1864	P 65	Russell, Henry C., B.A. *Syd.*, C.M.G., F.R.S., F.R.A.S., F.R. Met. Soc., Hon. Memb. Roy. Soc., South Australia, Government Astronomer, Sydney Observatory.
1897		Russell, Harry Ambrose, B.A., Solicitor, c/o Messrs. Sly and Russell, 379*b* George-street; p.r. 'Mahuru,' Milton-street, Ashfield.
1883		Rygate, Philip W., M.A., B.E. *Syd.*, Assoc. M. Inst. C.E., Phœnix Chambers, 158 Pitt-street.
1892		Schmidlin, F., 44 Elizabeth-street, Sydney.
1892	P 1	Schofield, James Alexander, F.C.S., A.R.S.M., University, Sydney.
1856	P 1	‡Scott, Rev. William, M.A. *Cantab.*, Kurrajong Heights.
1886		Scott, Walter, M.A. *Oxon.*, Professor of Greek, University, Sydney.
1877	P 4	Selfe, Norman, M. Inst. C.E., M. I. Mech. E., Victoria Chambers, 279 George-street.
1890	P 1	Sellors, R. P., B.A. *Syd.*, F.R.A.S., Trigonometrical Branch, Lands Department.
1891		Shaw, Percy William, Assoc. M. Inst. C.E., Resident Engineer for Tramway Construction; p.r. 'Epcombs,' Miller-street, North Sydney.
1883	P 3	Shellshear, Walter, M. Inst. C.E., Divisional Engineer, Railway Department, Goulburn.
1900		Simpson, R. C., Demonstrator of Physics, Sydney University.
1882		Sinclair, Eric, M.D., C.M. Univ. *Glas.*, Hospital for the Insane, Gladesville.
1893		Sinclair, Russell, M. I. Mech. E. &c. Consulting Engineer, 97 Pitt-st.
1884		Skirving, Robert Scot, M.B., C.M. *Edin.*, Elizabeth-street, Hyde Park.
1891	P 1	Smail, J. M., M. Inst. C.E., Chief Engineer, Metropolitan Board of Water Supply and Sewerage, 341 Pitt-street.
1893	P 22	Smith, Henry G., F.C.S., Technological Museum, Sydney.
1874	P 1	‡Smith, John McGarvie, 89 Denison-street, Woollahra.
1875		Smith, Robert, M.A. *Syd.*, Marlborough Chambers, 2 O'Connell street.
1899		Smith, R. Greig, M.Sc. *Dun.*, B.Sc. *Edin.*, Macleay Bacteriologist, 'Otterburn,' Double Bay.
1898		Smith, S. Hague, Colonial Mutual Fire Insurance Co., 78 Pitt-st.
1886		Smith, Walter Alexander, M. Inst. C.E., Roads, Bridges and Sewerage Branch, Public Works Department, N. Sydney.

Elected		
1896		Smyth, Selwood, Harbours and Rivers Branch, Public Works Department.
1896		Spencer, Walter, M.D. *Brux.*, 13 Edgeware Road, Enmore.
1892	P 1	Statham, Edwyn Joseph, Assoc. M. Inst. C.E, Cumberland Heights, Parramatta.
1889		Stephen, Arthur Winbourn, L S., 86 Pitt-street.
1879		‡Stephen, The Hon. Septimus A., M.L.C., 12—14 O'Connell-st.
1891		Stilwell, A. W., Assoc. M. Inst. C.E., Public Works Depart., Sydney.
1900		Stewart, J. D., M.R.C.V.S., Government Veterinary Surgeon, Department of Mines and Agriculture; p.r. Cowper-street, Randwick.
1883	P 3	Stuart, T. P. Anderson, M.D., LL.D. Univ. *Edin.*, Professor of Physiology, University of Sydney; p.r. 'Lincluden,' Fairfax Road, Double Bay.
1892		Sturt, Clifton, L.R.C.P., L.R.C.S. *Edin.*, L.F.P.S. *Glas.*, 'Wistaria,' Bulli.
1893		‡Taylor, James, B. Sc., A.R.S.M., Adderton Road, Dundas.
1899		Teece, R., F.I.A., F.F.A., Actuary, A.M.P. Society, 87 Pitt-st.
1861	P 19	Tebbutt, John, F.R.A.S., Private Observatory, The Peninsula, Windsor, New South Wales.
1896		Thom, James Campbell, Solicitor for Railways; p.r. 'Camelot,' Forest Road, Bexley.
1896		Thom, John Stuart, Solicitor, Athenæum Chambers, 11 Castlereagh-street; p.r. Wollongong Road, Arncliffe.
1878		Thomas, F. J., Hunter River N.S.N. Co., Sussex-street.
1879		Thomson, Dugald, M.L.A., 'Wyreepi,' Milson's Point.
1875		Thompson, Joseph, 159 Brougham-street, Woolloomooloo.
1885	P 2	Thompson, John Ashburton, M.D. *Brux.*, D.P.H. *Camb.*, M R.C.S. *Eng.*, Health Department, Macquarie-street.
1896		Thompson, Capt. A. J. Onslow, Camden Park, Menangle
1898		Thow, Sydney, General Manager, The Hercules Gold and Silver Mining Co., Mount Read, Tasmania.
1892		Thow, William, M. Inst. C.E., M. I. Mech. E., Locomotive Department, Eveleigh.
1886	P 5	Threlfall, Richard, M.A. *Cantab.*
1888		Thring, Edward T., F.R.C.S. *Eng.*, L.R.C.P. *Lond.*, 225 Macquarie-street.
1876		Tibbits, Walter Hugh, M.R.C.S. *Eng.*, Dubbo.
1894		Tidswell, Frank, M.B., M.Ch., D.P.H., Health Department, Sydney.
1876		Toohey, The Hon. J. T., M.L.C., 'Moira,' Burwood.
1894		Tooth, Arthur W., Kent Brewery.
1873	P 1	Trebeck, Prosper N., J.P., 2 O'Connell-street.
1879		Trebeck, P. C., F.R. Met. Soc., 2 O'Connell-street.
1877		‡Tucker, G. A., c/o Perpetual Trustee Co. Ld., 2 Spring-street.
1900		Turner, Basil W., A.R.S.M., F.C.S., 14 Castlereagh-street.
1883		Vause, Arthur John, M.B., C.M. *Edin.*, 'Bay View House,' Tempe.
1884		Verde, Capitaine Felice, Ing. Cav., viâ Fazio 2, Spezia, Italy.
1896		Verdon, Arthur, Australian Club.
1890		Vicars, James, M.C.E., M. Inst. C.E., City Surveyor, Adelaide.

Elected		
1892		Vickery, George B., 78 Pitt-street.
1876		Voss, Houlton H., J.P., c/o Perpetual Trustee Company Ld., 2 Spring-street.
1898		Wade, Leslie A. B., C.E., Department of Public Works.
1879		Walker, H. O., Commercial Union Assurance Co., Pitt-street.
1899		‡Walker, J. T., 'Rosemont,' Ocean-street, Woollahra.
1900		Wallach, Bernhard, B.E. *Syd.*, Electrical Engineer, 53 Boyce-street, Glebe Point.
1891		Walsh, Henry Deane, B.E., T.C. *Dub.*, M. Inst. C.E., Engineer-in-Chief, Harbour Trust, Sydney.
1896		Walsh, C. R., Prothonotary, Supreme Court.
1895		Ward, James Wenman, 1 Union Lane off George-street.
1898		Wark, William, 9 Macquarie Place; p.r. Kurrajong Heights.
1877		Warren, William Edward, B.A., M.D., M.Ch., Queen's University *Irel.*, M.D. *Syd.*, 263 Elizabeth-street, Sydney.
1883	P 11	Warren, W. H., Wh. Sc., M. Inst. C.E., Professor of Engineering, University of Sydney.
1876		Watkins, John Leo, B.A. *Cantab.*, M.A. *Syd.*, Parliamentary Draftsman, Attorney General's Department, 5 Richmond Terrace, Domain.
1876		Watson, C. Russell, M.R.C.S. *Eng.*, 'Woodbine,' Erskineville Road, Newtown.
1897		Webb, Fredk. William, C.M.G., J.P., Clerk of the Legislative Assembly; p r. 'Livadia,' Chandos-street, Ashfield.
1866		§Webster, A. S., c/o Permanent Trustee Co. of N.S. Wales Ld., 17 O'Connell-street.
1892		Webster, James Philip, Assoc. M. Inst. C. E., L. S., *New Zealand*, Borough Engineer, Town Hall, Marrickville.
1867		Weigall, Albert Bythesea, B A. *Oxon.*, M.A. *Syd.*, Head Master, Sydney Grammar School, College-street.
1881		‡Wesley, W. H.
1878		Westgarth, G. C., Bond-street; p.r. 52 Elizabeth Bay Road.
1879		‡Whitfeld, Lewis, M.A. *Syd.*, 'Oaklands,' Edgecliffe Road, Edgecliffe.
1892		White, Harold Pogson, Assistant Assayer and Analyst, Dept. of Mines; p.r. 'Quantox,' Park Road, Auburn.
1877		‡White, Rev. W. Moore, A.M., LL.D., T.C.D.
1874		White, Rev. James S., M.A., LL.D. *Syd.*, 'Gowrie,' Singleton.
1883		Wilkinson, W. Camac, M.D. *Lond.*, M.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 207 Macquarie-street.
1876		Williams, Percy Edward, Government Savings Bank, Sydney.
1878		Wilshire, James Thompsoa, F.L.S., F.R.H.S., J.P., 'Coolooli,' off Ranger's Road, Shell Cove, Neutral Bay.
1879		Wilshire, F. R., P.M., Penrith.
1891		Wilson, Robert Archibald, M.D. *Glas.*, Mast. Surg. *Glas.*, 2 Booth-street, Balmain.
1890		Wilson, James T., M.B., Mast. Surg. Univ. *Edin.*, Professor of Anatomy, University of Sydney.
1873		Wood, Harrie, J.P., 10 Bligh-street; p.r. 54 Darlinghurst Road.
1891		Wood, Percy Moore, L.R.C.P. *Lond.*, M.R.C.S. *Eng.*, 'Redcliffe,' Liverpool Road, Ashfield.
1899		Woolnough, W. G., B. Sc., Demonstrator in Geology, Sydney University.

Elected		
1876	P 1	Woolrych, F. B. W., 'Verner,' Grosvenor-street, Croydon.
1872		Wright, Horatio G. A., M.R.C.S. *Eng.*, L.S.A. *Lond.*, 15 York-st., Wynyard Square. *Hon. Treasurer.*
1893		Wright, John, C.E., Toxteth-street, Glebe Point.
1879		Young, John, 'Kentville,' Johnston-street, Leichhardt.

Honorary Members.

Limited to Thirty.

M.—Recipients of the Clarke Medal.

1878		Agnew, Sir James, K.C.M.G., M.D., Royal Society of Tasmania, Hobart.
1875		Bernays, Lewis A., C.M.G., F.L.S., Brisbane.
1900		Crookes, Sir William, F.R.S., 7 Kensington Park Gardens, London W.
1875	M	Ellery, Robert L. J., F.R.S., F.R.A.S., late Government Astronomer of Victoria, Melbourne.
1887		Foster, Sir Michael, M.D., F.R.S., Professor of Physiology, University of Cambridge.
1875	M	Gregory, The Hon. Augustus Charles, C.M.G., M.L.C., F.R.G.S., Brisbane.
1875	P 1 M	Hector, Sir James, K.C.M.G., M.D., F.R.S., Director of the Colonial Museum and Geological Survey of New Zealand, Wellington, N.Z.
1880	M	Hooker, Sir Joseph Dalton, K.C.S.I., M.D., C.B., F.R.S., &c., late Director of the Royal Gardens, Kew.
1892		Huggins, Sir William, K.C.B., D.C.L., LL.D., F.R.S., &c., 90 Upper Tulse Hill, London, S.W.
1888	P 1 M	Hutton, Captain Frederick Wollaston, F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.
1894		Spencer, W. Baldwin, M.A., Professor of Biology, University of Melbourne.
1888	P 3 M	Tate, Ralph, F.G.S., F.L.S., Professor of Natural Science, University, Adelaide, South Australia.
1900	M	Thiselton-Dyer, Sir William Turner, K.C.M.G., C.I.E., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.
1895		Wallace, Alfred Russel, D.C.L. *Oxon.*, LL.D. *Dublin*, F.R.S., Parkstone, Dorset.

Obituary.

1900.

Corresponding Member.

1886		Marcou, Professor Jules. [Died 17 April, 1898.]

Ordinary Members.

1875		Belisario, Dr. John.
1875		Knox, Sir Edward.
1890		Neill, Dr. L. E. F.
1879		Shepard, A. D.
1882		Shewen, Dr. Alfred.
1882		Steel, Dr. John,
1888		White, Hon. R. H. D.
1898		Wildridge, John.

AWARDS OF THE CLARKE MEDAL.

Established in memory of

THE LATE REVD. W. B. CLARKE, M.A., F.R.S., F.G.S., &c.,

Vice-President from 1866 *to* 1878.

To be awarded from time to time for meritorious contributions to the Geology, Mineralogy, or Natural History of Australia.

1878 Professor Sir Richard Owen, K.C.B., F.R.S., Hampton Court.

1879 George Bentham, C.M.G., F.R.S., The Royal Gardens, Kew.

1880 Professor Huxley, F.R.S., The Royal School of Mines, London, 4 Marlborough Place, Abbey Road, N.W.

1881 Professor F. M'Coy, F.R.S., F.G.S., The University of Melbourne.

1882 Professor James Dwight Dana, LL.D., Yale College, New Haven, Conn., United States of America.

1883 Baron Ferdinand von Mueller, K.C.M.G., M.D., PH.D., F.R.S., F.L.S., Government Botanist, Melbourne.

1884 Alfred R. C. Selwyn, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Canada, Ottawa.

1885 Sir Joseph Dalton Hooker, K.C.S.I., C.B., M.D., D.C.L., LL.D., &c., late Director of the Royal Gardens, Kew.

1886 Professor L. G. De Koninck, M.D., University of Liège, Belgium.

1887 Sir James Hector, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand, Wellington, N.Z.

1888 Rev. Julian E. Tenison-Woods, F.G.S., F.L.S., Sydney.

1889 Robert Lewis John Ellery, F.R.S., F.R.A.S., Government Astronomer of Victoria, Melbourne.

1890 George Bennett, M.D. Univ. *Glas.*, F.R.C.S. *Eng.*, F.L.S., F.Z.S., William Street, Sydney.

1891 Captain Frederick Wollaston Hutton, F.R.S., F.G.S., Curator, Canterbury Museum, Christchurch, New Zealand.

1892 Sir William Turner Thiselton Dyer, K.C.M.G., C.I.E., M.A., B.Sc., F.R.S., F.L.S., Director, Royal Gardens, Kew.

1893 Professor Ralph Tate, F.L.S., F.G.S., University, Adelaide, S.A.

1895 Robert Logan Jack, F.G.S., F.R.G.S., Government Geologist, Brisbane, Queensland.

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

1896 Hon. Augustus Charles Gregory, C.M.G., M.L.C., F.R.G.S., Brisbane.

1900 Sir John Murray, Challenger Lodge, Wardie, Edinburgh.

AWARDS OF THE SOCIETY'S MEDAL AND MONEY PRIZE.

The Royal Society of New South Wales offers its Medal and Money Prize for the best communication (provided it be of sufficient merit) containing the results of original research or observation upon various subjects published annually.

Money Prize of £25.

1882 John Fraser, B.A., West Maitland, for paper on 'The Aborigines of New South Wales.'

1882 Andrew Ross, M.D., Molong, for paper on the 'Influence of the Australian climate and pastures upon the growth of wool.'

The Society's Bronze Medal and £25.

1884 W. E. Abbott, Wingen, for paper on 'Water supply in the Interior of New South Wales.'

1886 S. H. Cox, F.G.S., F.C.S., Sydney, for paper on 'The Tin deposits of New South Wales.

1887 Jonathan Seaver, F.G.S., Sydney, for paper on 'Origin and mode of occurrence of gold-bearing veins and of the associated Minerals.

1888 Rev. J. E. Tenison-Woods, F.G.S., F.L.S., Sydney, for paper on 'The Anatomy and Life-history of Mollusca peculiar to Australia.'

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

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

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

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

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

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

1895 C. J. Martin, B.Sc., M.B. *Lond*, Sydney, for paper on 'The physiological action of the venom of the Australian black snake (*Pseudechis porphyriacus*).

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

ANNIVERSARY ADDRESS.

By William M. Hamlet, F.I.C., F.C.S.,

Government Analyst.

[*Delivered to the Royal Society of N. S. Wales, May 2, 1900.*]

"The fragmentary produce of much toil,
In a dim heap, fact and surmise together
Confusedly massed as when acquired.

Paracelsus.

The conception of the world, as a great kosmos or order, is the primary condition of human progress. In the industrial arts, in the rules of health, the methods of healing, the preparation of food, in morals, in politics every advance is an application of past experience to new circumstances, in accordance with an observed order of Nature. Philosophy consists in the conscious recognition of this method, and in the systematic use of it for the complete guidance of life.

Hierokles.

The honour you conferred upon me in electing me as your President, brings with it its own obligations and the consciousness of the inadequacy of any efforts of mine to fulfil them in a manner worthy of the Royal Society.

There comes also the important question as to what rightly constitutes the subject-matter of the Presidential Address: whether it should be a retrospect of the scientific work of the year, an announcement of something new in science, a history of science brought to date, a discussion of some "burning question" or merely a dissertation on some particular subject passing in the mind of the President. At the outset I frankly confess my inability to satisfy you with some of these good things, and I fall back upon the latter course and proceed to unburden myself of some thoughts that have come, unbidden perhaps, to my mind during the year. Obviously the doings of the Society during the period demands first attention, therefore, in common with the practice of my predecessors, I address you on the status and condition of the Society, and afterwards discuss certain topics that I think will not be without interest to you.

Roll of members.—The number of members on the roll on the 30th April, 1899, was three hundred and fifty-seven. Thirty-two new members have been elected during the past year and four names restored to the roll, we have however lost by death six ordinary and two Honorary members, and thirteen by resignation. There is thus left a total of three hundred and seventy-four on April 30th, 1900.

Obituary.—The following is a list of members who have died during the year 1899 :—

Honorary Members:

Elected 1895, Bunsen, Professor Robert Wilhelm.
,, 1875, M'Coy, Sir Frederick.

Ordinary Members.

,, 1886, Collingwood, Dr. David.
,, 1896, Elwell, P. B.
,, 1887, MacAllister, Dr. J. F.
,, 1878, Maitland, Duncan Mearns.
,, 1859, Watt, Charles.
,, 1878, Wilkinson, Rev. S.

Mr. Charles Watt left England in the *Sydney* in 1854—the first steamer that started for Australia, but after several attempts in commencing the voyage, put back and eventually came out in a sailing ship. On his arrival in the mother colony, he became interested in the manufacture of soap and candles, and afterwards, in the distillation of the shales found at Hartley Vale, on the Blue Mountains. In the absence of Professor Smith, he lectured for some time on Chemistry at the Sydney University. He practised as an Analyst in Sydney from 1870, and during the administration of Sir John Robertson he was appointed Government Analyst, a chemical laboratory being built for him on the site now occupied by the Department of Public Health, but his official connection with the Government dated back to the year 1875. Mr. Watt died at Parramatta on the 19th July, 1899.

Papers read in 1899.—During the past year the Society held eight meetings, at which the average attendance of members was 39, and of visitors 3, the following nineteen papers were read :—

1. President's Address, by G. H. Knibbs, F.R.A.S.
2. Key to Tribes and Genera of the Florideæ (Red or Purple Marine Algæ), by Richard A. Bastow. (Communicated by J. H. Maiden, F.L.S.).
3. On the metamorphosis of the young form of *Filaria Bancrofti*, Cobb, [*Filaria sanguinis hominis*, Lewis ; *Filaria nocturna*, Manson] in the body of *Culex ciliaris*, Linn., the "House Mosquito of Australia," by T. L. Bancroft, M.B.
4. Suggestions for depicting diagrammatically the character of Seasons, as regards Rainfall, and especially that of Droughts, by H. Deane, M.A., M.Inst. C.E., &c.
5. Observations on the determination of Drought-intensity, by G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney.
6. On the crystalline camphor of Eucalyptus Oil (Eudesmol), and the natural formation of Eucalyptol, by Henry G. Smith, F.C.S., Technological Museum, Sydney.
7. Divisions of some Aboriginal Tribes, Queensland, by R. H. Matthews, L.S.
8. The Initiation Ceremonies of the Aborigines of Port Stephens, N. S. Wales, by W. J. Enright, B.A. (Communicated by R. H. Matthews, L.S.).
9. Sailing Birds are dependent on Wave-power, by L. Hargrave.
10. Some applications and developments of the Prismoidal Formula, by G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney.
11. Current Papers, No. 4, by H. C. Russell, B.A., C.M.G., F.R.S.

12. Discovery of Glaciated Boulders at base of Permo-Carboniferous System, Lochinvar, N. S. Wales, by Professor T. W. E. David, B.A., F.G.S.
13. On N. S. Wales Copper Ores Containing Iodine, by Arthur Dieseldorff, M.E., Freiberg, Baden, Germany. (Communicated by A. J. Bensusan, Assoc. R.S.M., F.C.S.).
14. On the *Darwinias* of Port Jackson and their Essentials Oils, by R. T. Baker, F.L.S., Curator, and H. G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.
15. Orbit Elements Comet I., 1899 (Swift), by C. J. Merfield, F.R.A.S.
16. On the composition of N. S. Wales Labradorite and Topazes with a comparison of methods for the estimation of Fluorine, by G. Harker, B. Sc. (Communicated by Professor Liversidge, M.A., LL.D., F.R.S.)
17. On a remarkable increase of temperature after dark at Seven Oaks, Macleay River, by Hugh Charles Kiddle, F.R. Met. Soc., Public School, Seven Oaks, Macleay River.
18. Record of rock temperatures at Sydney Harbour Colliery, Birthday Shaft, Balmain, Sydney, N. S. Wales, by J. L. C. Rae, E. F. Pittman, Assoc. R.S.M. and Professor T. W. E. David, B.A., F.G.S.
19. Note on Edible Earth from Fiji, by the Hon. B. G. Corney, M.D., Professor T. W. E. David, B.A., F.G.S., and F. B. Guthrie, F.C.S.

Sectional Meetings.—The *Engineering Section* held seven meetings, at which the average attendance of members and vistors was 27 ; the following papers were read and discussed :—

1. The Annual Address to the Engineering Section, by Norman Selfe, M. Inst. C.E.
2. The Sewerage Systems of North Sydney and Double Bay, by J. Davis, M. Inst. C.E.
3. The Manufacture of Monier Pipes, by F. M. Gummow.
4. Lecture on Liquid Air, by Professor Liversidge, M.A., LL.D., F.R.S.
5. "*Le Pont Vierendeel,*" by J. I. Haycroft, M. Inst. C.E.I.

The Medical Section held four meetings at which numerous exhibits were shown, and the following papers were read and discussed :—

1. An outbreak of Dermatitis exfoliativa neonatorum, by Dr. Walter Spencer.
2. Bubonic Plague in 1141 B.C., by Frank Tidswell, M.B., and J. Adam Dick, M.D.
3. The Water Supply and Sewerage Systems of Sydney, by J. M. Smail, M. Inst. C.E.

Financial Position.—The Hon. Treasurer's Financial Statement shows that a further sum of £150 has been repaid to the Clarke Memorial Fund, and a balance of £36 14s. 5d. carried forward.

Library.—The amount expended on the Library during the past year was £128 15s. 6d., viz., £126 9s. 6d. for books and periodicals, and £2 6s. for binding. Amongst other works purchased were the collective indexes to the Transactions and Abstracts of the Chemical Society, London, from 1841 to 1892. The want of more shelving accommodation for the books is badly felt.

Exchanges.—Last year we exchanged our Journal with four hundred and fourteen kindred Societies, receiving in return two hundred and thirty-eight volumes, one thousand seven hundred and forty parts, one hundred and fifty-eight reports, one hundred and eighty-nine pamphlets. one framed photo, twenty-four mounted photos, fifteen meteorological charts, two maps, one atlas each hydrographic, and geological charts, a total of two thousand three hundred and sixty-nine publications. The following institutions have been added to the exchange list :—Naturhistorische Gesellschaft, Nuremberg; British Medical Association (N.S.W. Branch); Mount Kosciusko Observatory, N.S.W.; Bernice Pauahi Bishop Museum, Honolulu; University of Chicago Press; Maryland Geological Survey, Baltimore; Editor of the Mineral Industry, New York; American Institute of Electrical Engineers, New York.

Workers in Chemistry have not been idle during the past year, as may be seen from the list enumerated above, there having been five papers in this subject, two of which are of special interest; I refer to Nos. 6 and 14, by Mr. R. T. Baker, and Henry G. Smith, Curator and Assistant-Curator respectively of the Technological Museum of Sydney. The oils from some half dozen new species of Eucalypts have been chemically investigated by Mr. Smith, who has been successful in obtaining from these oils some important constituents. He has also contributed to this Society a paper on the chemistry of the camphor of Eucalyptus oil (eudesmol). The discovery that the little shrub found on the sand hills around Port Jackson (*Darwinia fascicularis*), yielded an oil consisting largely of geranyl acetate was also made. The presence of the important alcohol, geraniol, in this shrub in fairly large amount promises a great commercial future for this species.

Of the work and discovery published in Europe, many things of purely theoretical interest have been announced, chief among these items I would mention the solidification of hydrogen, the sterilisation of water on the large scale, the discovery of a substitute for india-rubber, which has been named 'velvril,' and the extension of the researches on nitrification by Winogradsky and Oméliansky.

The marked feature of modern chemistry is its broad comprehensiveness, embracing as it does so many separate divisions in the affairs of life, the concentration of attention necessary in any one branch of chemical research being such as to demand all the available energy on the part of the individual; hence in these times no single individual can presume to anything like a profound knowledge of the great science or even follow it in its many ramifications. I therefore affirm that it does not come within the grasp of any one man to master the vast accumulation of facts now forming the science of chemistry, and the far-reaching applications and multifarous adaptations of the science. On this account specialism is yearly becoming more pronounced, and the old dual divisions of the science into Organic and Inorganic, become extended to—Systematic or descriptive chemistry; systematic studies of chain molecules, variants of carbon and nitrogen; physical chemistry; mineralogical chemistry; pharmaceutical chemistry; applied metallurgical and manufacturing chemistry; physiological chemistry including its applications to pathology and biology generally; State chemistry. Caution is now more than ever needed in warning the science worker to avoid the danger he runs of falling into ruts on the highroad of Science, since the narrowing influence of specialism may, and probably does, cramp the vision, interfering with that coherent thought that sees the continuity and correlation of the Universe.

Pure Chemistry—the science dealing essentially with the constitution, properties and transformations of what we provisionally call 'matter'—co-existent throughout all time and space, presents us in imagination with a picture of our world in times so remote, that the interval between them and any historic period is greater than one can imagine or realise. The Hon. James Norton, LL.D., President of the Linnean Society, has lately given us an estimate of the age of Australia which he puts at ninety-three millions of years. Taking the period during which life has appeared on the earth as seven hundred and four millions of years, then probably one thousand millions of years will carry us back to the gaseous epoch—times when seas of liquid lava afforded footing neither for man, nor for any other living creature. Our terrestial history may thus be summarised :—

I. Cosmic epochs of molecular dissociation, when definite compounds as now revealed to our sense-organs, did not exist; epochs, for example, when silicon and oxygen could not assume the crystalline solid form we so familiarly know as quartz, forming as it does, a solid crust for a habitable earth.

II. Viscous epochs, or plastic times, when the globe began to consolidate and form its crust.

III. The long avenues of Geological Time.

IV. The succession of Palæolithic and Neolithic Ages.

V. Prehistoric ages covered by the science of Geology.

VI. Some ninety centuries of Historic Time.

I do not presume to discuss those far away fascinating epochs of gaseous kinetics when the earth began to condense from its initial glowing vapoury vortex; conditions that may be said to be, 'not yet within the range of practical crystallisation,' but, as with the wand of the magician, I pass over sundry millions of years, and come down to the earliest historic period—one opened up for us through the brilliant discoveries of the Egyptologist, who places at our disposal contemporary records unique in value. But it is hardly possible to think of Egypt and Africa without digressing for a moment or two on those activities that now dominate portions of the British Empire in the Southern Hemisphere.

That the end of so brilliant a century as the nineteenth should be marred by both war and plague, seems to me to be a humiliating blot upon the escutcheon of our human progress; for a generation or more peace and progress have gone hand in hand, until we believed it to be almost impossible that events such as those we now witness could have happened, "considering," as Carlyle says, "our present advanced state of culture, and how the torch of science has now been brandished and borne about with more or less effect." Such events are ugly survivals, not of the fittest, but of the undesirable, to be deplored by all thoughtful men, most of all by the man of science who has long contemplated their entire abolition from this planet. We have colonised this great continent of Australia, but there yet exists among us all the defects of the old regime, while the barrier of grim ignorance bars the way towards that true progress begotten of enlightment, whose reward is virtue and length of days. Here, so far as disease is concerned, I am reminded of the words of the illustrious Pasteur, "Il est au pouvoir de l'homme de faire disparaitre de la surface du globe les maladies parasitaires."

The ideal and as yet unattained Utopia—the City of Health depicted by Benjamin Ward Richardson—seems still very far off and will remain but the dream of the enthusiast, until the lessons of elementary sanitation shall have been learned and taken to heart by the masses of the people. This reproach on our vaunted civilisation must ever remain whilst science teaching is regarded as something dry and curious, apart and remote from the wants of every day life. What a field for the establishment of the new and perfect City of Hygeia—the very *Civitas Dei*—this Australia might have afforded us. I for one cherish the hope that the Federal City in this land of Australia will at least serve as the model of what can be accomplished in gilding the real with the ideal. Let the new city be the fruit of the full and complete knowledge of sanitation and an enlightened state policy, let it become the abode, figuratively and literally both of sweetness and light. May politicians arise from the dusty scramble for mere place and power, and labour towards the attainment of realisable ideals, and all that is implied by the term 'commonwealth.' But may not war and plague have their compensating after influences, witness already the ready outburst of Australian patriotism, and the application of modern research in dealing with maladies never dreamt of, say when Newton went down from Cambridge to the memorable seclusion of Woolsthorpe, to avoid the plague in the year 1666.

Let us turn our attention from South Africa to the north of the Dark Continent, to that ancient land—the cradle of our science —to Egypt the home and birth-place of what was then known as the black art hidden science represented by the word χημεια. The word χημεια[1] first occurs in the Lexicon of Suidas, a Greek writer of the eleventh century, where it is defined as the art of preparing gold and silver; but the idea of something black, *i.e.*, the black art, obscure and hidden, is related to the Coptic or Egyptian *khems*, signifying obscure. According to Plutarch, the derivation of *kemie* is confirmed, namely, as I have already said, from the black soil of Egypt, the native name for Egypt itself being *kemie*, signifying black, the black soil of the land of Egypt. Used in conjunction with the Arabic particle 'al' equivalent to our definite

[1] χημα, *chema.* τεχνη ἱερα, *the sacred art.*

article 'the,' we have a number of words interesting to the chemist including even the name given to the science itself.

It may be interesting to make four of these words serve as the frame-work or text of my address to you on this occasion, I therefore bring before your notice the words:—Alkemie, Alkali, Alkaloid and Alkohol. Any historical survey of chemistry necessarily leads us back to the days of early Egypt, back to the age in which flourished the long extinct University of On, or Heliopolis, or Diospolis, with its reputed hundred professors, amongst whom we may reasonably conclude there must have been someone corresponding to our modern professor, not of chemistry but of Kemie—the black art. Time will not, nor will your patience allow me to do more than glance at this fascinating subject, but among the notable alchemists of a later age I will mention two remarkable men, Geber and Paracelsus, and these but briefly, since both Geber and Paracelsus have received attention from two of our members, Professor Liversidge[1] and Mr. F. B. Guthrie,[2] in addresses given before the Australasian Association for the Advancement of Science.

Geber and Paracelsus both, stand out in prominent outline in the records of history; Berthelot gives the name of the former as Jabir ib Hayyam; another authority gives the name as Gescheber. However that may be, he was a physician of the eighth century, and in the fulsome exaggeration of eastern writers, was said to be the author of five hundred treatises! He knew probably of the properties of many metals and minerals, the hydrostatic balance, the smelting furnace, the arts of distillation, sublimation, crystallisation and filtration; all however subordinated to the search after the Elixir Vitæ and the Philosopher's stone.

Paracelsus, who stands immortalised by the poet Robert Browning, was of the sixteenth century, born at Einsiedeln in Switzerland in 1493, (obiit 1541) and taught that the object of chemistry

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1 Presidential Address, Australasian Association for the Advancement of Science, Sydney 1898.

2 Address Chemical Section, Melbourne 1900.

was not so much the making of gold, as the advancement of medicine in the service of man; that the operations that go on in the human body are chemical functions. Like the ancient that he was, he personified energy and attributed good digestion to the action of the good genius Archæus who rendered the nutriment consumed assimilable, and separated the indigestible and excretory products. Disease was to be cured by medicines; and these in turn were to be provided by the sacred science of chemistry, ἐπιστήμη ἱερά. Numbers, letters, the signs of the zodiac, animals, plants and organic substances form the symbolic notation of the time, and many of these there are in the vocabulary of the modern science of to-day, and not only of science, but our common language contains words of every day use; witness the word 'gibberish,' derived from the proper name Geber; and 'bombast,' from Paracelsus, who rejoiced in the name of Phillipus Aureolus Theophrastus Bombastus Paracelsus. The acidulous critic will, I trust, exonerate me from both bombast and gibberish taken in their modern significance.

Two other words of interest to the modern chemist, have come down to us from the alchemists, one, the familiar *bain marie*, used by the French for their water bath; the term being derived from the jewess Mary, contemporary with Democritus; and the other, the seal of Hermes. The ancients personified most things, and as Hermes was held high in reverence as the patron-father of the 'black art,' its devotees were spoken of as the Hermetic Philosophers: one of the methods of the art being that of enclosing their gold solutions in glass, out of contact with the air, hence to hermetically seal a vessel, is both an operation and a phrase in use to this day. But the *summum bonum* of the ancient alchemist, was the search for—

"that stone which
Philosophers in vain so long have sought.
In vain, though by their powerful art they bind
Volatile Hermes, and call up unbound
In various shapes old Proteus from the sea,
Drained through a limbec to his native form.
What wonder then if fields and regions here

Breathe forth elixir pure, and rivers run
Potable gold, when with one virtuous touch,
Th' arch-chemic Sun, so far from us remote,
Produces, with terrestrial humour mixed,
Here in the dark so many precious things
Of colour glorious and effect so rare?"

Arising from the fruitless search for the magic stone[1] and the elixir vitæ, there appear many useful things, but above all a working theory regarding the nature of things; I refer to the four-element theory of fire, air, earth, and water, of Empedocles, which by no means could appear absurd or worthless to the ancients, for only a century ago the term 'earth' meant, and included, many solid substances; three amongst them being known, and even known to this day as 'alkaline earths.' Moreover 'water' both meant and included all liquids, and embodied the idea of liquidity generally, while 'air' embraced all gases and vapours; and 'fire' was nothing less than the all-prevailing energy acting upon and changing all the visible forms of matter. Have we so very much advanced in our notions of general classification, when we remember that our three-fold division of matter stands as solid, liquid, and gaseous?

Historical chemistry, then, leads us back to the alchemists, the general trend of whose labours were, unconsciously, towards the foundations of our present science; but let us never forget that the changes we speak of as chemical, were in full operation away back in ages more remote than any historical period. Primæval is but a relative term, leading us back in imagination to periods when terrestrial atmospheres were irrespirable gases enfolding the reeking planet. To Egypt and the East—the theatre of many lost civilisations—the chemist turns with never-failing interest. Egypt he looks upon as the birthplace of the great science; where tombs, temples, papyri and cylinders of baked clay are now unfolding their interesting records and linking the present with the past.[2]

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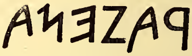
1 That gold was the chief object of search by the alchemist, by the aid of his "magic stone," is shown by the name which the science of chemistry originally bore, namely, *χρυσοποΐα*.

2 For many of these interesting details, I am indebted to the researches of Maspero, Mahaffy, Professor Petrie, and the Wiedemann *Geschichte*.

Pass with me, in imagination, to the two great rival cities of Egypt—Memphis and Thebes—the hundred-gated Thebes mentioned by Homer.[1] Both cities were presided over by their tutelary gods, Ptah Ra and Ammon, Amen, Amun or Ammon-Ra; and while Memphis had surrendered on the triumphal entry of Alexander the Great into Egypt, the Greek conqueror, for political reasons, had offered sacrifice to these deities in order to win over public opinion; but the greater amongst the gods was Ammon, whose temple was at Thebes, and whose celebrated shrine lay at some distance across the Nitrian desert at the Oasis of Ammon. This place was, in the eyes of the Egyptians, the holy of holies; for here, and here only, could the Pharoah become the anointed King of Egypt, the chosen of Ra, the beloved of Ammon, victor of the world, ruler supreme, and dispenser of immortality. Such a consummation of royal prerogatives was devoutly wished for by the great Alexander, who nothing lacking, proceeded forthwith to the oracle of Ammon where he was welcomed by the high priests, put through the rite and ceremonies of Ammon, endowed with the immortal token, the only formula which could stamp him as the chosen of Ra, the beloved of Ammon, the king divine of all Egypt. Unusual interest is, I think, attached to this regal formula and ceremonial, this famous dictum, 'chosen of Ra, beloved of Ammon'; inasmuch as two species of matter, one an element, the other a compound, take us back to very ancient stages of the historic period: I here refer to the element copper and the more complex nucleus ammonia. I believe the name copper is comparatively of modern origin, the Roman derivation being, as is well known, from the island of Cyprus, while the older χαλκος, may have come to the Greeks after having filtered its way, and therefore becoming corrupted, through the Phœnician and Etruscan languages. I hold it to be probable that the original word, signifying the well known red metal, is derived from the sun-god Ra, (ἠέλιος.)

The weapons and implements of primitive man in the land of the Nile were, of course, the chipped flints; many examples of

[1] Iliad, IX., 381.

which are given by M. J. De Morgan;[1] while later on, but still in pre-historic times, as well as during the earlier dynasties, copper tools, vases and weapons were in use in Egypt. It is easy to suppose that bright ruddy copper should be linked in name with the sun, and the Sun-god Ra, whose symbol in cartouche and hieroglyphic was ⊙. This supposition finds support in the survival of the word 'rame,' used to this day by the Italians to denote the metal copper. Rame seems to be derived from other sources than decayed Latin, for if we bear in mind that the people now speaking Italian, inhabit the very same country of ancient Etruria[2] and knowing the persistence with which some words survive, even the decay of empires, it seems to me to be by no means a far fetched theory to account for the word rame, as the survival of a word that has come down to us from Egyptian and Etruscan sources, it is, I think, more than a mere coincidence. It is also a curious fact that the word in the Etruscan language denoting the country itself, is—  Rasena (read from right to left). The word for copper would be in Etruscan—  if we form the word phonetically from the little we know of Etruscan—that unclassed solitary remnant of the languages of the past.

Passing from the question as to the derivation of the word 'rame' as an existing European name for copper, I would point out another link connecting the antiquity of ancient Egypt with our present day science; that link is to be found in the word given to the volatile alkali—that familiar, pungent, tear-exciting liquid—spirits of hartshorn, which, when vapourised, is the alkaline air of our forefathers—ammonia.[3] The Greek conquerors noted with what esteem Ammon was held by the Egyptians, and we have seen its importance in the anointing of kings. Among Greek gods, the

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1 M. De Morgan—Recherches sur l'origine d'Egypte.

2 The Cities and Countries of Etruria by Geo. Dennis London Murray.

3 Ammonia, as a gas, was discovered by Priestly in 1774; the solution was, however, known to the alchemists of the fifteenth century as *Spiritus salis urinæ.*

nearest analogue to Ammon would be their Zeus, whereupon they were not slow in identifying him with their great Jupiter—Θεος Θεον, as Plato calls him; so the god was henceforth given the double appellation, Jupiter Ammon.[1] Ammon is twice mentioned in the prophetical books of the Old Testament:—"I will punish Ammon of No,[2] and Pharoah, and Egypt, with her gods, and her kings; even Pharoah and them that trust in him."[3] "Art thou better than populous No, [Nu] Ammon, situate among the rivers, whose rampart was the sea, [the Nile] Ethiopia and Egypt were her strength, and it was infinite."[4]

Now it is highly probable that the distillation of camel's dung, or the soot derived from its combustion, yielded a product known to the Egpytians as a source of ammonia; while the white deposits found in some parts, notably in the Nitrian desert, yielded nitre,[5] called also nitron, which gives us, in turn, the root for our appropriate nitro-generator, nitrogen, so named by Chaptal. If, therefore, Zeus or Ammon,[6] the chief among gods, was the father of mankind,

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1 The fossils of the Mesozoic Age known as Ammonites are also named after the convoluted horn, pictured on the head of the god Jupiter-Ammon.

2 No, On, Heliopolis, or Διοσπολις. On or Beth-shemesh, Jer. xliii. 13. Curiously enough the letters of these words are often transposed in ancient writings, and may occur both as On or No.

3 Jer. xlvi. 25. 4 Nahum iii. 8.

5 By the word 'nitre,' often 'nitron' and 'natron,' was included a white generic soda compound. I am indebted to *The Chemist and Druggist* for a brief notice of Soda in Egypt, which bears on this subject:—"North-West from Cairo, between two small hills, stretches a valley which, by reason of the large quantity of soda found in it, was formerly known far and wide. Until the discovery of the Leblanc process, this soda was sent in large quantities to Europe, but during recent decades the export of Egyptian soda has been limited to Greece and Turkey. The soda-valley possesses a considerable number of lakes from ten to twelve metres under sea level. With the rising of the Nile, which takes place in about the end of August, the lakes begin to fill, and reach their highest point about the end of January. In the month of March the water gradually evaporates, and the bed is covered with a layer of natural soda, which presents the appearance of large lumps of ice. The deposits at Wady Natron are practically inexhaustible."

6 Whether the Ammonites, the tribes mentioned in the Old Testament, derive their name in this way is uncertain.

then this alkaline body[1] and its primary congener, nitrogen, both bear interesting names, associated as they are with all that pertains to life upon this planet.

Particularly interesting is the evolution of the simple symbol N for nitrogen. The hieroglyphic sign used by the ancient Egyptians, as may be seen in the cartouche of the Pharaohs, at Abydos and elsewhere, is 𓈖; the Phœnician is 7; the Etruscan form is 7; while the Greek form brings it nearly identical with the modern ν. If of such interest from the antiquarian point of view, will they not afford equal, or perchance greater interest, from the point of view of molecular mechanics?

Our position as to scientific belief is this:—that the departments of knowledge dealing with the properties of aggregates of matter, and hitherto labelled and recorded under the terms chemistry and physics, may, and rather should, be termed the mechanics of the Ether; for do we not exist in an Ethereal continuum, when facts are now being co-related, in a manner the like of which is unknown in history? The air is thick, it has been said, with impending discovery just as the world was in Newton's time waiting the arrival of the master mind who shall link together all that is now known, harvesting the results into a new and greater 'Principia.'

That those complete and radical changes exhibited in ethereal vortex motion, the so-called matter, should be classed as chemistry: while the transient vortex changes capable of speedy diminution, reversal, and change back again into the original state should form the domain of physics, is convenient for purposes of reference and study, but where chemistry ceases or physics begins, can nowadays be only of interest to the curious: the chemist must embrace both. Time does not allow of my treating these matters other than as

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[1] The word 'alkali' means 'to fry,' or 'the fry,' 'the roasted' (al kali), the arabic word *qualey*, or *kaley*, meaning fried, or roasted in a pan; hence the calcined ash left on the incineration of a plant or of any vegetable matter was called *al kali*, a word that has come down to us, practically unchanged, from the alchemists.

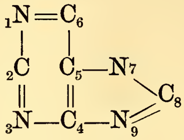
generalities, but we may, I think, try and picture in space and follow in imagination, the track of a molecule of ammonia, confining ourselves to common terrestial temperatures, disregarding on the one hand dissociation temperatures, as well as that wonderful approach to the absolute zero, made during the last year or so, by Dewar in solidifying hydrogen.

The mental picture I have of the ammonia molecule is that of a central nucleus and attendant atoms, which we may call the central sun and planets of an imaginary planetary system. This sun we call nitrogen, and, without doing violence to our newer conceptions of matter being a vortex motion, is a conceivable mass, holding three planets at fixed but, to us, unknown distances. These three planets are none other than the hydrogen atoms. Place these planets in their proper orbits, and we picture the ammonia system in space. But facts show us that there must be five possible orbits; witness the compound sal-ammoniac. But, with the magic clash of atoms and the redistribution of vantage positions in the molecule, let both a carbon atom, two oxygen atoms and a water molecule, come into position in opposition to two molecules of ammonia, and we have ammonia carbonate.[1]

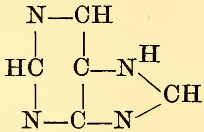
Once again, rearrange the positions inside the molecule and we have the molecule of urea, being in fact, the famous synthesis by Wöhler of the first compound of animal origin made artificially in the laboratory. Nitrogen being the central figure of the ancient alkaline air we call ammonia, is moreover the pivot-atom of a class of bodies of much later discovery, which, having the power of combining with an acid to form a salt, *resemble* an alkali and were therefore called alkaloids, [like alkali]. The relations and constitution of some of these alkaloids will be seen from what follows:—After the synthesis of urea by Friedrich Wöhler in 1828, it was felt that the structure of the more complex uric acid would yield to the atom-building-instinct of the modern chemist; this was effected by Behrend and Roosen, also by Horbaczewski,

[1] The Spiritus urinæ of the ancients.

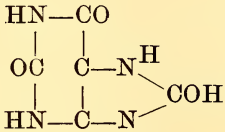
but the most complete demonstration of the structure of uric acid is given us by the brilliant researches of Fischer.[1] He formulates a framework thus :—



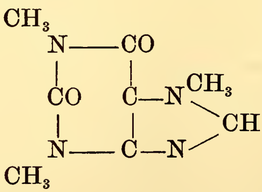
Filling up the available hydrogen positions, a compound is represented which has actually been obtained, called by Fischer, *purine, (purum uricum):*



Hypoxanthine is 6—oxypurine, and Xanthine is 2 : 6—dioxypurine. Extending the oxygen positions to 2 : 6 : 8 we get trioxypurine or uric acid :



Placing two methyl radicles in the third and seventh positions we have 3 : 7—dimethylxanthine which is the alkaloid—*theobromine.* The addition of a third methyl radicle formulates the composition of caffeine, the alkaloid present in tea and coffee, and which is 1 : 3 : 7—trimethylxanthine—



What may be the structure of the globulins, the albumoses, hetero- and deutero-, the peptones, and that family of compounds

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[1] Nature, Vol. LXI., p. 187.

often spoken of as albuminoids, we cannot yet determine, but I crave your attention for a few moments to consider the origin and final destiny of some of the nitrogenous bodies I have mentioned. The economical evolution of human energy, is a problem that is attracting a good deal of attention, but the human machine, in converting the potential energy of bread and cheese into muscular and mental activity, or into some equivalent work value, has to dispose of effete waste matter—excretory products—that may be compared to the smoke, ashes and scoriæ of the steam engine; for as in raising energy by means of steam we have waste products, so we have three excretory products expelled from the human body. They are:—(1) Carbon dioxide; (2) Urea and uric acid, together with a number of bodies of greater interest to the pathologist than to the sanitarian; (3) Surplus undigested food,[1] cellulose and indigestible fibre, embodying the waste—food-ashes called excreta.

Now all these substances, once outside man's body, recoil on him, offending all his senses, while under many circumstances they become a danger and a menace to his very life, but more particularly do they effect the well-being of his near neighbours; it is but a truism to say, that man's duty to his neighbour, therefore, includes also the continual adjustment of his internal relations to those external relations of the State, of which he is a member. This danger becomes accentuated, the offensiveness more pronounced, the more man becomes civilised, and the more closely men congregate together in towns and cities; I emphasise the latter condition, because the further men live apart, the easier of solution is the difficulty. We have then something to be gotten rid of. How ancient man, and how man in a state of nature, *does* get rid of it is obvious and known to all.[2]

How the question was severely let alone, down to within a half century ago, I need not particularise to any great extent,

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1 The greater the amount of the latter the worse for the individual, who in this respect is the slave of unproductive energy.

2 For the Mosaic injunction, see Deuteronomy, xxiii. 12 & 13, R.Ver.

sufficient it will be if I say that town inhabitants :—(1) Used the street as a sewer; (2) Advanced to the cespool system, the use of pans, tubs, et hoc genus omne; (3) Invented the water-carriage method of removal with discharge into rivers and seas. But a new danger arises from the mixing with water and removal to a distance, man is confronted with new dangers and new diseases—sewer disease, and the next question is, what is he to do with it? how dispose of it having in view two things: the health of the state, and economy—if needs be. Of the many methods of purification, by chemical precipitation, by electrical decomposition, I shall not weary you with, but proceed to the next stage of my subject, namely, that of fermentation, and afterwards, more particularly, to that of ammonical fermentation.

Fermentation is the name given to the phenomenon of change which takes place when saccharine and other liquids, are acted upon by micro-organisms at their proper life-temperatures, the word fermentation being derived from *fervere* to boil. When the minute organism known as *Saccharomyces cerevisœ* grows and multiplies at a temperature of 25° to 35° C. in sugar solutions, alcohol, carbon dioxide and some other bodies are formed; 100 parts of cane sugar or 105·26 parts of grape sugar yielding on fermentation :—Alcohol 51·11 per cent.; carbon dioxide 48·89 per cent.; succinic acid 0·67 per cent.; glycerin 3·16 per cent. Thus, out of one hundred parts of cane sugar, about ninety-five parts are decomposed, four parts disappear and form succinic acid, glycerin and carbon dioxide, while one part is added to the newly-formed ferment.

The chief body sought for in fermentation is alcohol, and here we have our fourth arabic word, *al-Kohol.* The word alcohol means in arabic 'the finest powder,' and at one time denoted the fine powder used by ladies to beautify the eyes; a fine metallic powder being used in the East to stain the eyelids. With the early alchemists, it meant a sublimate or anything in a very fine state of division; flowers of sulphur, for instance. It was probably applied to finely powdered quicklime, which if used to strengthen spirit by absorbing the water that always accompanies alcohol, would give meaning to the term *spiritus alcoholisatus;* thus alcoholised spirit soon became corrupted to simple alcohol, which is a far more modern term than either spiritus or aqua vitæ. Kopp, in his *Geschichte der Chemie,* supports this view as to the origin of the word alcohol.

Alcohol is also defined as an essence—a quintessence,[1] or spirit obtained by distillation or rectification, it is the shorter term for 'alcohol of wine,' this being the most familiar of spirits; the Teutonic 'Branntwein' from 'brennen,' to burn or to fire, giving rise to our word 'brandy,' while the Keltic, through the Erse or Irish rendering of *eau de vie* or aqua vitæ, usque-baugh, gives us, corrupted, 'whisky.' The modern chemical application of the word however, is given to a systematic series of compounds, the first term of which is methyl alcohol, the second, we hear a great deal of—one notorious name I will here modify to that of the 'soluble fiend,' but whether diluted into a drink, or employed as a vehicle for varnishing and polishing furniture, it is also a valuable and highly concentrated fuel, that may some day, when the coal measures are exhausted, become the fuel of the future.

We have traced through some periods of the world's history the four words—alkemie, alkali, alkaloid, and alkohol—and you will have perhaps perceived that I do not now intend dealing with the famous stimulant, the *aqua vitæ* of the ancients, the ethylic alcohol of the moderns, but my purpose is to show how the phenomenon of fermentation is now being made use of, through a totally different set of fermentation-products, in attacking one of the most important sanitary problems of the age. From what has already been said, the waste and effete products derived from human beings, when congregated in cities and towns, mixed with a miscellaneous variety of waste liquids from manufactories and human dwellings, make up a liquid of great complexity—a liquid well-known and well-hated as sewage. The question as to its disposal, quickly

[1] Quintessence means the fifth rectification beyond which it was thought useless or impossible to go.

cheaply, and above all effectively, is an important one. What is to be done with it? This is an oft-repeated cry, involving a question that has tried the patience and ingenuity of whole generations of men, while with too many of us this repugnant subject is shelved, the burden of dealing with it being laid on whomsoever will take it upon his shoulders. Men, ostrich-like, pretend not to know of the existence of the evil, 'pass by on the other side,' leaving it to Bumbledom to grossly mismanage.

To enumerate or describe a tithe of what has been done and suggested, and the multitude of schemes that have appeared, would fill a volume. Such a task I do not intend to enter upon; it is enough to know of the existence of a putrescible liquid that must —profitably or otherwise—be removed and disposed of: a duty imperative on the part of the body politic.

Methods of removal are mechanical, and belong to the domain of the engineer; methods of disposal are of another order, and belong to the domain of biology and chemistry; so that biologist, chemist, and engineer, join forces in attacking a problem, old as when Tarquinius Priscus first sought to do the same for ancient Rome twenty centuries back, when the famous Cloaca Maxima discharged itself into the Tiber. Hitherto, what has been done?

After great expenditure of time, energy and money, the latter probably running into millions, men begin to ask how mankind has borne with the evil in the past. The answer is, that water-carried sewage was unknown in pre-Roman times, everything being expeditiously returned to Mother Earth from whence it came. With us moderns, the method of removal by water considerably enchances the difficulty. With the idea of returning excreta to the soil the sewage farm came into existence, but experience has shown it to be a dismal failure, resulting in water-logging and fouling land that could otherwise be turned to more profitable uses. Now let us apply the method of fermentation to ordinary sewage, what must happen? In the case of sugary liquids, we see the cells of *Saccharomyces cerevisæ* break down the constitution of sugar, yielding carbon dioxide and alcohol. What should the organism in sewage do? In the light of experiments made during the last few years, this liquid should be resolved into ammonia, carbonate of ammonia, nitrate of ammonia, marsh gas and carbon dioxide, the chief nitrogen and carbon-constituents of the sewage—in other words, a complete breaking down of highly complex nitrogenous and carbonaceous bodies into harmless innocuous inorganic compounds.

This breaking down of nitrogenous matter may be best exemplified in its very simplest form, namely, in that of the ammoniacal fermentation of urine, the chief constituent of which is urea, a compound that may be resolved into other compounds, the next simplest in order to those resulting from its ultimate decomposition, (hydrolysis of urea, Dumas), for by simple heating with water, or heating in a alkaline solution, the following change takes place :—

$$CO\left\{\begin{matrix}NH_2\\NH_2\end{matrix}\right. + OH_2 = CO_2 + 2\,NH_3$$

By zymolysis, *i.e.*, by the intervention of life-changes, or in other words by simple ammoniacal fermentation (Pasteur, 1860, Van Tieghem, 1864) this self same change is brought about by the microscopic organism *Micrococcus ureæ.*

By simply abandoning urine exposed to the air, this organic change is quickly brought about; the whole of the urea becoming converted into carbon dioxide and ammonia, which, at common temperatures, would combine as ammonia carbonate, a compound easily resolvable by the nitrifying organisms into ammonia nitrite and finally, into ammonia nitrate. We have here what has been called the 'septic system of sewage disposal,' the analogue, in some respects, of alcoholic fermentation, but instead of ethylic alcohol being the product of the symbiotic change, it is probable that the simpler methylic alcohol[2] is evolved, which under the circumstances,

[1] Pasteur, Comptes rendus, Vol. I., 1860. Van Tieghem, Comptes rendus, Vol. LVIII., 1864. Jaksch, Zeitschrift, f. physiologische Chemie, Vol. V., 1881, p. 395. Leube and Grasser, Virchow's Archiv, Vol. C., p. 556.

[2] Mr. Doherty at my request searched Sydney sewage and effluents therefrom for methyl alcohol but hitherto without success. I am afraid that even should it be found the critic may say it had originally come from methylated spirit thrown away with the liquid domestic waste.

is resolved a stage further in the direction of simplification to methane, which with hydrogen and carbon dioxide, are the principal gases evolved in the process. After the discovery of the function of nitrification brought about by the nitrifying organisms by Warrington and Percy Frankland, the State Board of Health of Massachusetts in 1888-9 were induced to try the method of natural self-purification by these organisms. To Captain Sir Douglas Galton[1] belongs the credit of introducing the system to the notice of English sanitarians. The process was very soon tried, and Dibdin in 1893, was astonished to find that by merely passing sewage through a shallow coke filter, he obtained a fairly good effluent, as good as some that were then being obtained by more expensive precipitation processes.

Scott-Moncrieff in 1892 devised a clever application of the system, using an open tank filled with flints for the first fermentation, then passing the liquid over a series of trays containing coke, all exposed to the air, whereby the work of the nitrifying organisms had full effect, resulting in a beautiful clear effluent approaching in character to a potable water. Donald Cameron was the first to boldly take the process in hand and use it on a large scale, which he did in 1896 at Belle Isle, Exeter, since when, it has been known as the Biological Method, or Septic Tank System.

It should here be stated that several modifications have been introduced by others, so that we have the primary biological method, with or without previous chemical precipitation processes, but the true zymolysis of sewage should be carried on with absolutely no addition of chemicals or antiseptics whatsoever.

Ducat introduced his aërated, bacterial, self-acting coke-bed in 1897; Dibden[2] had, however, been working at the natural or self-purification of sewage from 1884 to 1898, and his results, obtained by simply passing crude sewage through coke and 'breeze' filter-

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[1] Jour. Sanitary Institute, Vol. XVII. p. 1.

[2] Journ. Soc. Chem., Ind., Vol. XIV., p. 922; and *Idem,* Vol. XVII., p. 315.

beds, were such a success that chemists and sanitarians could no longer afford to ignore the merits of the method; hence experiments were made in a number of places in the Empire, Sydney included. In the meantime the London County Council had determined to severely test the new, or rather old, biological process, and in the hands of Drs. Clowes and Houston such gratifying results were obtained that I make no apology in giving you an account of the treatment of the crude sewage of the City of London.[1] These two gentlemen are chemist and bacteriologist respectively to the London County Council, and great interest is now being taken in their results, inasmuch as they are both independent scientific men, having no patent-right interest in the process. Their attention was directed to the purification of London's crude sewage as it is delivered at the Barking and Crossness Outfall Works.

A bacteriological examination of the sewage showed that between three and four millions of micro-organisms are present in one centimeter cube of the crude sewage, their rate of propagation or growth being from sixteen to seventeen millions per twenty-four hours. They consist of[2]:—*B. Enteritides sporogenes; B. Coli communis; B. mycoides; B. subtilis; B. mesentericus; Sarcinæ* Yeast-cells, *Saccharomyces, sp.*; Moulds; *B. Fluorescens liquefaciens;* and other Protean forms, vaguely known in the elder Frankland's time as the 'sewage fungus.'

It is shown that the putrefaction of sewage may proceed by aërobic bacteria under aërobic conditions; by anaërobic bacteria under semi-anaërobic conditions; and by strictly anaërobic bacteria under strictly anaërobic bacteria.

Dr. Clowes abandoned all likely complications arising from over-elaboration of apparatus, doing away with the shallow trays used

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1 Bacterial Treatment of Sewage (Second Report) by Dr. Clowes and Dr. Houston. London: P. S. King and Son, Great Smith-street, Victoria-street, Westminster.

2 Filtration of Sewage—Report on the Bacteriological Examination of London Crude Sewage by Dr. Frank Clowes (First Report). London: P. S. King and Son, Great Smith-street, Victoria-street, Westminster.

by Scott-Moncrieff, as well as the closed septic tank of Cameron, reducing the experiments to the last stage of simplicity. Two plain open rectangular brick-lined tanks, twenty-two feet six inches long, ten feet eight inches wide, and twelve feet deep, giving a superficial area of $\frac{2}{363}$ of an acre each. A third tank, of similar shape and area, but six feet in depth, was also employed to note differences in efficiency caused by depth. Laid on the bottom of these tanks were parallel series of loosely-jointed drain pipes to assist in drawing off the effluent. Walnut-sized fragments of common gas-coke are placed in the tanks to the depths of four and six feet respectively.

When thus ready, the coke beds are filled with screened sewage, the screening intercepting some curious and miscellaneous items of the wealth of the absent minded citizen, such as tobacco pipes, purses (empty), brushes, combs, and Dr. Clowes even mentions 'wedding rings.' Seven minutes are allowed for the filling of the tank, then comes a resting period of three hours. The word 'rest' is here but a relative term, for it is really a period of great bacterial activity. The outflow afterwards extends over one hour, the bed remaining eight hours empty in order to aërate itself. The tank is again filled and the sequence continued, one million gallons per acre per day being the working capacity of the system.

Later experiments made with thirteen feet beds show no appreciable advantages over the six feet of coke. Here then we have an intermittent process for the treatment of sewage of undoubted simplicity: crude sewage is screened and flowed into a tank containing some four or six feet of coke, in pieces of the size of walnuts, submerged for three hours, and just allowed to flow out again. And what are the results? Clowes measures the degree of purification attained by this process by finding the amount of oxygen required to oxidise the putrescible organic matter; first in the raw sewage, and then in the effluent. The results show that over fifty per cent. of purification takes place. His figures show that 51·30 per cent.[1] of the putrescible organic matter is dealt with, so that an effluent is obtained pure enough to support fish life.

[1] In allowing a longer period of time for the fermentation, results as high as eighty-six per cent. have been obtained by Clowes.

The general conclusions arrived at by Dr. Clowes are:—that the process offers the readiest and the cheapest method of sewage purification at present known. He says, that "neither on chemical not possibly on bacteriological grounds can any serious objection be raised to the introduction of the effluent from the coke-beds into a portion of the river Thames which is cut off by locks from the intakes of the Water Companies, and the water from which is not employed for drinking purposes, and cannot be used on account of its 'brackish' nature. The effluent certainly will not cause any deposit upon the river-bed, and will even tend to render the turbid water of the lower river more clear and transparent. At the same time, the liquid discharged from the outfall into the river will be sweet and entirely free from smell. Further, it will carry into the river the bacteria necessary for completing its own purification in contact with the aërated river water, and under no conditions can it therefore become foul after it has mingled with the stream. The effluent will in no way interfere with fish-life in the stream."

As compared with the present process of chemical precipitation and sedimentation, the bacterial process presents the following advantages:—*(a)* It requires no chemicals; *(b)* It produces no offensive sludge, but only a deposit of sand or vegetable tissue which is free from odour; *(c)* It removes the whole of the suspended matter, instead of only about eighty per cent. thereof; *(d)* It effects the removal of 51.30 per cent. of the dissolved oxidisable and putrescible matter, as compared with the removal of seventeen per cent. only, affected by the present chemical treatment; *(e)* Further, the resultant liquid is entirely free from objectionable smell, and does not become foul when it is kept; it further maintains the life of fish.

"In their report a number of reasons are given, showing that it is unwise in the present state of our knowledge to recklessly condemn an effluent on bacteriological ground alone, without full knowledge of all the requirements of the case. In the attempt to treat sewage on biological lines, it is to be noted that the solution of the suspended matter and even the partial destruction of putrescible matters by microbial agencies afforded sufficient ground for justifying the process, at all events as a preliminary measure. Whether this preliminary treatment is to be supplemented by further treatment, either by passing through coke-beds or by land irrigation, or by any other method, is a matter largely dependent on circumstances. In the present case there are practical points which first of all demand consideration, and although it may be most desirable to obtain an effluent chemically pure and bacteriologically above suspicion of danger, it is to be thought of that an effluent not altogether satisfactory in one or other, or even in both, of these respects may yet fulfil all necessary requirements without passing out of the range of practicability. In certain cases it may be imperative to obtain an effluent bacteriologically sound, but it does not follow that a similar result is urgently called for in other cases, as, for example, where an effluent is turned into a watercourse which is not used for drinking purposes, and which already may contain practically all the bacteria that are found in sewage."

The history of fermentation, putrefaction, and nitrification has latterly been so frequently repeated that I hesitate in doing much more than mention dates, general results, and the names of those whose researches have opened up for us the possibilities of sewage zymolysis. The earliest observer to perceive the low forms of life that play so important a part in the decomposition of animal matter, was Leewenhoeck,[1] who in 1675 was not a little astonished in getting glimpses of that nether world—invisible to the unassisted eye—that world of life we now recognise as bacteriology. I can only mention men's names as the 'stepping stones to higher things'[2] in linking this seventeenth century science worker with the latest developments of this subject.

[1] Leewenhoeck—Opera omnia, 1722.

[2] Leewenhoeck 1675, Muller 1773, The Abbé Spallanzani 1777, Schulze 1836, Ehrenberg 1838, Schwann 1839, Dujardin 1841, Helmoltz 1843, Cohn 1853, Schroder and Von Dusch 1854, Davaine 1859, Pasteur 1862, Van Tieghem 1864, Schloesing and Müntz 1877, Beyerinck 1888, Winogradsky 1890, Warrington 1891, Oméliansky 1900.

Now, what is there in the nature of things to account for this process of putrefaction? The coke, like a sponge, is full of interstices and holds a large volume of atmospheric air, which is destined to play an important part in the process; carbon, as is well known, has the property of holding large volumes of gases; common charcoal can take up ninety times its own volume of ammonia gas. A fermentation is inaugurated in the sewage under these conditions, the sewage itself containing the micro-organism necessary for its own decomposition. Proteids break up, their nitrogen being changed into ammonia; urea is transformed into ammonia carbonate; sulphur is changed to hydrogen sulphide. Hydrogen is recombined to form methane; carbon takes oxygen to appear again as the dioxide; while some of the nitrogen suffers differing degrees of oxidation, appearing as the lower oxides and sometimes is even reduced to free nitrogen.

This change has been called the biological treatment of sewage, or the biolysis of sewage, (Scott-Moncrieff); or as I propose, I think, more correctly—the zymolysis of sewage. The fermentation-change known as putrefaction or decomposition, and tersely described by Duclaux in the following words:—"Whenever and wherever there is a decomposition of organic matter, whether it be the case of a herb or an oak, of a worm or a whale, the work is exclusively done by infinitely small organisms. They are the important, almost the only, agents of universal hygiene; they clear away more quickly than the dogs of Constantinople, or the wild beasts of the desert, the remains of all that has had life; they protect the living against the dead. They do more; if there are still living beings, if, since the hundreds of centuries the world has been inhabited, life continues, it is to them we owe it."

The appearance and disappearance of nitrogen is remarkable. During many years experience in the examination and analysis of sewage and sewage effluents, I have been unable to find nitrites, and very often have failed to find any nitrous or nitric nitrogen at all. During some recent researches as to the true composition of sewage, it was decided to take samples of sewage at all hours of the day and night. To do this an analyst had to be stationed at the Botany Sewage Farm for some consecutive days; and as a result, Mr. Doherty made the discovery that at certain hours, nitrites regularly make their appearance, commencing at the early hours of the morning from daylight until ten o'clock in the forenoon. After that hour, they disappear for the rest of the day; again making their appearance next morning. The process of nitrification is no doubt accelerated by light and oxygen, although the nitrifying organisms do their work to some extent in the dark.

Many reversible reactions go on in sewage, since as we know that in the process of oxidation of iron in air, ammonia is formed. Ammonia is converted into nitrous and nitric acids. Nitrous and nitric acids change back again into ammonia, while, in some cases even free nitrogen is formed; but the sequence of changes that happen when human dejecta, along with considerable volumes of water flow into the sewage fermentation-tanks are, that ammonia free and loosely combined, is the main result; and then, and then only, does the nitric fermentation take place, in two stages; first the formation of [1] nitrous nitrogen by *B. nitrificans* (nitrites), then a period of rest, and then, the final change into nitric nitrogen (nitrates), but, whether the changes are the immediate results of the bacteria themselves, or the result of enzymes secreted or elaborated by the organism, they are symbiotic changes of a remarkable character; my opinion is, that as in the other processes of fermentation, the enzymes are the immediate cause of the breaking down of proteid matter.

Notwithstanding the reproach cast upon Sydney by the revelations of her insanitary condition lately brought to light by the Plague in our midst, it should here be recorded that Mr. J. M. Smail, Engineer to the Metropolitan Board of Water Supply and Sewerage, and Mr. Davis, Chief Engineer for Sewerage Construction of the Public Works Department, have in looking

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[1] From Winogradsky's researches two organisms are concerned in the process of nitrification, M. nitrificans, (Van Tieghem) and two in the process of de-nitrification, B. De-nitrificans a and β.

forward to the application of biological methods in dealing with the sewage of Sydney, put the process into active operation at the Botany Sewage farm, on an experimental scale, and at Rookwood on a real working scale; plans and models of the system I have now the pleasure of showing you to-night, through the kindness of Mr. Smail, and of Mr. R. R. P. Hickson, the Under Secretary for Public Works. As many other substances have been in use by different observers for filling the sewage tanks, Mr. Smail used ordinary sandstone and gravel from the Nepean River. At the Botany Sewage Works an iron tank is used as an experimental filter bed where the initiatory biological process is commenced. This tank is provided with a false perforated bottom, upon which the pebbles or stones rest, the tank being filled with crude sewage and the fermentation process allowed to proceed for four hours, the liquid then passes into the filters, of which there are two—one filled with fragments of coke, the other charged with small pieces of coal; the tanks of coal and coke are so arranged that either one may be used at will, thereby testing the relative merits of each kind of material. The effluent is then run on to a bed of lucerne and domestic vegetables, whereby the manurial value can at once be estimated and practically put to use. One thing is thus proved, that whereas crude sewage soon clogs the land and renders the soil 'sewage sick,' the effluent acts at once as a fertiliser, and a luxuriant crop of lucerne or vegetables is produced. The cause is not far to seek, for the effluent is rich in nitrates and ammonia, both compounds readily appropriated by the growing crops. The crude sewage has the following composition on analysis. Mean of twenty-four samples taken every hour, 18 - 19 April, 1900 :—

Total solids	56	Parts per 100,000
Chlorine	12	" "
Free ammonia	3	" "
Albuminoid ammonia	2	" "
Oxygen absorbed in four hours	5	" "
Nitrous nitrogen	0·2	" "
Nitric nitrogen...	0	" "

Composition of effluent from Coke Tank, Botany Sewage Farm (Scott-Moncrieff.) Mean of twenty-four samples taken every hour 18 and 19 April, 1900, corresponding in point of time with the entry of the crude sewage—

Total solids	44	parts per 100,000
Chlorine	12[1]	,, ,,
Free Ammonia...	4	,, ,,
Albuminoid ammonia	0·3	,, ,,
Oxygen absorbed in four hours	1·5	,, ,,
Nitrous nitrogen	0·1	,, ,,
Nitric nitrogen...	0	,, ,,

The purification here effected amounts to eighty-five per cent. based on the changes undergone by the nitrogenous matter, or seventy per cent. if based on the oxygen absorbed in four hours, which compares well with results obtained elsewhere. No sludge results: all the solid matter has undergone the fermentive change, and even such things as feathers, string, paper and banana skins are reduced to the liquid condition. Almost any solid bodies may be used for the packing of the filter beds: such as broken bricks, coke, cinders, clinkers, boulders, pebbles, charcoal, breeze, and even road-metal. I regret that I cannot give the results of purification in tabular form upon a common basis of analysis. Scott-Moncrieff's result, and the results obtained by Kenwood and Butler, are based on the ratio between the free and albuminoid ammonia, and both are good; while Dr. Clowes, estimates the oxygen absorbed, the percentage of improvement being showed by the following statement:—

$$K = \frac{(c - b)\,100}{c}$$

K = purification in per cents.; c = oxygen absorbed by the crude sewage; b = oxygen absorbed by the effluent.

The figures obtained by Clowes are as follows:—

Average raw sewage... ...	5·28	parts per 100,000
Effluent from four-feet bed ...	2·49	,, ,,
,, primary six-feet bed	2·64	,, ,,
,, secondary six-feet bed	1·63	,, ,,

Effective purification, equals fifty-one per cent.

1 All calculation as to the common chlorine basis is here avoided.

Another standard, suggested by Rideal, is the ratio between the oxidised and the unoxidised nitrogen. In this matter I feel assured that such confusing methods of comparing results will soon be amended and we shall be able to judge an effluent as we now judge a potable water.

This method of dealing with sewage has been termed a process of biolysis; it may with reason be called the zymolysis of sewage, since the changes are brought about through the agency of fermentation. It is, in reality, the natural method of sewage purification subject to control; I would emphasise the latter phrase—purification subject to control—because, all the processes hitherto known, have *not* been kept under control, but have been the ruin both of inventor and capitalist. This method, however, is both rational and natural, and man is but going back to 'Nature his dear old nurse,' who has carried on the process and purified the dejecta of animal life during all these centuries: indeed, were it otherwise, this world must have become but a huge charnel house. As it is, the micro-organisms of purification and nitrification have full action; antiseptics and disinfectants being wholly superfluous in fermenting the mixture of slops, kitchen waste, storm water and dejecta, whereby the solids break up and pass into solution, gases being evolved. The liquid is then allowed to nitrify, with access of atmospheric air resulting in an effluent being produced which may be purified to a degree equal to some drinking waters. The process now being tried at Botany is intermittent, but there is no reason why it should not, when worked properly, become continuous, requiring very little attention.

Here then is a field eminently suited to the energies and capabilities alike of the chemist and the engineer; here also lies the explanation of the reason why sewage farms were failures and could not be other than failures. Finally we have the end in view with regard to the disposal of city sewage, for if we *must* have the sewage carried out of our dwellings by the aid of a current of water, and I admit it to be the easiest method for populous centres, although not the easiest in country houses where, I still think, dry earth will have a long reign, then the zymolysis of sewage will become the only rational mode of solving, what has hitherto been a difficult and a costly problem. Let me in conclusion ask those amongst us here in Australia who are possessed of wealth, leisure and qualifications, to lend their aid in the investigation of problems such as these. Original work is still needed, and it should be done by those who are unhampered by official routine, and duties that absorb the whole of their time and energy.

Epilogue.

Time was when this earth was but a crustless mass—a reeking nucleus of vortex motion. Æons after, Herculean Gravity pulls the molecules together making for density, then comes cohesion, chemic combination and crystallisation, with life-giving Nitrogen, Oxygen, Carbon and the rest. There pass long ages of Geologic Twilight, and Life dawns—

> 'Upon the firm opacious globe
> Of this round world,
> From Chaos and th'inroad of Darkness old.'

Man is evolved—product of organism and environment—attuned to the music of the spheres to dominate the world, who, finding gold to be a changeless object of beauty and his changeful life but of short duration, looks out about him, searching, first for a Stone, that may turn all the baser metals into precious gold, and then, for an Elixir that shall prolong his earth-life indefinitely—

> 'A tincture
> Of force to flush old age with youth, or breed
> Gold, or imprison moonbeams till they change
> To opal shafts.'

Many centuries of fruitless toil are consumed in this pursuit; and the alchemist, as he is called, finds out some things that were really useful for ends of lesser ambition, and so, based on these results, are laid the foundations of Medicine and of Chemistry. Skipping over the centuries—passing by the Mediæval Ages—and calmly surveying our own times, we are beset by the problem of the concentration of peoples in cities, nay, we are compelled to concern ourselves, not so much in providing food for these populous centres, that is a problem that will assert itself later on; as in dealing with the excretory products from dwellers in towns; a problem over which vast sums of money, and numberless lives have been wasted. Thus having learned by patient toil and tribulation, some lessons from

'Immortal Nature's ageless harmony'

our studies lead us away from the Alchemy of Antiquity and we are confronted with those problems of Sanitation and the Public Health that call for prompt solution. With what success one of these problems shows promise of speedy and satisfactory treatment it has been my pleasure to indicate.

On the RELATION, in DETERMINING the VOLUMES of SOLIDS, whose parallel transverse sections are n^{ic} functions of their position on the axis, between the number, position, and coefficients of the sections, and the (positive) indices of the functions.

By G. H. Knibbs, F.R.A.S.,

Lecturer in Surveying, University of Sydney.

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1. Problem defined.
2. General relation between indices, number and position of sections, and weight-coefficients.
3. Determination of the ratio of the $m+1$ weight-coefficients, when the number m of indices is one less than the number of values of the variable.
4. Number of indices greater than the number of values of the variable, diminished by unity.
5. Number of indices less than the number of values of the variable, diminished by unity.
6. Determination of the $n-k=m$ weights.
7. Position of a single section.
8. Positions of two sections.
9. Limiting positions of two symmetrically situated sections.
10. Two symmetrically situated sections and their conjugate indices.
11. Asymmetrical positions of two sections.
12. Three symmetrical sections, viz., a middle and the terminal sections.
13. A middle section, and two other sections equidistant therefrom, all of equal weight.
14. Two terminal and one intermediate section.
15. General result of the method of finite differences.
16. General theory of symmetrically situated sections with symmetrical weight-coefficients.
17. Examples of the application of the general formula.
18. The number of indices satisfied by a given number of symmetrical sections.
19. Manifold infinity of possible formulæ with symmetrical sections.

1. *Problem defined.*—If a quantity $A_z = f(z)$ be expressed by the equation

$$A_z = A + Bz^p + Cz^q + Dz^r + \text{etc}\ldots\ldots\ldots\ldots(1),$$

in which let us suppose the constants A, B, C, etc., have any finite value positive or negative including zero, and the indices p, q, and r, etc., are in ascending order of magnitude and positive,[1] the integral

$$\int A_z dz = V = z\left(A + \frac{B}{p+1}z^p + \frac{C}{q+1}z^q + \text{etc}\ldots\right)\ldots\ldots\ldots(2)$$

will represent an *area* included between the curve (1), the axis z, and the limiting ordinates, z_1 and z_2 say, provided A_z represents an ordinate: and similarly it will represent a *volume* should that function denote the area of xy planes at right angles to the z axis. The volume will of course be that included between the parallel terminal planes, intersecting the axis at the limits of the variable, and the surface formed by the boundary of one of these, considered as *generator*, moving along the z axis at right angles thereto, and changing its area in terms of the function.

Since the origin of z and the linear scale of the unit by which it is measured do not affect the *degree*, but merely alter the *constants* of the above expressions, viz. (1) and (2), these may be regarded as quite general in form. A may consequently be conceived as the ordinate, or as the area, for $z = 0$, and V corresponingly as the area or the volume for $z = 1$; provided that the limits of the integral be 0 and 1, and the constants be suitably determined. Hence, subject to the restriction defined, unity may be substituted throughout for the quantities z, z^p, z^q, etc., in (2).

Let a, b, c, etc., represent any proper fractions in ascending order of magnitude; and α, β, γ etc. any series of weight-coefficients[2] to be multiplied into the values of the function, for values of z equal to those fractions; and for brevity let the sum of the

[1] Negative indices give a series of hyperbolas if A_z be regarded as an ordinate, the asymptotes being the axis z and the ordinate for $z = 0$. We consider only the positive indices, that is the parabolas.

[2] We shall call these 'weight-coefficients' because they express the relative importance of the sections.

coefficients be denoted by σ: *i.e.* let

$$a < b < c \text{ etc. } < 1; \text{ and } \alpha + \beta + \gamma + \text{etc.} = \sigma;$$

then since the coefficients may have any value whatever we may evidently write

$$V = \frac{1}{\alpha + \beta + \text{etc.}} \left\{ \alpha A_a + \beta A_b + \text{etc.} \right\} =$$

$$A + \frac{1}{\sigma} B(\alpha a^p + \beta b^q + \text{etc.}) + \frac{1}{\sigma} C(\alpha a^q + \beta b^q + \text{etc.}) + \text{etc.} \ldots\ldots (3)$$

A_a being the value of the original function (1) for $z = a$, A_b that for $z = b$ etc. Remembering that z is to be considered unity, we have by equating (3) with (2)

$$B(\alpha a^p + \beta b^p + \text{etc.}) + C(\alpha a^q + \beta b^q + \text{etc.}) + \text{etc.} =$$

$$B\frac{\sigma}{p+1} + C\frac{\sigma}{q+1} + \text{etc.} \ldots (4)$$

The disposable terms, included within the brackets on the left-hand side of this last equation are αa, βb, etc., viz., the fractions, and the weights assigned to the corresponding functions representing say sections or ordinates thereat: we propose to investigate the general relations which subsist among these—when so determined as to satisfy this last equation, viz. (4). Or to restate this in the light of an application in solid geometry of the results of such investigation, the inquiry may be thus expressed :—

In a solid, whose right section is the function (1) of the distance along its z axis, what weight should be assigned to the sections at different distances on that axis so as to give the mean value of the section ; and conversely at what points thereon may the xy planes be taken, so that with equal, or with any other definite system of weights, their mean shall be the mean cross-sectional area of the solid ?[1] A similar statement will apply to the case of ordinates and areas, since mathematically it is identical in form.

2. *General relation between indices, number and positions of sections, and weight-coefficients.*—In order that a relation of the character indicated may obtain, it must be wholly independent of the values of the constants, viz., A, B, C etc. The necessary and

[1] Determined by the expression $A_m = V_z / z$.

sufficient condition for this is, that each quantity included within brackets on the left-hand side of (4) must be equal to the corresponding quantity within brackets on the right hand side; that is to the quantity which is to be multiplied by the same constant. Or

$$\alpha a^u + \beta b^u + \gamma c^u + \text{ etc.} = \frac{\alpha + \beta + \gamma + \text{etc.}}{u+1} \quad \ldots\ldots\ldots(5)$$

where u denotes p, q, or r, etc. This last equation may be written,

$$\alpha\left(a^u - \frac{1}{u+1}\right) + \beta\left(b^u - \frac{1}{u+1}\right) + \gamma\left(c^u - \frac{1}{u+1}\right) + \text{etc.} = 0 \ldots\ldots(6).$$

It will therefore be requisite to solve merely a system of equations of this last form, viz. (6), the *quæsitum* being α, β, etc., when the indices are supposed known. Put

$$\left.\begin{array}{lll} a_1 = a^p - \dfrac{1}{p+1}\ ; & b_1 = b^p - \dfrac{1}{p+1}\ ; & \text{etc.} \\ a_2 = a^q - \dfrac{1}{q+1}\ ; & b_2 = b^q - \dfrac{1}{q+1}\ ; & \text{etc.} \end{array}\right\} \ldots\ldots(7)$$

and similarly throughout: then the system of equations of the type in question, viz. (6) is simply the linear system

$$\left.\begin{array}{l} a_1\alpha + b_1\beta + \ldots + n_1\nu = 0 \\ a_2\alpha + b_2\beta + \ldots + n_2\nu = 0 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \ldots \\ a_m\alpha + b_m\beta + \ldots + n_m\nu = 0 \end{array}\right\} \ldots\ldots (8)$$

there being n terms in each of the m lines or rows; or, disregarding the zeros, say n columns and m lines; that is an *assemblage* of m linear homogeneous equations in n variables. Hence if $n = m + 1$, then although there will be a one-fold infinity of solutions, the *ratios* of α, β, γ, etc., will be determinate;[1] and since these represent *relative* weights, they are all that are needed. Consequently,

PROP. (a). *In order that the ratios of the weight-coefficients, positive or negative, of values of the original function, arbitrarily taken for any different values of the variable, shall be determinate, it is necessary that, in general, the arbitrary values be* m + 1 *in number,* m *being the number of different indices in the function.*

[1] It is obvious that in (8) any common multiplier of all the terms will not vitiate any equation, hence the relative value of the variables is all that such a system can furnish.

We proceed to the solution for the evaluation of these ratios.

3. *Determination of the ratio of the* m + 1 *weight-coefficients, when the number* m *of indices is one less than the number of values of the variable.*—Let the *ratio* of the weights be denoted by

$$\alpha' = \alpha/\nu\ ;\ \beta' = \beta/\nu\ ;\ldots\text{etc.}\ldots\ldots\ldots(9)$$

then, since each term is divided by ν, equations (8) may be written:

$$\left.\begin{array}{l} a_1\alpha' + b_1\beta' + \ldots + n_1 = 0 \\ a_2\alpha' + b_2\beta' + \ldots + n_2 = 0 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \ldots \\ a_m\alpha' + b_m\beta' + \ldots + n_m = 0 \end{array}\right\}\ldots\ldots(10)$$

in which $m = n - 1$; that is, there are m lines or rows, and $m + 1$ columns. Let the *determinant* of the mth order

$$\Delta \equiv \begin{vmatrix} a_1 & b_1 & \ldots & m_1 \\ a_2 & b_2 & \ldots & m_2 \\ \cdot & \cdot & \ldots & \cdot \\ \cdot & \cdot & \ldots & \cdot \\ a_m & b_m & \ldots & m_m \end{vmatrix} \quad \ldots\ldots\ldots(11),$$

in which m is the coefficient of the term, μ' say, in the mth or $(n-1)$th column in (10); and let $\Delta_1, \Delta_2, \ldots \Delta_m$ denote the determinants derived from (11) by substituting, for the 1st, 2nd, and mth or $(n-1)$th columns therein, the n or final column in (10): we shall then have for the ratios of the weight-coefficients, ν being taken as unity,

$$\alpha' = \frac{\alpha}{\nu} = -\frac{\Delta_1}{\Delta}\ ;\ \beta' = \frac{\beta}{\nu} = -\frac{\Delta_2}{\Delta}\ ;\ \ldots\mu' = \frac{\mu}{\nu} = -\frac{\Delta_m}{\Delta}\ ;\ldots(12)$$

provided that Δ is not 0, which since a, b, c, etc. and p, q, r, etc., are both positive and in ascending order of magnitude may readily be demonstrated as usually true.

4. *Number of indices greater than the number of values of the variable, diminished by unity.*—If (10) $m = n + k$, $k + 1$ equations will exceed the number necessary to determine the ratio α', β' etc.; hence, unless $k + 1$ suitable conditions are imposed, that number of equations will be inconsistent. In general, therefore, the number of different indices should not exceed $n - 1$.

Since this last number of equations determine α', β' etc.; and since also a, b etc. are by hypothesis fixed quantities, the problem of suitably conditioning all equations beyond the $(n-1)$th will depend upon exponential relations. Let the index of a, b, etc., in the $(n+k)$th equation—that is the mth line or row in (8)—be u; then from (7), (9) and (10) we have, similarly to (6)

$$a'\left(a^u - \frac{1}{u+1}\right) + \beta'\left(b^u - \frac{1}{u+1}\right) + \ldots + \left(n^u - \frac{1}{u+1}\right) = f(u) = 0 \ldots (13)$$

as the general form of the equation, in which u is to be so determined as to make its value zero. It is obvious that the values p, q, r etc. are all solutions of this equation: consequently any higher index than that of the mth line or row in equations (8), must be a solution of (13) other than those already to hand. Consequently,

PROP. (b). *If the number of indices in the original function exceed by* k, *any given number of arbitrary values thereof,* k + 1 *of the indices must be conditioned.*

The condition is that $f(u) = 0$, where the function is of the form (13).

5. *Number of indices less than the number of values of the variable diminished by unity.*—If on the other hand the number of indices in (10) be $m = n - k$, then there will be $k - 1$ too few equations for the determination of the ratios of the whole of the weight-coefficients: *i.e.*, there will in general be a k-fold infinity of solutions, and $k - 1$ of the ratios or k of the weights may be arbitrarily assumed, or $k - 1$ suitable conditions may be imposed upon them. Consequently

PROP. (c). *If any given number of arbitrary values of the original function, exceed by* k *the number of different indices therein, then* k − 1 *of the weight-coefficient-ratios, or* k *coefficients must be arbitrarily assigned, before the ratios of the remainder can become determinate.* The *ratio* may be expressed of course in terms of any other weight-coefficient, hence the assumption of $k - 1$ ratios is equivalent to assuming k weights absolutely.

6. *Determination of the* n − k = m *weights.*—Reverting to equation (8), the ratio, in terms of which the $k - 1$ others are

expressed, will of course be unity; so that whether $k-1$ ratios, or k absolute values are assigned, the result is the same, viz., that there are m linear equations in m variables. These k terms are then known terms, or more correctly, terms that can be numerically evaluated; they may therefore be summed and denoted by κ_1, κ_2, etc. Thus (8) takes the form

$$a_k a + b_k \beta + \ldots\ldots + \kappa_k = 0 \quad \ldots\ldots\ldots (14)$$

in which k has all values from 1 to m. Hence, as before, writing Δ for the determinant of the mth order, whose *constituents* are the coefficients of the quantities to be determined; and Δ_1, Δ_2, etc. for the determinants derived therefrom by substituting the κ or absolute column for the first and second columns etc., we have again

$$a = -\frac{\Delta_1}{\Delta}; \quad \beta = -\frac{\Delta_2}{\Delta}; \quad \text{etc.} \ldots\ldots\ldots (15)$$

in which a, β, etc. may be considered as ratios merely, whether $k-1$ *ratios*—one of the others being taken as unity—or k weight-coefficients, have been assigned.

7. *Position of a single section.*—Suppose the original function to be

$$A_z = A + Bz^p, \quad \ldots\ldots\ldots\ldots (16)$$

then either directly, or by propositions (a) (b) and (c), it is evident that a single value of the variable, or "section"[1] may be taken at which the value of the function shall be a mean, (*i.e*, ordinate or area). Thus :—

PROP. (d). *If the original function have one positive index only a single mean value may be taken at a point on the axis determined by the index.*

The position of the point is found as follows :—

$$a = \frac{1}{\sqrt[p]{(p+1)}} \quad \ldots\ldots\ldots (17)$$

or logarithmically

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[1] The weight-coefficient a will of course be unity. The "section" is the point on the axis where the value of the function is a mean value, in this case.

$$\log a = -\frac{1}{p}\log(p+1) \quad \ldots\ldots\ldots(17a)^1$$

from which the following numerical values for a, with the argument p, are calculated and shown by curves No. 1. Fig. 1.

I.—*Position of section of axis, for a "one-term" formula.*

Index.	a	Index.	a	Index.	a
0	·3678794	2	·5773502	9	·7742636
$\frac{1}{4}$	·4095999	3	·6299605	10	·7867934
$\frac{1}{3}$	·4218751	4	·6687430	11	·7977974
$\frac{1}{2}$	·4444444	5	·6988271	12	·8075536
$\frac{2}{3}$	·4647581	6	·7230203	13	·8162746
1	·5000000	7	·7429969	14	·8241257
$1\frac{1}{2}$	·5428836	8	·7598357	15	·8312380
		∞	1.0000000		

NOTE.—a is the distance along the axis (= 1) from the initial end.

A formula for area or volume depending upon the ordinate or sectional area (16) at some particular point on the axis (z) may be called a "*one-term formula*," that is, V denoting the area or volume,

$$V = zA_1 \quad \ldots\ldots\ldots\ldots(18)$$

A_1 being the ordinate or cross-sectional area at the point determined by (17).

8. *Positions of two sections.*—Let the function of z be

$$Az = A + Bz^p + Cz^q \quad \ldots\ldots\ldots\ldots(19)$$

and first let us suppose the weights of the selected values of the function to be equal. Then from (7) and (8) we have the symmetrical equations :—

$$a^p + b^p = \frac{2}{p+1} \text{ and } a^q + b^q = \frac{2}{q+1} \quad \ldots\ldots\ldots(20)$$

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1 The limits are somewhat peculiar. Suppose p to be very small, then $-\frac{1}{p}\log_e(1+p) = -\frac{1}{p}(p - \frac{p^2}{2} + \frac{p^3}{3} - \text{etc.}) = -(1 - \frac{p}{2} + \frac{p^2}{2} - \text{etc.})$ that is -1 when p is 0. Hence for the zero value of p, $\log_{10} a = -·43429448$, or $\bar{1}·56570552$, that is $a = ·3678794$. Again when p is very large the value of $-\frac{1}{p}\log p$ is required, since the unit will be negligible in relation to p. Put $e^P = p$ so that $P = \log_e p$. Then since $e > 1$, if $P = \infty$, $p = \infty$. Hence obviously $\frac{e^P}{P} = \frac{p}{\log_e p} = \infty$ and the reciprocal $\frac{\log_e p}{p} = 0$, that is $a = 1$.

to solve. If, for particular values of p and q, identical values for a and also for b can be derived, they will mark points on the z axis satisfying both equations; and the mean of the values of the function at these points will be the mean of all values of the function (19) from 0 to 1.

We consider first values symmetrically situated with respect to the middle point on the axis. Put therefore

$$a=\tfrac{1}{2}-\xi \text{ and } b=\tfrac{1}{2}+\xi \quad \ldots\ldots\ldots\ldots(21)$$

so that $a+b=1$; then expanding (20) and dividing by 2,

$$\tfrac{1}{2}(a^p+b^p)=\frac{1}{2^p}+\frac{p(p-1)}{2!\quad 2^{p-2}}\xi^2+\frac{p(p-1)(p-2)(p-3)}{4!\quad 2^{p-4}}\xi^4+\text{etc.}=\frac{1}{p+1}(22)$$

p of course having any positive value whatever. If p be fractional the series is infinite but convergent, since both the coefficients and the powers of ξ, ξ being a proper fraction, are convergent. If p be integral the series is finite, having $p/2$ terms in ξ, if p be even; or $(p-1)/2$ if p be odd. Or again, writing $b=1-a$, expanding, and dividing by $-p$, we have, when p is odd,

$$a-\frac{p-1}{2!}a^2+\frac{(p-1)(p-2)}{3!}a^3-\ldots-a^{p-1}=\frac{p-1}{p(p+1)}\quad\ldots\ldots\ldots(23),$$

and when p is even

$$a-\frac{p-1}{2!}a^2+\frac{(p-1)(p-2)}{3!}a^3-\ldots+a^{p-1}-\frac{2a^p}{p}=\frac{p-1}{p(p+1)}\quad\ldots.(23a);$$

that is, the equation for any even integer is of the same degree as that for the odd integer next above it, as is obvious also from (22). Since also if p be 1, ξ or a may have any value from 0 to $\tfrac{1}{2}$, it is at once evident that two equations can be simultaneously satisfied as long as the index of one is unity. Therefore

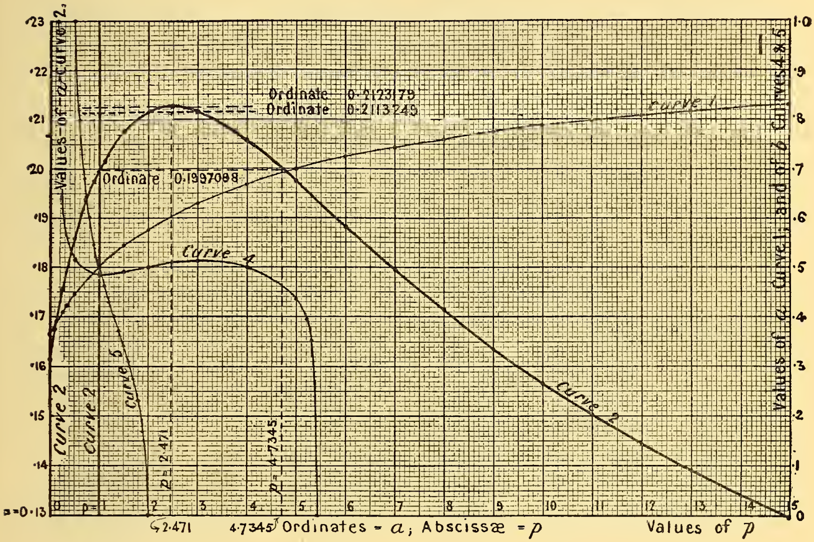
PROP. (*e*). *If one of the positive indices in the original function be unity, then always two points on the axis, symmetrically situated with respect to its centre, may be taken, so that the mean of the values of the function at those points, will be the mean value of the function.* In other words a "*two-term formula*" will always apply in such a case.[1]

---

[1] This result was obtained for prismoidal solids, in which the sectional area is a quadric function of the z coordinate (*i.e.* $p=1$, $q=2$) by Echols, Annals of Mathematics 1894; I have not, however, seen his article. See also, "Prismoidal Formula and Earthwork," by T. U. Taylor, 1898—Wiley and Sons, New York.

The following computed values of a are shewn by Curve No. 2, Fig. 1, on which they are indicated by dots.

Fig. 1.



Curve 1.—The ordinates indicate the distance from the initial line or plane at right angles to the axis, to the point thereon where the line or plane has a mean value corresponding to the index p; the total length of the axis being considered as unity.

Curve 2.—Graph of the function $a^p - (1-a)^p - 2/(p+1) = 0$; p being the independent and a the dependent variable: a will be the distance from the terminals of the axis of two lines or planes satisfying the corresponding indices, which constitute the abscissæ of the graph.

Curve 4.—Middle and terminal sections, the indices 2 and 4 being made conjugate by suitable coefficients.

Curve 5.—Shewing the relation between index and the position of an intermediate section, when it and the terminal sections have equal weight.

9. *Limiting positions of two symmetrically situated sections.*—Let $a = f(p)$, in which p, or u in (5), is to be regarded as the independent variable; then for symmetrically situated sections, a real and positive value for a may be found by suitable methods[1] from

---

[1] For very large values of p, we may put, at any rate for a first approximation,

$$a = 1 - \log^{-1}\left(\frac{1}{p} \log \frac{2}{p+1}\right)$$

the equation

$$a^p + (1-a)^p = \frac{2}{p+1} \quad \ldots\ldots\ldots (23b).$$

Restricting the consideration to real positive values between 0 and $\frac{1}{2}$ it will be found that for $p = 1/\infty$,[2] $a = 0{\cdot}1613782$; for $p = \infty$, $a = 0$; while for $p = 1$, a may have any value from 0 to $\frac{1}{2}$; but for all other positive values of p, the ordinates a corresponding to the abscissæ p are terminated by a continuous curve, the values for $p = 0$ and $p = 1$ being respectively about 0·1613782 and 0·1997088, and for $p =$ about 2·471 reaching a maximum of about 0·2123179.

II.—*Positions of two symmetrically situated sections.*[3]

Index.	a	Index.	a	Index.	a
·00	·1613782[4]	2·45	·2123160	6	·1880587
·10	·1674245	2·46	·2123172	7	·1796675
·25	·1752683	2·47	·2123178	8	·1713937
·50	·1857300	2·471	·2123179	9	·1637491
·90	·1974990	2·48	·2123176	10	·1567357
1·00	·1997088[5]	2·49	·2123164	11	·1503130
1·00 also	0 to 0·5	2·50	·2123147	12	·1444266
1·10	·2016800	2·60	·2122537	13	·1390213
1·50	·2075308	3·00	·2113249[6]	14	·1340444
2·00	·2113249[6]	4	·2056192[7]	15	·1294440
2·40	·2122970	5	·1974029[8]	∞	·0000000

NOTE.— $b = 1 - a$.

$\log^{-1} x$ denoting the number of which x is the logarithm. Since a is numerically always less than 0·3, the powers of a are rapidly convergent. For $p = 9{\cdot}5$, a is about 0·16; hence to 7 places of figures, and for p equal 10 or more, $a^p = 0$: therefore $b^p = 2/(p+1)$, from which the above formula is derived. Again, for exceedingly small values of p, b^p will be much nearer unity than a^p; hence we may commence the approximation by assuming that $a^p = 2/(p+1) - 1$, and put afterwards the deduced value of b^p in the place of unity, Other cases may be calculated by (22) or (23), or by such methods as will readily suggest themselves to computers.

2 Strictly for $p = 0$, a is indeterminate; but as p becomes very small a approaches the limiting value given.

3 The seventh place of figures is generally uncertain.

4 $a^0 = 1$ and a may have any value whatsoever: in itself it is therefore indeterminate. In the case considered however it really has a definite limit which may be found as follows :—

$$a^p + (1-a)^p = a^p + 1 - pa\left[1 + \frac{a}{2}(1-p) + \frac{a^2}{3}\left(1-p+\frac{p^3}{3}\right) + \text{etc.}\right] = 2(1-p+p^2-)$$

From these results, and the figure representing them, it is evident that :—

PROP. (*f*). *Two symmetrically situated sections cannot be at a greater distance from the terminals of the axis than about 0·2123179, the length of the axis being regarded as unity; at that distance* p *and* q *are respectively 1 and about 2·471, and no other values can be satisfied.*

Since the curve in Fig. 1 is intersected by the ordinate for $p = 1$, at the distance of about 0·1997088 from the axis of abscissæ; for values of a greater than this, and less than the maximum, two indices greater than unity can be satisfied, together with unity

---

Rejecting the second and higher powers of p, since it is extremely small, as inappreciable, and transposing we have

$$a^p = 1 - p\left(2 - a - \frac{a^2}{2} - \frac{a^3}{3} - \text{etc.}\right)$$

Taking logarithms, and again rejecting the 2nd and higher powers of p

$$p \log_e a = -p\left(2 - a - \frac{a^2}{2} - \text{etc.}\right)$$

Dividing both sides by $-p$, applying the operator $\log^{-1}$, transposing, and dividing the numerator and denominator of the left hand number by a, we have

$$\frac{1}{a} + 1 + a + a^2 + \text{etc.} = \overset{-1}{\log_e} 2 = \overset{-1}{\log_{10}} 2\mu = 7{\cdot}3890561$$

μ being the modulus of common logarithms; so that

$$\frac{1}{a} + a + a^2 + \text{etc.} = 6{\cdot}3890561$$

from which a is found by suitable methods of approximation to be ·1613782.

[5] In general a is of course indeterminate and may have any value whatsoever. The curve studied has a limiting value for $p = 1$, which may be found by putting $1 + h$ for the index. Rejecting powers of h

$$a^{1+h} + b^{1+h} = a(1 + h\log a) + b(1 + h\log b) = 2/(2+h) = 1 - \tfrac{1}{2}h$$

from which after putting $b = 1 - a$, remembering that

$$\log(1-a) = -\frac{a}{1} - \frac{a^2}{2} - \frac{a^3}{3} - \text{etc.}$$

dividing by ah, and arranging the terms in the order of their numerical magnitude, we obtain

$$\frac{1}{2a} + \log_e a + \frac{a}{1.2} + \frac{a^2}{2.3} + \frac{a^3}{3.4} + \ldots \frac{a^n}{n(n+1)} + \text{etc.} = 1$$

from which by suitable methods the limiting value of a may be found. The convergency of the first three terms is very slight, consequently in practical computation it is advantageous to tabulate the sum of these three at least. See § 16 hereinafter.

[6] Both roots are $\frac{1}{2} \pm \frac{1}{6}\sqrt{3}$. [7] $\frac{1}{2} \pm \sqrt{(\sqrt{\tfrac{7}{10}} - \tfrac{3}{4})}$. [8] $\frac{1}{2} \pm \sqrt{(\sqrt{\tfrac{7}{60}} - \tfrac{1}{4})}$.

itself; while for less values of a one index will be less than unity and the other greater than 4·7345; inasmuch as this ordinate meets the curve again for a value of p of about that amount. Consequently:—

PROP. (g). *If the symmetrically situated sections be at a distance of 0·1997088 from the terminals of the axis, considered as of unit length, only two indices can be satisfied viz.,* $p = 1$ *and* $q = 4·7345$.

10. *Two symmetrically situated sections and their conjugate indices.*—In Fig. 1, any line drawn parallel to the axis of abscissæ at a less distance than 0·2123179 cuts it in two points, and cuts also the heavy vertical line, viz. the ordinate for $p = 1$. For any definite value of a let the abscissæ of the intersections be called *conjugate.* Then the limits are as follows :—

	Lesser index	Greater index
$a > 0·1997088$	1 to 2·471;	2·471 to 4·7345
$a < 0·1997088$	0 to 1 ;	4·7345 to ∞

It happens that the indices 2 and 3 are conjugate to one another, a having the value in each case $\frac{1}{2} - \frac{1}{6}\sqrt{3}$, or 0·2113249, consequently a "two-term formula" applies not only to the prismoid and prismatoid, but to figures and solids whose ordinates or right-sections are cubic functions of the distances along the axes. Or

PROP. (h). *If two symmetrically situated sections be at a distance of not more than 0·2123179 from the terminals of the axis, considered as of unit length, then in general the index 1 together with two conjugate indices, one greater, and one less than 2·471 can be satisfied.*

Let u and v denote the conjugate indices and A_1 and B_1 the corresponding symmetrical positions, then for the function

$$A_z = A + Bz + Cz^u + Dz^v$$

we shall have $V = \frac{1}{2}z\,(A_1 + B_1)$ ....(24).

And further as a special case :—

PROP. (i). *If two sections be taken 0·2113249 from the terminals of the axis, considered as of unit length, then the indices satisfied will be 1, 2, and 3.* That is to say a symmetrical two-term formula applies to a solid whose right-sectional area is a cubic function of the distance along its axis; the same is true also for an area, where the ordinate is similarly a cubic function.[1] If A_1 and B_1 denote the values of the ordinates or sections at 0·2113249 and 0·7886751, then whenever

$$A_z = A + Bz + Cz^2 + Dz^3$$

we shall have

$$V = \tfrac{1}{2} z (A_1 + B_1) \quad \ldots\ldots\ldots (25).$$

11. *Asymmetrical positions of two sections.*—Since the number of fractions is the same as the number of indices they cannot both be arbitrarily taken: Prop. (a) § 2. Let the weight unity be assigned to the section at a, so that the weight of that at b will be relative thereto: we shall then have from (5)

$$a^p + \beta b^p = \frac{1+\beta}{1+p}, \text{ and } a^q + \beta b^q = \frac{1+\beta}{1+q} \quad \ldots\ldots\ldots (26)$$

so that the condition to be satisfied is

$$(1+p)(a^p + \beta b^p) = (1+q)(a^q + \beta b^q) \quad \ldots\ldots\ldots (27);$$

as might be anticipated this does not lead to simple relations. The only cases that appear to be worth consideration are $a = 0$, and $b = 1$, the former involving the determination of the value and weight of b: the latter the value of a and weight either of a or b.

If $a = 0$, then its powers are also zero, putting its weight $= 1$, we have at once from (27)

$$b = \left(\frac{1+p}{1+q}\right)^{\frac{1}{q-p}}; \text{ or logarithmically } \log b = \frac{\log(1+p) - \log(1+q)}{q-p} \quad (28)$$

and when b is obtained

$$\beta = \frac{1}{b^p(1+p) - 1} = \frac{1}{b^q(1+q) - 1} \quad \ldots\ldots\ldots\ldots (29)$$

Putting A_0 for the initial ordinate or area, and B_1 for that at b, the formula for the area or volume will be

$$V = \frac{1}{1+\beta} z (A_0 + \beta B_1) \quad \ldots\ldots\ldots\ldots (30)$$

and the integral solutions up to the fourth power are contained in the table hereunder :—

III.—*Position and coefficients of second section, the first being the initial section.*

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[1] A less general proof of this is given by T. U. Taylor, *op. cit.*, pp. 99 – 100

Indices.		b = Distance along axis.		β = weight-coefficients of B_1		General coefficient $\frac{1}{(1+\beta)}$
$\frac{1}{2}$	1	$\frac{9}{16}$ or	0·56250000	8	or 8·0000000	0·1111111
1	2	$\frac{2}{3}$,,	0·6666667	3	,, 3·0000000	0·2500000
1	3	$\frac{1}{2}\sqrt{2}$,,	0·7071068	$1+\sqrt{2}$	,, 2·4142136	0·2928933
1	4	$\sqrt[3]{\frac{2}{5}}$,,	0·7368063	$1/(2\sqrt[3]{\frac{2}{5}}-1)$	,, 2·1114303	0·3213952
2	3	$\frac{3}{4}$,,	0·7500000	$1\frac{5}{11}$	,, 1·4545455	0·4074074
2	4	$\sqrt{\frac{3}{5}}$,,	0·7745967	$1\frac{1}{4}$	,, 1·2500000	0·4444444
3	4	$\frac{4}{5}$,,	0·8000000	$\frac{125}{131}$	,, 0·9541985	0·5117187

These, and the more extended results in Table IIIA., are the b curves shewn on Fig. 2. The results of Table I. are also included for completeness: these last correspond to $p=0$.

IIIA.—*Position of second section the first being the initial section.*

Index p	Indices q. 0	1	2	3	4	5	6	7
0	·3679	5000	5774	6300	6687	6988	7230	7430
1	·5000	6066	6667	7071	7368	7598	7784	7937
2	·5774	6667	7165	7500	7746	7937	8091	8219
3	·6300	7071	7500	7788	8000	8165	8298	8409

Index p	Indices q. 8	9	10	11	12	13	14	15
0	·7598	7743	7868	7978	8076	8163	8241	8312
1	·8067	8178	8274	8360	8435	8503	8564	8620
2	·8327	8420	8501	8572	8636	8693	8745	8792
3	·8503	8584	8654	8717	8773	8823	8868	8909

The above results are of course decimal throughout.

If on the other hand we make $b=1$ and determine a, the relations are less simple. As before the weight-coefficient of the latter, viz. a, may conveniently be taken as unity. This gives then, instead of (26)

$$a^p+\beta=\frac{1+\beta}{1+p}, \text{ and } a^q+\beta=\frac{1+\beta}{1+q} \;\ldots\ldots\ldots\ldots(31);$$

consequently a can be found only by solving the equation

$$a^p-\frac{p(1+q)}{q(1+p)}a^q-\frac{q-p}{q(1+p)}=0\ldots\ldots\ldots(32)$$

and then β from

$$\beta=\frac{1}{p}\left\{1-(1+p)a^p\right\}=\frac{1}{q}\left\{1-(1+q)a^q\right\}\ldots\ldots\ldots(33)$$

The integral solutions up to the third power inclusive are exhibited in Table IV. hereunder.[1]

IV.—*Positions of first section; the second being the terminal section.*

Indices. p	q	a = Distance along axis.	β = coefficient of B_0	General coefficient $1/(1+\beta)$
$\frac{1}{2}$	1	0·2500000	0·5000000	·6666667
1	2	0·3333333	0·3333333	0·7500000
1	3	0·3660254	0·2679492	0·7886751
2	3	0·4215352	0·1692577	0·8552434
2	4	0·4472136	0·2000000	0·8333333

The formula for volume or area will of course be

$$V = \frac{1}{1+\beta} z (A_1 + \beta B_0) \quad \text{.........(34)}$$

A_1 denoting the area or ordinate at a, and B_0 that at the terminal. For $p = 1$, $q = 2$, we may instead of (30) and (34) write

$$V = \tfrac{1}{4} z (A_0 + 3B_{\frac{2}{3}}) = \tfrac{1}{4} z (3A_{\frac{1}{3}} + B_0) \text{.........(25)}^2$$

A_0 denoting as before the initial section or ordinate: this reciprocal symmetry does not extend to other cases. Some of the formulæ of III. and IV. may be expressed in the following forms:—

$$\left.\begin{array}{ll} p = \frac{1}{2}\,;\; q = 1 :— & V = \frac{1}{9} z (A_0 + 8B_{\frac{9}{16}}) \\ & V = \frac{1}{3} z (2A_{\frac{1}{4}} + B_0) \\ p = 2\,;\; q = 4 :— & V = \frac{1}{9} z (4A_0 + 5B_{\sqrt{\frac{3}{5}}}) \\ & V = \frac{1}{6} z (5A_{\sqrt{\frac{1}{5}}} + B_0) \end{array}\right\} \text{.........}(35a)^3$$

in which the suffix indicates the distance along the axis from the A end. By means of (28), (29), (32) and (33) it is easy to develope similar expressions to these last; they would however probably be of no practical moment, and are not here further considered.

---

[1] The equations equal to zero, and the roots are as follows:—

$p \cdot q$	a Equation.	β Equation.	Values of a and β
1 . 2	$a^2 - \frac{4}{3}a + \frac{1}{3} = 0$;	$\beta = 1 - 2a = \frac{1}{2}(1 - 3a^2)$;	$a = \frac{1}{3}$; $\beta = \frac{1}{3}$
1 . 3	$a^3 - \frac{3}{2}a + \frac{1}{2} = 0$;	$\beta = 1 - 2a = \frac{1}{3}(1 - 4a^3)$;	$a = \frac{1}{2}(\sqrt{3} - 1)$; $\beta = 2 - \sqrt{3}$
2 . 3	$a^3 - \frac{9}{8}a^2 + \frac{1}{8} = 0$;	$\beta = \frac{1}{2}\,1 - 3a^2) = \frac{1}{3}(1 - 4a^3)$;	$a = \frac{1}{16}(1 + \sqrt{33})$; $\beta = \frac{1}{256}(77 - 3\sqrt{33})$

[2] Kinkelin's formula.—Grunert's Archiv., Bd. XXXIX., pp. 181–186, 1862.

[3] Puller's formulæ. See 'Erweiterung der Prismatoidformel.'—Zeit. für Vermess., Bd. XXIX., p. 36, January 1900.

12. *Three symmetrical sections: viz. a middle and the terminal sections.*—Turning to the case of three sections, obviously the simplest possible condition in regard to their position is,—$a = 0$, $b = \frac{1}{2}$, $c = 1$. If further we make their weights symmetrical, α and γ may each be unity, and then we can determine β: this would be the simplest possible solution in regard to the weight-coefficients. Equation (5) thus becomes, keeping the fraction b general,

$$\beta \left(b^p - \frac{1}{p+1}\right) + \frac{p-1}{p+1} = 0 \ldots\ldots (36)$$

from which if $b = \frac{1}{2}$,

$$\beta = \frac{(1-p)2^p}{(1+p) - 2^p} = \frac{2^p(p-1)}{2^p - (p+1)} \ldots\ldots\ldots (37)$$

from which values of β may be readily computed. The following table, giving the values for a considerable range; is the basis from which the curve β in Fig 2 is plotted. The general coefficient will be $1/(2+\beta)$, see (38) hereinafter.

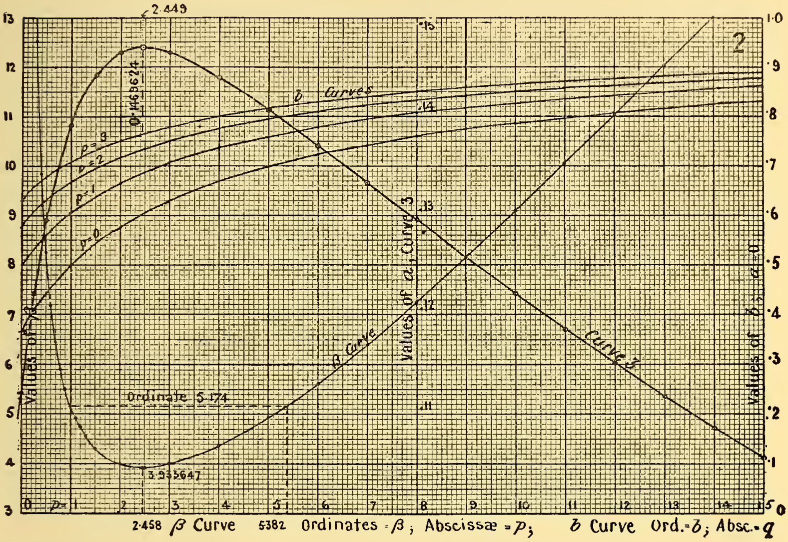
V.—*Weight-coefficients for the middle-section, the weights of initial and terminal sections being unity.*

Index p	β	$\frac{1}{(2+\beta)}$	Index p	β	$\frac{1}{(2+\beta)}$	Index p	β	$\frac{1}{(2+\beta)}$
0·0	∞	0	1·01	5·1494	·13987	4	4·36$\dot{3}\dot{6}$	·15714
0·1	31·884*	·02951	1·10	4·9224	·14446	5	4·9231	·14444
0·2	17·913*	·05022	1·2	4·7176	·14886	5·382	5·174	·13939
0·3	12·516*	06889	1·3	4·5517	·15263	6	5·6140	·13134
0·4	9·8358	·08449	1·5	4·3060	·15858	7	6·4 exact	·11905[6]
0·5	8·2426[1]	·09763	2·0	4· exact	·16667[3]	8	7·2461	·10815
0·6	7·1934	·10877	2·40	3·9346	·16850	9	8·1594	·09843
0·7	6·4554	·11827	2·45	3·9337	·16853	10	9·0977	·09010
0·8	5·9122	·12639	2·458	3·9336[4]	·16853	11	10·0589	·08292
0·9	5·4993	·13334	2·5	3·9341	·16852	12	11·0350	·07671
0·99	5·2063	·13877	2·6	3·9387	·16839	13	12·0205	·07133
1·00	5·1741[2]	·13939	3·0	4· exact	·16667[5]	14	13·0119	·06661[7]

Since β may have any value whatever for $p = 1$, any value of β greater than 3·933647 will satisfy the index unity together with two conjugate indices, as is evident from the β curve on Fig. 2. Consequently

1 $4+3\sqrt{2}$; 2 Really indeterminate, the curve crosses at this ordinate; 3 Exactly $\frac{1}{6}$; 4 More exactly 3 933647; 5 Exactly $\frac{1}{6}$; 6 Exactly $\frac{10}{84}$; 7 For $p = \infty$, $\beta = \infty - 1$.

Fig. 2.



b Curves.—The ordinates denote the distance of the second section of of the axis from the first and initial section—the whole axis being unity—corresponding to pairs of values of the index, one series of values being the abscissæ.

β Curve.—The ordinates shew the weight that must be assigned to a middle section, that of the terminal sections being unity, in order to satisfy any index and its conjugate.

Prop. (*j*). *Two terminal sections and a middle section will in general satisfy the index unity together with two conjugate indices the one greater and the other less than 2·458; these indices are dependent upon the coefficient assigned to the middle section, which coefficient can in no case be less than 3·933647, viz., than its value at the critical index 2·458.*

The value 1 is conjugate to 5·382, corresponding to the coefficient $\beta = 5{\cdot}174$; consequently at that point $p = 1$, $q = 5{\cdot}382$ and no other index can be satisfied. Again if $p = 1$ and $q = 2{\cdot}458$, the coefficient β will be 3·933647 and no other values can be satisfied. Again 2 and 3 are conjugate indices, and correspond to the weight-coefficient 4 : therefore

PROP. (k). *If the coefficient 4 be assigned to the middle section, the indices satisfied will be 1, 2 and 3, and none other.*

The formula for volume or area in the case above considered, and when the original function

$$A_z = A + Bz + Cz^u + Dz^v,$$

u and v as before being conjugate ; is :—

$$V = \frac{1}{2+\beta} z\,(A_0 + \beta B_m + C_0) \ldots\ldots\ldots (38)$$

the subscript 0 denoting terminal sections, and m a middle section.

13. *A middle section, and two other sections equidistant therefrom, all of equal weight.*—In this case, if each section have unit weight, (5) reduces to

$$a^p + (1-a)^p = \frac{3}{p+1} - \frac{1}{2^p} \ldots\ldots\ldots (39)$$

which is clearly analogous to (23b) § 9, and may similarly to (22) be written

$$\frac{p(p-1)}{2\,!\,2^{p-2}}\xi^2 + \frac{p(p-1)(p-2)(p-3)}{4\,!\quad 2^{p-4}}\xi^4 + \text{etc.}\ldots = \frac{3}{2}\left(\frac{1}{p+1} - \frac{1}{2^p}\right)\ldots (40)$$

By these equations the results in Table VI. are calculated ; the curve is shewn in Fig. 2, Curve 3.

VI.—*Position of two sections equidistant from a middle-section.*

Index.	a	Index.	a	Index.	a
0	·1121500[1]	3	·1464466[3]	10	·1221566
·25	·1221114	4	·1439328	11	·1185688
·5	·1295311	5	·1406342	12	·1151021
1	·1391506[2]	6	·1370589	13	·1117833
1·5	·1442089	7	·1333554	14	·1086176
2	·1464466[3]	8	·1295980[4]	15	·1056064
2·449	·1469624	9	·1258477	∞	·0000000

NOTE.—$b = \frac{1}{2}$; $c = 1 - a$. The coefficient of each section is unity.

1 The limiting value may be found as previously shewn : the equation is $\log_e a - \frac{a}{1} - \frac{a^2}{2} - \ldots - \frac{a^n}{n} -$ etc. $= -3 + \log_e 2 = -2{\cdot}3068528.$

2 The equation for the limiting value is :—

$$a \log_e a - a + \frac{a^2}{1.2} + \frac{a^3}{2.3} + \ldots + \frac{a^n}{(n-1).n} + \text{etc.} = \tfrac{1}{2}\log_e 2 - \tfrac{3}{4} = -{\cdot}4034264$$

See § 16 hereinafter for a fuller consideration of these limits.

3 Both roots, that is for $p = 2$ and $p = 3$ are the same, viz., $a = \frac{1}{2} - \frac{1}{4}\sqrt{2}$.

4 For seven places of figures, we may, after $p = 7$, put $a^p = 0$, consequently $b^p = 3/(p+1) - 1/2^p$.

From the nature of the curve we see that, in general, three indices may be satisfied, when a middle and two other sections equidistant therefrom are taken, each having equal weight, two of these indices however will be conjugate. For the same index-values the sections are nearer to the terminals than in the case of two symmetrically situated sections. The result may be summed up in the two following propositions :—

PROP. (*l.*) *When a middle section and two others equidistant therefrom, all of equal weight are taken, the latter can never be at a greater distance than ·1469624 of the length of the axis from its terminals: at that distance the only indices that can be satisfied are 1 and about 2·449.*

Remembering that the indices 2 and 3 are conjugate, we have also the second proposition :—

PROP. (*m.*) *For sections nearer the terminals of the axis than this limiting value, the index 1 and two conjugate indices may be satisfied the one greater and the other less than 2·449; and if the distances from the terminals be ·1464466 the conjugate indices satisfied, together with 1, will be 2 und 3.*

The formula for area of volume satisfying the function

$$A_z = A + Bz + Cz^u + Dz^v,$$

u and v being conjugate, is

$$V = \tfrac{1}{3}z\,(A_1 + B_m + C_1) \text{.........} (41).$$

14. *Two terminal sections and one intermediate section.*—Equation (5) in this case reduces to

$$b^p = \frac{\alpha + \beta - \gamma p}{\beta(p+1)} \text{ ....} (42)$$

The values of α, β and γ are all at our disposal, hence there is a three-fold infinity of solutions for b^p. Since the solution loses no generality by making β unity, inasmuch as α and γ merely become the *ratios* of the weight-coefficients of the terminal sections to the intermediate section, which is all that is required, the above equation becomes simply

$$b^p = \frac{1 + \alpha - p\gamma}{1 + p} \text{ ....} (42a)$$

which it is sometimes convenient to put in the form

$$b^p(1+p)+p\gamma = 1+\alpha \quad \ldots\ldots\ldots\ldots (42b)$$[1]

Thus the solution for b is

$$\log b = \frac{1}{p}\left\{\log(1+\alpha-p\gamma)-\log(1+p)\right\}$$
$$= \frac{1}{q}\left\{\log(1+\alpha-p\gamma)-\log(1+q)\right\} = \text{etc.} \ldots (43)$$

In (42) and (43) the only solutions of utility are those which give values of b lying between 0 and 1: it is moreover convenient to employ only positive values of α and γ. Hence the conditions of limitation are, β being unity,

$$-1 < (\alpha - p\gamma) < p$$

and the equation obviously can be made to satisfy any two positive values of p. The degree of the resultant equation for b will n general, be the same as the index. If however the value of b be assigned the solution for α and γ is in all cases merely linear. Table VII. indicates a few formulæ, such as may readily be deduced, the section B being at the distance b from the initial end and the other two sections, viz. A and C, being terminal sections.

VII.—*Position and coefficients of intermediate section, with coefficients of terminal sections.*[2]

$$A_z = A + Bz^p + Cz^q; \quad V = \frac{1}{\sigma} z\,(\alpha A_o + \beta B_b + \gamma C_o)$$

Indices. p	q	b	$\frac{1}{\sigma}$	α	β	γ
$\frac{1}{2}$	1	$\frac{25}{64}$	$\frac{1}{45}$	3	32	10
,,	,,	$\frac{9}{25}$	$\frac{1}{36}$	2	25	9
,,	,,	$\frac{16}{36}$	$\frac{1}{12}$	1	9	2
,,	,,	$\frac{25}{49}$	$\frac{1}{60}$	5	49	6
1	2	$\frac{2}{5}$	$\frac{1}{36}$	3	25	8
,,	,,	$\frac{3}{5}$	$\frac{1}{36}$	8	25	3
,,	,,	$\frac{1}{2}$	$\frac{1}{6}$	1	4	1
,,	,,	$\frac{4}{9}$	$\frac{1}{40}$	5	27	8
,,	,,	$\frac{5}{9}$	$\frac{1}{40}$	8	25	5
2	4	$\frac{1}{2}$	$\frac{1}{45}$	6	32	7

etc., etc., etc.

---

1 Thus we may write

$$1\tfrac{1}{2}\sqrt{b} + \tfrac{1}{2}\gamma = 2b + \gamma = 3b^2 + 2\gamma = 4b^3 + 3\gamma = \text{etc.} = 1+\alpha$$

and solve by inspection. For example, for $p=\frac{1}{2}$, $q=1$ the first and second expressions give $\sqrt{b} = \frac{1}{8}[3 \pm \sqrt{(9-16\gamma)}]$; and similarly for $p=1$, $q=2$ the second and third give $b=\frac{1}{3}[1 \pm \sqrt{(1-3\gamma)}]$.

2 The table is merely illustrative.

It is obvious that an infinite number of such expressions may be obtained, satisfying any two indices. A little consideration will shew that a definite system of weight-coefficients deduced to satisfy two indices will in general satisfy a third conjugate index. Suppose for example we put in (42) the values $\alpha = \frac{3}{16}$; $\beta = 1$; and $\gamma = \frac{7}{32}$, viz., those satisfying $p = 2$, $q = 4$ in Table VII., when $b = \frac{1}{2}$: if then we calculate the values for b corresponding to different values of p, we shall find that for $p = \frac{2}{13}$ $b = 1$, and for $p = 5\frac{3}{7}$ $b = 0$. Between $p = 2$ and $p = 4$ b is greater than $\frac{1}{2}$; and between $p =$ about $\frac{2}{3}$ and $p = 2$ less than $\frac{1}{2}$:—see Curve 4, on Fig. 1, which exhibits the whole curve between the indicated limits. Hence, with the coefficients adopted, the function

$$A_z = A + Bz^u + Cz^v + Dz^w$$

would have been satisfied, u, v, and w being the three conjugate indices.

From the figure referred to—Curve 4, Fig. 1—it is evident that u and v, or v and w, may become identical for a particular value of b: so also for particular weights the whole three may become identical. If, for example the coefficient be unity for each of the three sections, and the position of b is alone to be determined, we shall have from (5) or from (42*a*)

$$b^p = \frac{2 - p}{1 + p} \quad \text{.........(44)}$$

Since b can neither be greater than unity, nor negative, the limits of p are $\frac{1}{2}$ and 2, the corresponding limits of b being 1 and 0; hence no values outside these can be satisfied. Further since within the limits there is one and only one value of b corresponding to any definite value of p, and *vice versa*, only one value of p can be satisfied. Hence the function in such a case is reduced to

$$A_z = A + Bz^p;\ 2 > p > \tfrac{1}{2};$$

and the formula for area or volume to

$$V = \tfrac{1}{3}z\,(A_0 + B_1 + C_0) \quad \text{...........(45)}$$

The following table contains sixteen values of b between the indicated limits.

VIII.—*Two terminal sections and one intermediate, all of equal weight.*

Index.	*b*	Index.	*b*	Index.	*b*	Index.	*b*
·5	1·00000	9	·54484	1·3	·40049	1·7	·27459
·6	·80047	1·0	·50000	1·4	·37150	1·8	·23081
·7	·68165	1·1	·46289	1·5	·34200	1·9	·16995
·8	·60240	1·2	·43042	1·6	·31041	2·0	·00000

The curve is shewn in Fig. 1, see Curve 5.

The general results of this section may be summed up as follows:

PROP. (n). *When the weights of three sections, viz., two terminal and one intermediate in a definite position, are deduced so as to satisfy two indices, a third conjugate to these will in general be satisfied: two of the indices, or all three, may, with particular values for the weight-coefficients, become identical.*

15. *General result of the method of finite differences.*—If the axis z be divided into n equal parts, and sections be taken at the terminals and points of section, the areas of these may be represented by the $n + 1$ ordinates thereat. It is always possible to draw through the $n + 1$ ordinate-terminals a curve of the nth degree, so that if the order of the surface is really represented by that curve, the indices in the original function viz., p, q, r, etc., are merely 1, 2, 3,... n.

By the calculus of finite differences it is shewn that the volume or the area, may be readily expressed in terms of the first rank of differences, and n, the number of parts into which the axis is divided. To a curve or surface of the sixth degree the equation is, y denoting the first ordinate, and $\Delta^{i}y$, $\Delta^{ii}y$, etc., the first rank of differences,

$$V = \frac{z}{n}\left\{\begin{array}{l} ny + \frac{1}{2}n^2\Delta^{i}y + \frac{1}{12}(2n^3 - 3n^2)\Delta^{ii}y + \frac{1}{24}(n^4 - 4n^3 + 4n^2)\Delta^{iii}y \\ + \frac{1}{720}(6n^5 - 45n^4 - 110n^3 - 90n^2)\Delta^{iv}y \\ + \frac{1}{1440}(2n^6 - 24n^5 + 105n^4 - 200n^3 + 144n^2)\Delta^{v}y \\ + \frac{1}{60480}(12n^7 - 210n^6 + 1428n^5 - 4725n^4 + 7672n^3 \end{array}\right\} \quad (46)$$
$$- 5040n^2)\,\Delta^{vi}y + \text{etc.}$$

This may be recast in terms of the ordinates themselves by observing that the coefficients thereof, connecting them with the differences, follow the law of binomial development; that is,

$$\Delta^n y = y_n - ny_{n-1} + \frac{n(n-1)}{2\,!}y_{n-2} - \text{etc.} \;\ldots\ldots(47)$$

so that we have only to insert the proper line of coefficients from Pascal's triangle and reduce. In this way the following formulæ are obtained.

IX.—*Weight-coefficients with terminal and equidistant intermediate sections.*

$$V = \tfrac{1}{2}z(A_0 + B_0) = \tfrac{1}{6}z(A_0 + 4B_m + C_0) = \tfrac{1}{8}z(A_0 + 3B + C + D_0)$$
$$= \tfrac{1}{90}z(7_0 + 32B + 12C + 32D + 7E_0)$$
$$= \tfrac{1}{288}z(19A_0 + 75B + 50C + 50D + 75E + 19F_0)$$
$$= \tfrac{1}{840}(41A_0 + 216B + 27C + 272D + 27E + 216F + 41G_0)$$ [1]

The deduction of formulæ for volumes or areas by this method does not fully reveal the sphere of their legitimate application. For example the first formula in IX. is legitimate only when the sectional-area linearly changes with the distance along the axis: the second formula is deduced on the necessary assumption that the sectional area is a *quadratic* function of the axial distance; it proves to be absolutely correct also when that area is a *cubic* function. The third formula is derived by assuming that the sectional area function is cubic: it is a good approximation, even when the function is *quartic*, but is not exact, since it involves an

[1] "Weddle's" rule is merely an approximation. The exact expression in difference-terms is

$$V = z\,(y + 3\Delta^{i}y + 4\tfrac{1}{2}\Delta^{ii}y + 4\Delta^{iii}y + \tfrac{41}{20}\Delta^{iv}y + \tfrac{11}{20}\Delta^{v}y + \tfrac{41}{840}\Delta^{vi}y)$$

If, in this, the coefficient $\frac{41}{840}$ be changed into $\frac{42}{840}$, and if moreover the proper coefficient of D is diminished by $\frac{42}{840}$, that is if $\frac{230}{840}$ be put for $\frac{272}{840}$ in the above formula, then the formula may be simplified into Weddle's approximation, and written

$$V = \tfrac{1}{20}z\,(A_0 + 5B + C + 5D + E + 5F + G_0)$$

The statement in the Encyclopædia Britannica 9° Edit. XVI., 22, would be less liable to mislead if it read "approximate formula for the area" instead of "formula for the approximate area." The statement that the formula is derived in the manner indicated is moreover inaccurate. It is obtained by a purely arbitrary proceeding. Prof. Johnson's statement, in his "Theory and Practice of Surveying," p. 610 Edit. 1887, that, if the coefficient $\frac{41}{840}$ be changed in the manner indicated, Weddle's rule may be obtained, is also not accurate. The expression is not exact even when the sixth difference is zero.

alteration of $\frac{1}{270}$ in the coefficient[1] of z^4 We pass on therefore to the consideration of the general theory of symmetrical and symmetrically weighted sections.

16. *General theory of symmetrically situated sections with symmetrical weight-coefficients.*—The general theory of the relation of indices, sectional positions, and weight-coefficients is sufficiently indicated in § 2 – § 6 : it is proposed now to consider only the case where both the weight-coefficients and the sections are symmetrically disposed with reference to the middle-section, the first and last being at the terminals of the axis. Equation (5) then takes the following form, viz.

$$\Sigma_{k=0}\,\kappa\left\{\left(\frac{k}{n}\right)^p + \left(1-\frac{k}{n}\right)^p - \frac{2}{p+1}\right\} \ldots\ldots(48)$$

n being the number of parts into which the axis is divided, so that including the terminals there are $n+1$ sectional points. When n is odd, k has the values $0, 1, 2, \ldots \frac{1}{2}(n-1)$, that is there are $\frac{1}{2}(n+1)$ terms : but when even, $0, 1, 2 \ldots \frac{1}{2}n$, that is there are $\frac{1}{2}(n+2)$ terms. It is important to remember in the latter case that the final value of the weight-coefficient is one-half its proper value ; that is the coefficient to be applied to the middle section is double that in the formula : in other words if κ' be the final weight-coefficient in the formula, $2\kappa'$ will be the proper weight-coefficient.

From (48) it is obvious, as we have before seen, that for $p=0$ and $p=1$, the equation is satisfied, whatever the values of κ, k or n, since in either case each term is zero, and the expression becomes simply $\alpha 0 + \beta 0 + \text{etc.} = 0$. Nevertheless, regarding each term as a function of p, it is represented by a continuous curve, whose abscissæ are the values of p, and whose ordinates for $p = 0 + dp$ and $p = 1 + dp$ are perfectly definite. This we proceed to demonstrate. Writing either k/n or $1 - k/n$, as K, we have

---

1 If the coefficient E in the term Ez^4 is essentially positive it gives a slight excess in volume or area : the proper coefficient in the expression of that quantity being $\frac{1}{5}Ez^5$, while the formula gives $\frac{11}{54}Ez^5$. If E be small the difference $\frac{1}{270}Ez^5$ may often be negligible.

$$K^{p+dp} = K^p(1 + \log K\,dp) \ldots\ldots\ldots (49);$$

the logarithm being of course Napierian, we have also

$$-\frac{2}{p+dp+1} = -\frac{2}{p+1} + \frac{2\,dp}{(p+1)^2} \ldots\ldots\ldots (50)$$

For brevity let the expressions of the type (48), but *not* multiplied by weight-coefficients (κ), be denoted by $F(p\,.\frac{k}{n}\,.2)$: then remembering that

$$\log\left(1-\frac{k}{n}\right) = -\frac{k}{n} - \ldots - \frac{k^r}{rn^r} - \text{etc.} \ldots\ldots (51)$$

we have from equations (48) to (51),

$$F(p+dp\,.\frac{k}{n}\,.2) = F(p\,.\frac{k}{n}\,.2) + \left\{\left(\frac{k}{n}\right)^p \log\frac{k}{n} + \left(1-\frac{k}{n}\right)^p \left(-\frac{k}{n} - \frac{k^2}{2n^2} - \text{etc.}\right) + \frac{2}{(p+1)^2}\right\} dp \ldots\ldots\ldots (52)$$

which is quite general. If now in passing from p to $p + dp$ the function $F(p\,.\,k/n\,.\,2)$ is *continually* zero, we must have

$$\left(\frac{k}{n}\right)^p \log\frac{k}{n} + \left(1-\frac{k}{n}\right)^p \left(-\frac{k}{n} - \frac{k^2}{2n^2} - \frac{k^3}{3n^3} - \text{etc.}\right) = -\frac{2}{(p+1)^2} \ldots (53)$$

that is, the quantity in the larger brackets in (52) must be zero. This last equation determines the values of k/n in terms of p; when $p=0$, it becomes ;—

$$\log\frac{k}{n} - \frac{k}{n} - \frac{k^2}{2n^2} - \ldots - \frac{k^r}{rn^r} - \text{etc.} = -2 \ldots\ldots (53a)$$

and when $p=1$;—

$$\frac{k}{n}\log\frac{k}{n} - \frac{k}{n} + \frac{k^2}{1\,.\,2n^2} + \ldots + \frac{k^r}{(r-1)\,.\,rn^r} + \text{etc.} = -\tfrac{1}{2} \ldots\ldots\ldots (53b)$$

expressions which can readily be transformed so as to suit the exigencies of computation with respect to convergency etc., and which are the basis of values already found for such limits. It is now evident that the *graph* of the function $F(p\,.\,k/n\,.\,2) = 0$ is of the type shewn by heavy lines on Fig. 1, viz., the two lines whose abscissæ are 0 and 1, and the curve numbered 2.

When however k/n is constant, and only p is variable, the curve is of very different form, as may be seen in Fig. 3. In this, curve 6 is the graph of $2/(p+1)$; curves 7, 8, and 2 of $\{(k/n)^p + (1-k/n)^p\}$ in which the fraction has the values $\frac{1}{2}$, $\frac{1}{8}$, and $\frac{1}{6}$

respectively. The ordinates are identical for $p=0$, 1, and ∞ for all values of k/n, and since in (48) the coefficient κ is multiplied into the term $2/(p+1)$ as well as the two other terms, it is evident that a series of terms of the type (48), satisfying any system of values of p, will always satisfy also the special values 0, 1 and ∞.[1]

It may be remarked in regard to the k/n curves, that if for certain abscissæ, $p > 1$, their ordinates be greater than those of the $2/(p+1)$ curve, then for sufficiently large values of p, they will become equal to the corresponding ordinates of the latter, and ultimately less than them. Thus the graphs make it obvious that the differences of the ordinates of the $2/(p+1)$ curve and the others vary differently with p, excepting, as already indicated for $p=0$, 1, and ∞; and therefore also that, by combining the proper number of curves, with suitable changes in their parameters, any number of given indices may be satisfied. It is moreover also evident, both from algebraic considerations, and from the graphs, that by properly determining the coefficients, at least as many different indices may be satisfied, 1 included, as there are terms in (48). We shall shew later that a larger number may be satisfied.

When $n=1$, that is when there are only terminal sections, $p=0$ and 1 only can be satisfied: we have already seen that when $n=2$, that is when there are two terminals and a middle section, the values $p=0$, 1, 2 and 3, may be satisfied, the coefficient of the middle section being 4, The case is instructive: equation (48), reduced, becomes

$$\beta = \frac{2^{p-1}(p-1)}{2^p-(p+1)} \quad \text{...........(54)}$$

[1] For solids $p=0$ represents a cylinder; $p=0$ to 2 conoids, the meridian curves of which are outwardly concave, at the limit $p=2$ becoming a cone; $p=2$ to ∞ represent conoids whose meridian curves are convex outwards. At the limit $p=\infty$, it cannot be said that a real solid is represented. $A_z = Bz^\infty$ is a straight line for $z=0$ to $z=1$, coinciding with the axis itself, at $z=1+dz$ it becomes an infinite plane at right angles to the axis.

which, if we make $\beta = 2$, satisfies these last mentioned values of p.[1] This fact, viz., that certain values of the weight-coefficients may satisfy other indices than those which are used to determine them, will be found to have a wider applicability than is immediately evident: in general the indices other than 0 and 1, which are satisfied by any system of weight-coefficients may be called *conjugate*, as hereinbefore.

For brevity let

$$\kappa P_k = n^p \kappa \left\{ (k/n)^p + (n-k)^p/n^p \right\} = \kappa \left\{ k^p + (n-k)^p \right\} \ldots\ldots\ldots (55)$$

and similarly in regard to Q_k, R_k, etc.; the capital letter corresponding to that denoting the index, while the subscript k is to be the same integer as k. Then the equations to be satisfied are

$$\Sigma(\kappa P) - 2n^p \Sigma\kappa/(p+1) = 0 \ldots\ldots\ldots (56)$$

κ having the values a, β, γ, etc., and the limits for κP being 0 to $\frac{1}{2}(n+1)$ when n is odd, and 0 to $\frac{1}{2}(n+2)$ when n is even. Remembering that the number of sections is independent of the number of indices in any series, and that the solution does not lose generality by making $a = 1$, we have from (48) and the last two equations,

$$\beta\{(p+1)P_1 - 2n^p\} + \gamma\{(p+1)P_2 - 2n^p\} + \ldots + (p-1)n^p = 0 \ldots\ldots (57)$$

and similar expressions in which $q, Q,_q$, etc. are substituted for $p, P,_p$; the number of terms in addition to the last or absolute term being now the same as the number of weight-coefficients to be evaluated, viz. $n/2$ if n be even, $(n-1)/2$ if n be odd. By means of these last equations, viz. (57), any case can be readily solved.

17. *Examples of the application of the general formula.*—For $n = 2$, that is for a middle and terminal sections, (57) becomes, on dividing each quantity by 2,

$$\beta'(p + 1 - 2^p) + (p-1)2^{p-1} = 0 \ldots\ldots\ldots (58)$$

which gives the following series of formulæ, remembering that the coefficient must be $2\beta'$ as already pointed out.

---

[1] It has already been pointed out in connection with (48) that for even values of n, the coefficient is half its proper value: (54) is of course one half of (37). That the values $p = 0$, $p = 1$ hold, may be verified by considering the limits.

X.—*Integral expressions for volume: three symmetrical sections.*

$$V = \frac{1}{\sigma}(\alpha A_0 + \beta B_m + \gamma C_m).$$

Index p	$\sigma =$	α	β	γ
2 or 3	6	1	4	1
4	70	11	48	11
5	90	13	64	13
6	434	57	320	57

The index 1 is satisfied with the others and 0 of course: but no other index: 2 and 3 are conjugate, and as shewn on the β curve on Fig. 2, the indices conjugate to 4 and 5 lie between 1 and 2, and those conjugate to 6 to ∞ between 1 and 0.

If $n = 3$, (57) becomes

$$\beta\{(p+1)(1+2^p) - 2 . 3^p\} + (p-1)3^p = 0 \text{.........(59)}$$

which gives the following values for four sections:—

XI.—*Integral expressions for volume: four symmetrical sections.*

$$V = \frac{1}{\sigma}\alpha A_0 + \beta B_1 + \gamma C_1 + \delta D_0)$$

Index p	σ	α	β	γ	δ
2 or 3	8	1	3	3	1
4	640	77	243	243	77
5	60	8	27	27	8
6	9296	1003	3645	3645	1003

The indices 0 and 1 are simultaneously satisfied with any one of these: 2 and 3 are again conjugate. The indices greater than 3 are conjugate to indices less than 2: the curve β/α being similar to the β curve in Fig. 2. It will be noticed that the four sections satisfy only a cubic function, the coefficients being 1, 3, 3, 1.

If $n = 4$, (57) becomes

$$\beta\{(p+1)(1+3^p) - 2.4^p\} + \gamma'\{(p+1)\,2.2^p - 2.4^p\} + (p-1)4^p = 0 \text{...(60)}$$

solving which for either $p = 2$, or $p = 3$ gives

$$\gamma' = 2 - \tfrac{1}{4}\beta \text{.........(61).}$$

Hence there is a one-fold infinity of solutions, whenever five symmetrical transverse sections are taken, if the indices are 1, 2 and 3. Thus we may write out such solutions as the following, in all cases doubling the value of γ' as it is a middle section.

XII.—*Integral expressions for volume: five symmetrical sections.*

Index $p = 1, 2$ and 3.

σ	α	β	γ	δ	ϵ
9	1	2	3	2	1
12	1	4	2	4	1
15	1	6	1	6	1
18	1	8	0	8	1

etc., etc.

On solving for $p = 4$, we find

$$\gamma' = \frac{24}{11} - \frac{51}{11.16}\beta \ldots\ldots\ldots(62);$$

and on combining this solution with (61): and putting $\gamma = 2\gamma'$, the solution for β and γ becomes determinate, and for indices at any rate as far as $p = 1$, 2, 3 and 4,[1] we have

$$\beta = \tfrac{32}{7};\ \gamma = \tfrac{12}{7}.$$

Consequently for those indices the series of coefficients are

$$\sigma = 90,\ \alpha = 7,\ \beta = 32,\ \gamma = 12,\ \delta = 32,\ \epsilon = 7$$

as already given in Table IX.

Again solving for $p = 5$, 6 and 7 we find

$$p = 5\quad \gamma' = \frac{32}{13} - \frac{73}{13.16}\beta.\ \ldots\ldots\ldots\ldots(63)$$

$$p = 6\quad \gamma' = \frac{160}{57} - \frac{1541}{57.64}\beta.\ \ldots\ldots\ldots\ldots(64)$$

$$p = 7\quad \gamma' = \frac{16}{5} - \frac{159}{5.64}\beta.\ \ldots\ldots\ldots\ldots(65)$$

By combining these results with (61) and (62) we obtain formulæ satisfying different indices. For example combining (63) with (61) the resultant coefficients are again the same; identical results being given by the solutions for $p = 2$ or 3 and 4, $p = 2$ or 3 and 5, or again for $p = 4$ and 5. Hence the series of weight-coefficients last given satisfy a *quintic* function, or the formula

$$V = \frac{1}{90} z\,(7A_0 + 32\,B_1 + 12\,C_m + 32\,D_1 + 7E_0)\ldots\ldots(66)$$

is absolutely exact when the original function is

$$A_z = A + Bz + Cz^2 + Dz^3 + Ez^4 + Fz^5$$

these indices, viz. 2 to 5 are thus seen to be conjugate for the indicated coefficients.[2]

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1 It will be seen later that the solution is true also $p = 5$; that is a five-section formula is true for a quintic function, the weights being as shewn.

2 This fact does not appear when the formula is deduced by finite differences.

The following table shews the coefficients obtained by combining in different ways equations (61) to (65).

XIII.—*Integral expressions for volume, five symmetrical sections.*

Indices p	σ	α or ϵ	β or δ	γ
1, 2, 3, 4 and 5	90	7	32	12
1, 2, 3 „ 6	8190	629	2944	1044
1, 2, 3 „ 7	1050	79	384	124
1, 4 „ 6	69510	5323	25088	8688
1, 4 „ 7	9730	729	3584	1104
1, 5 „ 6	44730	3389	16384	5184
1, 5 „ 7	8190	607	3072	832
1, 6 „ 7	9310	679	3584	784

Still further, if $n=5$, the general equation (57) becomes

$$\beta\left\{(p+1)(1+4^p)-2.5^p\right\}+\gamma\left\{(p+1)(2^p+3^p)-2.5^p\right\}+(p-1)5^p=0 \quad \ldots(67)$$

giving the following solutions for γ:—

$$\text{Index } p = 2 \text{ or } 3 \qquad \gamma = \tfrac{25}{11} + \tfrac{1}{11}\beta \ldots\ldots\ldots\ldots\ldots(68)$$

$$p = 4 \qquad \gamma = \tfrac{125}{51} + \tfrac{7}{153}\beta \ldots\ldots\ldots\ldots(69)$$

$$p = 5 \qquad \gamma = \tfrac{125}{46} - \tfrac{1}{46}\beta \ldots\ldots\ldots\ldots(70)$$

$$p = 6 \qquad \gamma = \tfrac{78125}{25699} - \tfrac{2571}{25699}\beta \;\ldots.\; (71)$$

From (68) and (69), (68) and (70), and from (69) and (70) we find $\beta = \frac{75}{19}$, $\gamma = \frac{50}{19}$, hence these are conjugate indices: (68) and (71) however give $\beta = \frac{5398}{2699}$. Hence we see that (67) with the indicated weights satisfies only a quintic function, *and not a sextic.* Hence if the transverse section of a solid is known to be a quintic function of the distance along its axis, five sections, that is two terminal, a middle, and two other equidistant sections are sufficient, and there is no advantage in taking six sections. Thus the function being *quintic*, as before following (66), the volume is exactly given by the formula in Table IX., $V = \frac{1}{288}\, z\, (\Sigma.\mu M)$, μ denoting any coefficient and M the corresponding section.

As before, an infinite number of formulæ can be developed for $p=1$, 2 and 3; for example, any of the following series of formulæ satisfy a cubic function.

XIV.—*Integral expressions for volume: six symmetrical sections.*

Indices p = 1, 2, and 3.

σ	α or ζ	β or ϵ	γ or δ
24	1	8	3
48	1	19	4
72	1	30	5
96	1	41	6

etc., etc.

So also expressions can be deduced satisfying $p = 1, 2, 3, 6;\ 1, 2, 3, 7;$ etc.; 1, 4, 6; 1, 4, 7; 1, 5, 6; 1, 5, 7; etc., etc.; that is to say the weight coefficients may be so determined as to make these indices excepting 1 conjugate.

This will be a sufficient indication of the application of the general formula. The identity of the formulæ may be shewn graphically by treating p as the independent variable, and writing y instead of 0 in (57), and in the particular formulæ deduced therefrom. For example the curve represented by (60) and that represented by (67), are plotted with identical parameters and shewn in Fig. 3, Curves 10 and 11. The numerical results are as follows:—

$p =$	$\frac{1}{2}$	1	$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	6
(60) =	−·0268	0	+·0058	0	−·0068	0	+·0140	0	−·0721	0	+10.67
(67) =	−·0247	0	+·4058	0	−·0063	0	+·0163	0	−·1128	0	+73.33

18. *On the number of indices satisfied by a given number of symmetrical sections.*—Let, in (57), and in the similar expressions in which p is replaced by q, r, etc., the absolute or final terms be denoted by A with suffixes corresponding to the indices. Expressions of that type may then be briefly written

$$\left.\begin{array}{l} B_p\beta + C_p\gamma + \ldots + A_p = 0 \\ B_q\beta + C_q\gamma + \ldots + A_q = 0 \\ \text{etc.} \quad \text{etc.} \quad\quad \text{etc.} \end{array}\right\}\ldots(72)$$

the number of unknowns, viz. β, γ, etc., being as already pointed out, $\frac{1}{2}n$ when n is even, or $\frac{1}{2}(n-1)$ when n is odd. We proceed to shew that in a system of equations of this type, viz. (72), A, B, C, etc., being the particular functions of p, q, etc., indicated in (55) and (57), the indices may have all integral values from 1 to $n + 1$ when n is even, and from 1 to n when n is odd, provided that the coefficients β, γ etc., are suitably determined. That is to say the series (72) will in all cases have $2m + 1$ lines, m being the number of coefficients, whether n be odd or even, when p, q, etc., are the successive integers 1, 2, etc.

We have already seen that when $p = 1$, A_1, B_1, C_1 etc., are all zero, and hence β, γ etc. may have any values whatever: it has also been shewn that when $n = 2$, or $n = 3$, the indices 1, 2, and 3 are satisfied, provided that β has in the former instance the value 4,[1] and in the latter 3. Further it has been demonstrated that when $n = 4$ and $n = 5$, the integral indices extend to 5, β and γ' being $\frac{32}{7}$ and $\frac{6}{7}$ in the former, and β and γ $\frac{75}{19}$ and $\frac{50}{19}$ in the latter case. Moreover it may also be readily verified that when $n = 6$ a *septimic* function is satisfied, and only a septimic when $n = 7$.

It may also be noted that all the equations in (72) are not independent. For example

$$\frac{K_2}{K_3} = \frac{(2+1)\left\{k^2 + (n-k)^2\right\} - 2n^2}{(3+1)\left\{k^3 + (n-k)^3\right\} - 2n^3} = \frac{1}{2n} \quad \ldots\ldots(73)$$

that is to say the values A_3, B_3, C_3 etc, are simply $2n A_2$, $2n B_2$, $2n C_2$, etc. Again if p denote an even (*p*ar) number, and i the odd (*i*mpar) number a unit greater than p, that is $i = p + 1$, then we shall have

$$K'_p = \frac{1}{p+1} \cdot K_p = \frac{p-1}{p+1} n^p - p n^{p-1} k + \frac{p(p-1)}{2\,!} n^{p-2} k^2 - \ldots - p n k^{p-1} + 2k^p \quad (74)$$

$$K'_i = \frac{1}{i+1} \cdot K_i = \frac{i-1}{i+1} n^i - i n^{i-1} k + \frac{i(i-1)}{2\,!} n^{i-2} k^2 - \ldots - \frac{i(i-1)}{2\,!} n^2 k^{i-2} + i n k^{i-1} \quad (75)$$

that is K_i has the same number of terms as K_p, and k is raised to the same powers. We may divide this last equation (75) by n, hence substituting $p + 1$ for i we have

$$K'_{p+1} = \frac{1}{n(p+2)} \cdot K_{p+1} = \frac{p}{p+2} n^p - (p+1) n^{p-1} k + \frac{(p+1)p}{2\,!} n^{p-2} k^2 - \ldots$$
$$\ldots - \frac{(p+1)p}{2\,!} n k^{p-1} + (p+1) k^p \quad ..(75a)$$

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[1] β' will be 2.

that is the powers of n are all identical with those in (77), and only the coefficients differ.

Similarly

$$A'_p = \frac{1}{p+1} \cdot A_p = \frac{p-1}{p+1} n^p \quad .....(76)$$

$$A'_i = \frac{1}{n(p+2)} A_i = \frac{p}{p+2} n^p \quad ......(77)$$

Hence we may divide all the equations with *even* indices by $(p+1)$, and all those with *odd* indices by $n(i+1)$. The resulting quantities $K_p/(p+1)$, $K_i/(i+1)$, etc., may be conveniently distinguished by accents, as in these five last equations. Let the even indices be denoted by p, r, t etc.; then commencing the series (72), as modified, with $p=2$, we obtain the equations

$$\left.\begin{array}{l} B'_p\beta + C'_p\gamma + \quad \ldots A'_p = 0 \\ B'_{p+1}\beta + C'_{p+1}\gamma + \ldots A'_{p+1} = 0 \\ \quad \text{etc.} \qquad \text{etc.} \qquad \text{etc.} \end{array}\right\} \ldots\ldots(78)$$

the factors of β, γ, etc., being of the type (75) and (75a): k will be 1 for the term β, 2 for γ, 3 for δ and so on, and we may write r and $r+1$, t and $t+1$, etc., for the successive pairs of indices. Then it will suffice to shew that values of β, γ, etc. which satisfy the general equation for p, an even integer, will also satisfy it for $p+1$, an odd integer, provided p be not greater than n. In other words it will then be evident that the m coefficients may be calculated from either the m even indices commencing with 2, or the m odd indices commencing with 3; the solution from the one series satisfying the other. That a n^{ic} function is satisfied in any case, when the coefficients are symmetrical with respect to the middle section, is shewn in the derivation of formulæ, by the method of finite differences. If therefore we write the general equation by commencing with the sections nearest the middle section when n is odd, or the middle section when n is even, we have for $n=i$

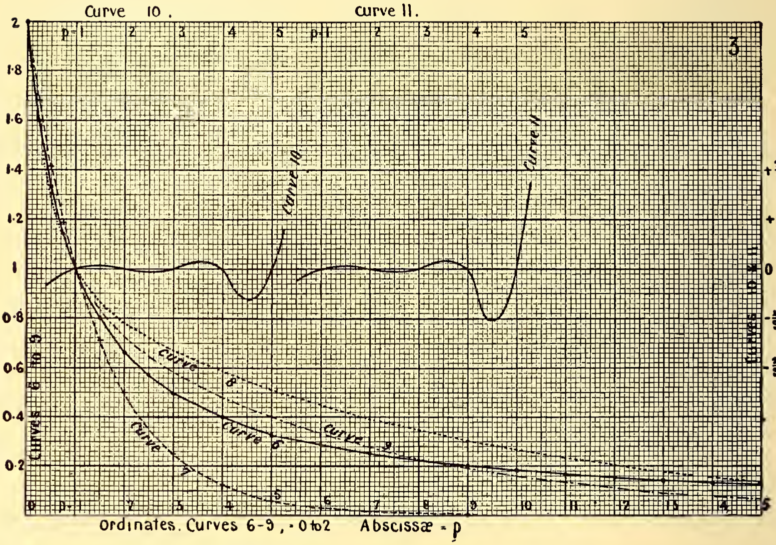
$$\mu\left\{\left(\frac{1}{2}-\frac{1}{2n}\right)^i+\left(\frac{1}{2}+\frac{1}{2n}\right)^i-\frac{2}{i+1}\right\}+\lambda\left\{\left(\frac{1}{2}-\frac{3}{2n}\right)^i+\left(\frac{1}{2}+\frac{3}{2n}\right)^i-\frac{2}{i+1}\right\}+\text{etc.} \quad (79)$$

continuing with terms $5/2n$, $7/2n$, etc.; and also for $n=p$

$$\mu\left\{\left(\frac{1}{2}-\frac{0}{2n}\right)^{p}+\left(\frac{1}{2}+\frac{0}{2n}\right)^{p}-\frac{2}{p+1}\right\}+\lambda\left\{\left(\frac{1}{2}-\frac{2}{2n}\right)+\left(\frac{1}{2}+\frac{2}{2n}\right)^{p}-\frac{2}{p+1}\right\}+\text{etc.} \quad (79a)$$

continuing $4/2n$, $6/2n$, etc. Obviously too, in expanding, we have the same number of terms, since in (79) the final terms in the expansion cancel one another. By considering (74) to (79*a*) we easily see that (79*a*) will satisfy the same values for p as will (79), or, as has been illustrated in the graph of curves 10 and 11 in Fig. 3, an n^{ic} function is satisfied when n is *odd*, and a $(n+1)^{\text{ic}}$ when n is *even* : that is to say :—

Fig. 3.



Curve 6.—Graph of $2/(p+1)$.

Curve 7.—Graph of $[k^{p}+(n-k)^{p}]/n^{p}$; $k/n=\frac{1}{2}$

Curve 8.— „ „ ; „ $=\frac{1}{8}$

Curve 9.— „ „ ; „ $=\frac{1}{6}$

Curve 10.—Five symmetrical sections: graph shews that a quintic function is satisfied.

Curve 11.—Six symmetrical sections: graph shews that a quintic function only, and not a sextic is satisfied.

PROP. (*o*). *When the transverse sections include the terminal sections, are equidistant, and have assigned to them suitable weight-coefficients, the coefficient being the same for any pair of sections* *equidistant from the centre, then if one of the sections be a middle section the function satisfied will be of the same degree as the number of sections, but if there be no middle section the degree will be one less than the number of sections.*

19.[1] *Manifold infinity of possible formulæ with symmetrical sections.*—It has been shewn that for any given number of indices a certain number of sections must be taken, these having definite weight-coefficients. In symmetrical sections it has also been demonstrated that if m be the number of different coefficients, excluding that for the terminal sections, the degree of the function satisfied will be $2m + 1$. If k coefficients more than are necessary in a particular case are taken, then a k-fold infinity of formulæ may be developed.[2]

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[1] Added 16th June, 1900.

[2] The solids referred to in Note 1, page 62, are solids of revolution merely. The form of the xy function is however quite immaterial.

On the AMYL ESTER of EUDESMIC ACID, occurring in EUCALYPTUS OILS.

By Henry G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, June 6, 1900.*]

In a paper by Mr. R. T. Baker and myself "On the Stringybark Trees of New South Wales," read before this Society, July 1898, we show that an ester must be present in the oil of *Eucalyptus macrorhyncha.* We had several times detected the presence of esters in other Eucalyptus oils but always in too minute quantities to allow them to be isolated with any success.

The investigation into the constituents of these oils, now being undertaken on material obtained from undoubted species, enables the statement to be made, that most probably esters are present in all Eucalyptus oils, and it is to be supposed, therefore, that to these the characteristic odour of Eucalyptus oil is largely due.

There is an organic connection between the constituents of the oils of the genus Eucalyptus, and it appears almost certain that most if not all of those constituents occurring in minute quantities in the oils of some species, are present in larger amount in the oils of other species. It is certainly so with the two pinenes present in these oils, with lævo-phellandrene,[1] with eudesmol, with (?) cuminaldehyde, with eucalyptol and with other constituents which have been isolated during this research; the chemistry of these, however, is not yet completed.

The ester that forms the subject of this paper has been detected in several oils in increasing amount. The oil of the "Black Gum"

[1] Investigation of the oils of most of the New South Wales species of Eucalyptus points to the fact that dextro-phellandrene does not occur in these oils.

Eucalyptus aggregata, contains the ester in sufficient quantity to enable its constituents to be isolated and determined.

Unfortunately the yield of oil is small in those species of Eucalyptus giving this ester in largest amount. The leaves of the "Black Gum" *E. aggregata*, from which this oil was obtained, were sent by the Museum collector, Mr. Baüerlen, in the month of October, from Fagan's Creek, near Braidwood, in this colony. Four hundred pounds of leaves were received, but the amount of oil obtained was only two and a half ounces, equal to 0·04 per cent. More material was not obtainable later, without great trouble and expense, as trees of this species do not occur within easy distance of Sydney. More leaves of the "Black Gum" will be obtained at the first opportunity and the chemistry of the acid completed, a research I would like to reserve to myself.

It is probable, however, that we may yet find other species of Eucalyptus containing this ester in fairly large quantities. The oils of *E. botryoides* and of *E. saligna* contain an ester in fair amount; it is present in the oil of *E. rostrata*, and in the oils of several other species its presence can be proved.

The determination of this ester explains much in reference to Eucalyptus oil that previously seemed obscure. It is most probable that the amyl alcohol of this ester is connected with the valeraldehyde known to be present in these oils, and it may, perhaps, be found eventually, that the (?) cuminaldehyde, existing in so many of these Eucalyptus oils, has some connection with the acid of the ester. In the oil of *E. rostrata* both the ester and (?) cuminaldehyde occur together. The presence of this aldehyde is much more frequent in these oils than was previously supposed.

[Since this paper was prepared I have been investigating the aromatic aldehyde found in many Eucalyptus oils. This constituent was previously supposed to be cuminaldehyde and its odour and reactions certainly suggested that substance; but further research points to the fact that it is not ordinary cuminaldehyde. When isolated in a pure condition its odour is more aromatic than cuminaldehyde, and it differs from that aldehyde in having a somewhat high rotation to the left, a less specific gravity, a lower boiling point, and its oxime melts at a much higher temperature. It is now being further investigated.][1]

It must not be thought that the odour of some Eucalyptus oils is entirely due to this ester. In the oil of *E. patentinervis* a very small quantity of an ester is present, but the odour of the saponified oil is excellent, resembling somewhat that of Bergamot oil, and there is little doubt but that either linaloöl or geraniol is present. Acetylation of the oil showed no less than 16·5 per cent. of free alcohol to be present in the oil of this species, calculated as linaloöl. A small quantity of citral was removed from the oil of this species (*E. patentinervis)* by acid sodium sulphite, and determined by the formation of the alcyl-β-naphtocinchoninic acid characteristic of citral,[2] and it seems reasonable to suppose that this citral has some connection with the aromatic alcohol present in the oil of this species. The leaves have a lemon odour when crushed and are quite aromatic. It was previously supposed that botanically *E. patentinervis* was connected with *E. resinifera* but the chemical determination of the constituents of its oil shows it to have no immediate connection with that species, but to be allied to *E. botryoides* and perhaps more closely to *E. saligna.*

In the list of known constituents of the oil of *E. globulus*, published by Schimmel and Co., report April 1897, we find amyl alcohol mentioned, it may be considered that this amyl alcohol was originally derived from the ester now being described, and goes to show that even in an oil like that of *E. globulus* an ester is present at some time, although when distilled these oils usually consist largely of pinene and eucalyptol.

The oil of Eucalyptus aggregata.

The crude oil of the "Black Gum" *E. aggregata*, is very fluid, much like water in that respect, it is light orange-brown in colour

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1 Added 25 July, 1900.

2 There is no doubt but that citral does occur naturally in some Eucalyptus oils.

and the odour has but little resemblance to ordinary Eucalyptus oil. It has a high specific gravity for an Eucalyptus oil, and it was this peculiarity that first directed attention to it. On distillation under atmospheric pressure 26 per cent. was obtained, distilling between 156° and 164° C.,[1] this was principally dextropinene, proved by its boiling point, formation and character of its nitrosochloride, its odour and other tests; only 12 per cent. was obtained, distilling between 164° and 245° C. while 22 per cent. distilled between 245° and 292° C.; the remainder was poured from the still and became semi-crystalline on cooling. The portion adhering to the still was removed by ether. The crystalline residue was reserved for further determination.

The specific gravity of the crude oil at 15° C. was 0·956

,,	,,	fraction	156° – 164° C.	at 15° C.	= 0·866
,,	,,	,,	164° – 245° C.	,,	= 0·8769
,,	,,	,,	245° – 292° C.	,,	= 0·9868

Specific rotation, fraction 156° – 164° C. = $[\alpha]_D$ + 27·13°. Light did not pass with the crude oil.

Phellandrene could not be detected in this oil, and eucalyptol also appears to be quite absent. The principal constituents present are dextropinene and the ester, with perhaps some polymerised terpenes. A small quantity of a new constituent is also present, this has not yet been determined, but it has been isolated from the oils of several other species of Eucalyptus in some of which it occurs in fairly large quantities.

Determination of Ester in the oil of E. aggregata.

As it was evident that an acid had been separated at the high temperature used during the distillation, determinations of the ester in the original oil were made. The oil was boiled for half an hour with a known quantity of alcoholic potash, standardised by semi-normal sulphuric acid, a condenser being used in the ordinary way.

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[1] These temperatures have been corrected to the nearest whole degree.

(1) 1·017 gramme oil required 0·1148 gramme potash, therefore saponification figure = 112·8.

(2) 3·2378 gramme oil required 0·3612 gramme potash, saponification figure = 111·6.

The result of the analysis of the acid gave a molecular formula $C_{14}H_{18}O_2$ as determined by its silver salt. Amyl alcohol is the alcohol of the ester, and considering the acid as monocarboxylic, the formula of the ester would be $C_{13}H_{17}COOC_5H_{11}$ with a molecular value of 288, therefore the percentage of ester in the oil of *E. aggregata* is for No. 1 determination 58 per cent., for No. 2 equivalent to 57·4 per cent. or a mean value of 57·7 per cent.; this is assuming no other ester to be present in the oil.

Determination of the alcohol of the ester.

A portion of the oil of *E. aggregata* was boiled for some time with aqueous potash, a good reflux condenser being used. The solution was then distilled. The aqueous solution obtained was surmounted by an oily substance in which the odour of amyl alcohol could be detected. The aqueous solution, which gave the iodoform reaction, was separated from the oily portion and redistilled. Nothing was obtained boiling below 100° C.; the distillate contained a few oily globules; neither methyl nor ethyl alcohol was present. The distillate gave the iodoform reaction readily, and on boiling it with sulphuric acid and sodium acetate the solution had the characteristic odour of amyl acetate. The oily portion of the first distillate was redistilled, it commenced to distil at 130° C., and the portion distilling between 130° – 135° C. was collected; although masked somewhat by the presence of a portion of the other constituents of the oil it had the odour and gave the reactions for amyl alcohol. When oxidised with potassium bichromate and sulphuric acid, and treated in the usual way, the acid obtained had the characteristic odour and reactions of valeric acid. The alcohol of this ester is therefore amyl alcohol.

Determination of the acid of the ester.

The fraction obtained distilling between 245° – 292° C. was agitated with aqueous potash, the alkaline solution was acidified with hydrochloric acid, when a soft paraffin-like substance separated, this soon became crystalline. The separated oil, after agitating with the potash solution, was saponified with alcoholic potash in the usual way, water added and the aqueous solution acidified, more of the crystalline acid was thus obtained showing that some of the ester had distilled unchanged, it may be mechanically.

The residue left in the still above 292° C. was agitated with aqueous potash, and on acidifying the alkaline solution a fairly large quantity of the crystalline acid was obtained. On saponifying the portion insoluble in aqueous potash in the usual way and acidifying the solution, only a very small quantity of the crystalline acid was obtained, showing that the greater portion of the ester had been decomposed by the temperature at which the oil had been distilled. The crystalline substance thus obtained was the acid of the ester occurring in this oil, and on purifying each of the portions obtained as described above, an identical crystallised acid was obtained. No phenols could be detected.

The purification of the acid was carried out as follows:—The crystalline substance, obtained by acidifying the potash solution, was dissolved in alcohol and boiled with the addition of a little animal charcoal, filtered, and allowed to crystallise. The crystals were separated, dissolved in boiling water, and filtered boiling hot. On cooling the acid was deposited in crystals, recrystallisation from boiling water was repeated two or three times, a product of constant melting point was thus obtained. It is very necessary to obtain the crystals thus, as the impurities present cannot otherwise be removed, and these lower the melting point considerably. If purification be carried out as described above, the melting point of the crystals obtained in any direction will be constant. The same crystals were obtained when the original oil was saponified with alcoholic potash, and also when aqueous potash was used for determining the alcohol.

The acid is quite white and in general appearance is not much unlike salicylic acid, it crystallises in rhombic prisms and these polarize brightly in colours. The melting point of the crystals is 160° C. (uncor.) and a crystalline mass is again formed on cooling. The melting point is that of the individual crystals adhering to the inner side of the tube, the melting point of the mass in the tube is not sharp, and an error of two degrees might easily occur. The acid is a very weak one, but it is exceeding soluble in ammonia and the alkalis. It is very sparingly soluble in cold water, easily soluble in hot water, in alcohol, in ether, in acetone and chloroform, but it is insoluble in benzene, in petroleum spirit (even on boiling) and in carbon bisulphide (slightly on boiling).

Sublimation—The acid sublimes with difficulty and at rather a high temperature, it sublimes unchanged.

Ammonium salt—The acid is exceedingly soluble in ammonia, the solution was evaporated to dryness over sulphuric acid, it crystallised very well, it is not readily soluble in cold water, but is so in hot water; it does not separate out again at once on cooling, thus differing from the acid itself.

Ferric salt—The aqueous solution of the ammonium salt was used, ferric chloride gives a light orange precipitate insoluble even in a large quantity of water.

Copper salt—Sulphate of copper gives a light bluish-green precipitate in the aqueous solution of the ammonium salt.

Silver salt—When nitrate of silver is added to the aqueous solution of the ammonium salt fine crystallisation of the silver salt soon takes place, the crystals are white but become pinkish on exposure to light.

Neither barium chloride nor calcium chloride gives a precipitate.

Solubility of the acid in water at 20° C.

The pure acid was dissolved in boiling distilled water, and when at the temperature given the crystals which had separated were removed by filtration; 25·48 grammes of the filtrate gave 0·0188 gramme solid, equivalent to 0·0738 per cent., or the acid required 1,355 parts of water at 20° C. to dissolve one part of acid.

Determination of the Bromide.

On adding bromide water to the aqueous solution of the acid it it was at once bleached; the acid is, therefore unsaturated. The acid was dissolved in hot water and bromine added until in excess. The bromide was very soluble in hot water, on cooling and standing a crystalline mass was obtained, this was almost colourless, it melted at 102° - 103° C. The determination of this bromide was made by ignition with lime in the usual way. 0·1576 gramme bromide taken, total silver bromide obtained 0·1546 gramme or 0·0658 gramme bromine, equivalent to 41·75 per cent. bromine. $C_{14}H_{18}Br_2O_2$ requires 42·6 per cent. bromine. This indicates a dibromide. The reactions showed the bromine to be present in the side chain.

Molecular value of the acid.

On adding silver nitrate to the cold aqueous solution of the acid no precipitate was obtained, the silver salt being soluble in dilute aqueous solution. The method adopted was to add a little water to some of the pure acid crystals, and then just sufficient ammonia to dissolve the acid. On adding two or three drops of silver nitrate solution a curdy precipitate formed at once, the solution was removed from this and silver nitrate added in excess; fine crystallisation rapidly took place, this was finally crystallised from water. The silver salt is exceedingly soluble in hot water and is fairly soluble in cold water. 0·0762 gramme of the silver salt gave 0·0258 gramme metallic silver on ignition, equivalent to 33·86 per cent.; the molecular weight of the acid from this determination is 212. 0·0204 gramme silver salt gave 0·0068 gramme silver, equivalent to 33·33 per cent., molecular weight of acid from this is 217.

An acid with a formula $C_{14}H_{18}O_2$ has a molecular weight 218, and $C_{13}H_{17}COOAg$ contains 33·23 per cent. silver.

Action of Nitric Acid.

On treating the acid crystals with nitric acid they at once dissolved with formation of a crimson colour, this soon changed to orange, on heating it became almost colourless. On adding water, colourless crystals were obtained; these were little soluble in cold water but soluble in alcohol. It is doubtful if this was a nitro-compound. The crystals are microscopic needles, acid to litmus, and melted at 113° C.; on powdering the fused material it again melted at the same temperature. This is near the melting point of cumic acid, and if it be that acid, then ordinary oxidation of the side chain had taken place.

Theoretical.

As shown above, the molecular weight of the acid of the ester is near 215. The alcohol present is amyl-alcohol, so that the formula for this ester is $C_{13}H_{17}COOC_5H_{11}$ assuming the acid to be monobasic. The only consideration is that of the structure of the acid. Eudesmic acid is unsaturated, taking up bromine to form a dibromide. It is not a member of the series of fatty acids, and its characters remove it from the acrylic series. Probably it belongs to the series of acids homologous with cinnamic acid. The formula for cumyl-angelic acid is $C_{14}H_{18}O_2$ having a molecular weight of 218, this approaches very closely the molecular weight found for eudesmic acid. [An aldehyde resembling][1] cuminaldehyde is frequently found occurring in Eucalyptus oils, and it may be that this has some connection with eudesmic acid. Perkin[2] describes a series of acids he had formed from cuminaldehyde. The cumyl or cumenylacrylic acid $C_{12}H_{14}O_2$ thus obtained consisted of white needles melting at 157° – 158° C., and giving reactions somewhat resembling those obtained from eudesmic acid. The results show some resemblance between the two acids, but there are many differences between them; the observed molecular weight might suggest cumyl-angelic acid as the more probable. The cumenyl-angelic acid formed by Perkin melted at 123° C.; probably the side chain in eudesmic acid constitutes an isomeric form of angelic acid, this may explain the differences in melting points. When the research on this acid is continued, Perkin's experiments will be repeated. The crystalline acid, obtained by the action of nitric acid, had the characters of cumic acid. If this is eventually

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1 Added 25th July, 1900. 2 Journ. Chem. Soc., xxxi, 388.

shown to be that acid then the side chain in eudesmic acid is in the para position relatively to the iso-propyl. This will be decided when more material has been obtained.

The name, eudesmic acid, is from Robert Brown's name for the genus "Eudesmia." L'Heritier's name "Eucalyptus," however, had priority.

I would like to express my thanks to my colleague Mr. R. T. Baker, F.L.S., for botanical assistance in the preparation of this paper, it being necessarily of the greatest importance that the material worked upon should be true to name.

Note on a NEW METEORITE from NEW SOUTH WALES.

By R. T. Baker, F.L.S.,
Curator, Technological Museum, Sydney.

[With Plate I.]

[*Read before the Royal Society of N. S. Wales, June 6, 1900.*]

The meteorite, the subject of this note, was found early in January of this year, about two miles from Bugaldi Post Office, fifteen miles north-west of Coonabarabran by Mr. W. Gould. I am indebted to Mr. Robert Wilcox, Postmaster of Bugaldi for the data in connection with the discovery of it. This gentleman obtained all particulars for me from Mr. Gould. and it was through his agency that it came into the possession of the Museum.

Mr. Wilcox writing me when despatching the specimen to Sydney, states:—"The stone or supposed meteorite was found showing on the surface of the ground. It was noticed by the ground being torn and broken on such a hard ridge. It had penetrated the ground and rose out. It was found about two miles from Bugaldi Post Office. Mr. Gould was driving a team of horses and passed over it and examined the broken ground to discover the cause."

In reply to another letter of mine asking for further data, Mr. Wilcox informed me that he accompanied Mr. Gould to the side of the Box Ridge where he obtained the meteorite, and with him examined the spot where it struck the earth. There was only a small impression as there had been general showers of rain. The spot was viewed from all sides, and from the impression on the ground and by the way the meteorite was lying, it must have come from the north-west. When picked up it was lying flat, the larger end slightly in the earth, but it had probably shifted from the position when it first struck the earth.

Shape and General Description.—Its greatest longitudinal measurement is about $5\frac{3}{8}$ inches, its greatest breadth about $3\frac{1}{8}$ inches, and its greatest thickness about $2\frac{1}{4}$ inches. It is pear-shaped, or as one person described it, similar to a bicycle seat. This meteorite belongs to that class known as siderites, and is probably composed of iron and nickel. It has a well defined closely adhering 'skin' of black magnetic material, while the metal immediately beneath this coating is silvery white in appearance. This 'skin' has apparently formed after the impact. At the extremity of the larger end a smooth portion remains, and on this can be seen very distinctly, Widmanstatten figures.

The specimen has an exceedingly new appearance as if it had only just arrived upon the earth. It is almost a replica in shape of the Bingara Meteorite described before this Society by Prof. Liversidge in 1882, but much larger than that one. It has similar cracks and pits on the surface. The narrow end appears from indications in the skin to have slightly twisted, but whether this end is the original mass and the thick end to have twisted from it can only be determined by analysis. The skin on the upper surface and towards the base of the thicker end is undulate, and on the corresponding part of the lower surface is longitudinally ridged. These two irregular surfaces enclose a smooth one on which are impressed the Widmanstatten figures.

Specific Gravity.—The specific gravity is 7·853 at 16° C. Its weight is 2053·7 grammes or 4 lbs. 8·43 ounces avoirdupois.

How it probably struck the Earth.—It is only perhaps in exceptional cases that meteorites possess features that will permit of any advancing of a theory in regard to the mode of impact with the earth. In the case of this meteorite the furrow made by it showed that it came from the north-west, also it must have struck the earth at a very acute angle as proved by its shape, which shows very little evidence of impact.

The chief features of this meteorite are:—(*a*) Its new appearance, for it looks as though it has been just taken from a mould in an iron foundry. (*b*) There are no indications of slow oxidation and where the skin has been broken off, the metal surface exposed is just as though it had been polished. (*c*) The natural presence of Widmanstatten figures.

Professor Liversidge, M.A., LL.D., F.R.S., has kindly undertaken to make a chemical investigation of this meteorite, the result of which will be published later.

NOTES ON RACK RAILWAYS.

By C. O. Burge, M. Inst. C.E.

[*Read before the Royal Society of N. S. Wales, August 8, 1900.*]

The method of overcoming the difficulties in railway construction caused by unavoidable steep ascents, by means of the rack and pinion connexion between locomotive and road, is a comparatively old one, but it has only been in quite recent years that it has been carried out to any great extent. As there are now nearly one hundred rack railways in various parts of the world in use, of which some are in the neighbouring colonies, and as surveys have been made and information obtained by the Railway Construction Branch, N. S. Wales Government, with the view to their introduction here, it was thought that a few notes on the subject might be acceptable to the Society.

Ordinary road traction is heavy owing to two causes, friction and unevenness. Friction, because the wheel under its load sinks in the ground and friction is set up between the sides of the rim and those of the groove made by the impression of the wheel; and unevenness, because the ground, not being of uniform hardness, is shaped at the bottom of the groove, by the load, into a succession of small grades, which have to be overcome. To avoid these, iron plates, a century ago, were laid upon the road, thus forming the rudimentary railway from which all the enormous subsequent development has sprung. The name of this primitive contrivance for ordinary horse traffic, survives in that of the "plate-layer" of the modern railway. Edge rails, as they were called, and the steam locomotive followed; but the introduction of the smooth and hard rail brought with it difficulties of its own in respect of what is known as adhesion—difficulties which were practically imperceptible in the ordinary road.

If the resultant between the direction of the force of gravity, and that of the traction force of a locomotive, developed at the circumference of the driving wheel, forms a less angle with the rail surface, longitudinally, than the angle of friction between steel and steel, evidently, when the driving wheel is impelled, there will be insufficient resistance, and it will slip, causing no motion to the vehicle in the contrary direction. There is no purchase to work from. Extra weight on the driving wheel increases the resultant angle referred to, and, by distributing the weight over as many driving or coupled wheels as possible, the purchase is increased, but there is a limit to this, and when in surmounting heavy gradients, the resistance due to the gravity is added to that due to the friction of the load to be drawn, a point is reached in the amount of the load, when the traction is so great in proportion to the greatest practicable weight on the drivers, that the resultant angle referred to cannot be kept greater than the angle of friction, and adhesion ceases unless either the angle of friction—which varies with the weather—is decreased by sanding the rails, or some special contrivance is adopted. Such a contrivance is the rack and pinion, which is the subject of this paper.

The apparatus, in its simplest form, consists of a rack, laid centrally between the ordinary rails, with which one or more steam driven pinions, which can be coupled in sets under the engine, engages. At first the rack took the form of a ladder, the rungs of which were acted upon by the cogs of the central engine wheel, but this was soon abandoned for the ordinary rack and pinion. It is clear that such a contrivance must be absolutely free from all danger of breakage, for if either rack or pinion were to break, the train would have nothing to hold it but the brakes, and as the incline to which the system is applied is necessarily severe, a great strain would be put upon these, and a great risk of a dangerous runaway incurred.

This led to the introduction by Mr. Roman Abt, whose rack system has been more generally adopted than any other, to devise two racks side by side, the teeth of which are staggered, that is to say the tooth of one is opposite the space of the other, an additional engine pinion being set to correspond. On extremely steep grades or where loading is heavy, three racks have been used, where the teeth of each are set one-third of the pitch behind its neighbour. Hence, should there be a failure in one set of rack or pinion teeth, the other set serves to hold the engine. Moreover there are generally two sets of pinions, set tandem fashion and coupled, to each rack.

The following is the description of the permanent way of the Nilgiri rack railway, which is one of those most recently laid, and is from the Government Report. I have had some particulars of this line, which is on the metre gauge, courteously supplied by an old colleague—the present Engineer-in-Chief, Madras Railway—and the rack line in question is an extension of a branch line with which I was connected when in India.

The rails are 50 lbs. steel, flat footed, 28 ft. $1\frac{3}{4}$ in. long on the straight, held down by single spiking, except at joints, where the outer spikes are double. The rails are fastened with deep, angle iron, six bolted, fish-plates, weighing 40 lbs. per pair. The sleepers are of Pyngadu wood, spaced 2 ft. $6\frac{5}{16}$ in. apart, size 6 ft. × 8 in. × 6 in. The rack is a double plate Abt steel rack on cast iron chairs, weighing in all 90 lbs per yard. The length of the rack bars is that of four sleeper spaces. The bars break joint, and are each $4\frac{5}{16}$ in. × $\frac{7}{8}$ in., the pitch is $4\frac{1}{16}$ in. and the pitch line is $\frac{13}{16}$ in. below top of bar. The two bars have a space of $1\frac{3}{4}$ in. between them. The slope with the vertical of the rack tooth at pitch line, is 1 in 4. The radius of pitch circle of pinion is $11\frac{1}{4}$ in. full. There is a pair of pinions keyed on to the rack shaft to correspond with the pair of rack bars. The rack teeth break pitch. The foregoing dimensions are mostly given in millimetres in the report, and are converted in the above to the nearest equivalent in sixteenth parts of an inch. The steepest grade is 1 in $12\frac{1}{2}$, and the sharpest curve 328 ft. or about 5 chains, radius.

The Abt engines used are described as follows. They are six-wheeled, the lower or down hill two pairs being coupled. The wheel base is 10 ft., of which 3 ft. 6 in. is between the coupled wheels. Length over buffers 24 ft. The loads on the wheels are $11\frac{1}{2}$ tons on each pair of coupled, and 10 tons on the pair of uncoupled wheels, total 33 tons, in steam and coal. The wheels are 2 ft. 8 in. diameter. Midway between the non-coupled and the inner pair of coupled wheels are two pairs of rack pinions in tandem 2 ft. $5\frac{1}{2}$ in. apart, driven by a third pinion keyed on a crank axle. This crank axle is driven by a pair of cylinders $10\frac{3}{4}$ in. in diameter and 14 in. stroke inside the main frame of the engine. Outside the main frame, and in line with the rack cylinders, is a second pair of cylinders 13 in. diameter and 16 in. stroke, which drive the adhesion wheels. The boiler which is 8 ft. 4 in. long in the barrel has a tilt of 1 in 20. There are tanks and coal bunkers. The overall breadth of the engine is 8 ft. 6 in. and its height over chimney 10 ft. 6 in. The heating surface is 750 square feet, and the grate area about 16 square feet.

The Government Inspector took two fully loaded vehicles and a brake van, in all 67 tons 14 cwt., or with the engine about 100 tons, up 500 ft. on the 1 in $12\frac{1}{2}$ gradient at about 4 miles per hour, the pressure being 175 lbs. to 180 lbs.

The permanent way proposed by the Abt patentee for the New South Wales lines, has not yet reached the stages of consideration by the Department, and the particulars of it have only been supplied in order that some idea of its character might be before us, in arriving at an estimate. As however, the design is the result of the great experience of the Abt Company in similar cases, it may be, with the above qualification, described in this paper, the gradient in view being 1 in $12\frac{1}{2}$, and the sharpest curve 9 chains, the gauge being, of course, 4 ft. $8\frac{1}{2}$ in.

The rails are of the T section 80 lbs. per yard, with fish-plates 59 lbs. per pair, fixed by $\frac{7}{8}$ in. bolts to steel sleepers 7 ft. $10\frac{1}{2}$ in. long 3 in. deep of the usual inverted hollow shape, $\frac{3}{8}$ in. thick. The rack bars three in number, are $4\frac{7}{8}$ in. deep and $1\frac{1}{8}$ in. thick, and are $1\frac{5}{8}$ in. apart, set in cast iron chairs, with two jaws $2\frac{3}{4}$ in. high, through which, and the three racks, $\frac{7}{8}$ in. bolts pass. The base of the chair, which is $9\frac{7}{8}$ in. wide, is attached to the sleeper by $\frac{7}{8}$ in. bolts. In this case also the dimensions given are in millimetres, and have been converted into the nearest fraction of an inch.

In the Mount Morgan 3 ft. 6 in. line in Queensland, which is also a comparatively recent work, the maximum grade is 1 in $16\frac{1}{2}$, on which there are 10 chain curves, and the engines used are four wheel coupled, with rear truck, having adhesion cylinders and valve gear outside and rack cylinder and mechanism inside, this latter being arranged with four pinions for double rack bars. The adhesion cylinders are $11\frac{1}{2}$ in. diameter, stroke 20 in., driving two pairs coupled wheels 3 ft. diameter, with a base of 6 ft. 3 in. The rack cylinders are $11\frac{1}{2}$ in. diameter and $15\frac{1}{2}$ in. stroke, and the diameter of the pinions at pitch line is $22\frac{9}{16}$ in. The heating surface is $454\frac{1}{2}$ square feet, and the grate area 11·28 square feet. The weight of the engine is 26 tons 17 cwt. in working order, and it takes 50 to 60 tons besides its own weight, up the incline of 1 in $16\frac{1}{2}$.

In the Strub system of rack, which has chiefly come into prominence by its adoption for the ascent of the Jungfrau metre gauge electric line, there is only one rack, but it is of very strong section forming a heavy central cogged bar $2\frac{3}{8}$ in. thick, and it is of special design in order to throw off accummulation of snow and prevent lodgement of ice, which was specially necessary in that case. To guard against consequence of breakage a very powerful grip brake, which will be referred to later, is in use. There is a grade of 1 in 4 on this line, full particulars of which are given in the Bulletin of the International Railway Congress for May 1899.

The grades dealt with by the rack system seldom exceed 1 in 4, but there is one of 1 in 2 built on the Locher system, in which the racks are horizontal, extending outward from a central rail, the pinions being horizontal. Except under special circumstances such as light weighted tourist traffic, nothing steeper than 1 in 10 should be used, in fact in regard to a line, now under survey in this colony, the agent of the Abt Company states that the 1 in 10 at first contemplated, must if possible, be reduced to 1 in 12½ at least, as this is the limiting grade in practice, up which an ordinary adhesion locomotive could travel light with its own weight only, in all weathers, so that any steeper grade would isolate the systems connected by the rack line, as regards free circulation of ordinary locomotive stock, and also much more expensive brake power must be applied, as the ordinary adhesion brakes would be of little or no assistance. Further, in the extremely steep rack lines which form part of a general system to be worked by combined rack and adhesion locomotives, the difficulty would occur of arranging the boiler to suit both. The tilt in the barrel suitable to an excessive grade, such as that allowable in a purely rack line of great steepness, would be unworkable on the level or ordinary adhesion grades.

Again, on the other hand, the usefulness of the system diminishes considerably when the grades can be eased to 1 in 25 or thereabouts, the gain not being worth the complication of a special system, the exact limit depending upon the circumstances of each particular case.

The difficulty of the entry of the engine easily on to the rack portion has been ingeniously got rid of by a contrivance invented by Mr. Abt. The rack bars are continued for a short distance on to the level or easy grade, at either end, and the last length of them is bevelled off, as regards its depth, down to nothing, at the end next to the adhesion line, and hinged vertically at the other end to the previous rack bars. These end bars are supported below by several strong spiral springs. The pinions on the engine which are left free to revolve on the approach to the rack, are thus gradually and easily, by means of the bevel and the elastic movement of the end rack bars, engaged with it, and by the time that the incline is reached, the pinions are in workable position to be acted upon by the cylinders driving them.

The changes between varying rates of grades on the rack must be gradually effected in vertical curves—4,000 ft. is the minimum radius of these on the Nilgiri line, and 3,300 ft. is that recommended by the Abt Company in the case of the 1 in $12\frac{1}{2}$ grade here. This is required to prevent the tendency to mount the rack, and for the same reason, it is evidently necessary that the relative levels of the ordinary bearing rails and of the rack should be rigidly preserved. With this view, steel sleepers have been advocated, and have been adopted in the Jungfrau line, so that a more rigid framework is attained, than if the fastenings were to ordinary wooden sleepers. But when the sleepers are of hard wood, such as in the Nilgiri case, and in Australia, the framing would appear to be sufficiently rigid with the timber foundation. It need hardly be stated that in either case, the road must be well ballasted, and maintained in the best order.

Points and crossings might generally be avoided on a rack portion, and limited to stopping places and junctions where easy adhesion grades for other reasons might be interposed. I find however that in the case of the Nilgiri line already referred to, the consulting engineer has ordered the short gaps in the rack at easier portions, including stations, as first constructed, to be filled up with the rack, making it continuous, so as to leave as few re-entering places as possible.

When points and crossings cannot be avoided on the rack itself, the point is made in the same form that we are familiar with in a contractor's temporary road, that is that the two meeting sets of rack bars stop one length short of the actual junction, and the interval is filled in with a moveable rack bar hinged horizontally at the junction end, and adjustable by switch rods at the other, to either line.

The two rack crossings required, when each set of rack crosses the bearing rail are so arranged that at these places the rack bars and bearing rail are made of the same length, and interlocked so that the same action which moves the rack points described above, causes the rail at one crossing to be moved aside and replaced by the equivalent length of rack, and the rack at the other crossing to be replaced by the rail.

The braking on rack lines must necessarily be of a very powerful and trustworthy character, and in the steeper grades must be applied to the rack mechanism, the adhesion brakes being in that case insufficient in themselves. Usually there are brake discs on the shaft of the pinion mechanism, by means of which the pinions may be completely locked, and there is an auxiliary loose pinion with brake discs on the trailing axle. The last serves merely for stopping the train, in case of any accident to the driving pinions or their gear. The braking on down gradients is done by using the steam cylinders as air compressors, there being special provisions for this purpose. On the Nilgiri line the engines are furnished with the Chatelier brake on both rack and adhesion cylinders. All stock, both passenger and goods, are fitted with the vacuum automatic brake acting on all six engine wheels and all eight wheels of each vehicle. The rack pinions are also powerfully braked. The trains are worked down the descent almost entirely by the Chatelier brake, the driver keeping one hand on that, and the other on the handle of the vacuum. Thus in an instant, he can apply the former on the engine and the latter throughout the whole length of the train.

A similar system is in use on the Mount Lyell 3 ft. 6 in. rack line in Tasmania.

In the Strub system, the form of the central rack with smooth high vertical sides, allows of the employment of a scissors shape grip brake, which is worked by hand from the vehicle fitted with it, gripping the rack bar itself, and it forms an effective addition to the other brakes used.

For bridges under the railway, arches instead of girders are preferable, as otherwise the action of the pinions on the racks would tend to cause the whole superstructure to creep downwards. When girders are used, heavy abutments must be built on the lower end of the bridge bearing against the end of the girders. To guard against creep in the road generally, anchoring stop posts butting against the down side of sleeper at intervals are sometimes required to be driven. However, in the Nilgiri line, the deep fish plates butting against the sleepers, seem to be sufficient.

Sharp curves must be avoided in steep rack inclines, not only for the reason applying to ordinary lines, that the resistances due to these should not, if possible, be coincident, but for others due to the working of the system itself. Owing to the danger arising from possible failure of drawbars, the rack engine is usually placed at the lower end of the train, and in ascending, is therefore pushing its load. The limiting safe stress on drawbars for instance in New South Wales railways is 25,000 lbs. which on a grade of 1 in 12½ would be the strain produced, together with train friction, by a load of about 130 tons only, so that accidental overloading might conceivably occur, and cause a breakaway, if the engine were in front. Now sharp curves are always likely to cause derailment of a train if it is impelled from the rear, as it is obvious that if there is any tendency on the part of any vehicle to mount the rail, which is more likely on curves, this is intensified if pushed, and counteracted if pulled by an engine still on the rails.

The serious nature of an accident through the breaking of a drawbar in a train which is being pulled up such a severe grade as the provision of a rack implies, is evident, as there would be certain to be some small interval of time between the fracture of the bar and the full application of the brakes, during which the speed on such a grade would probably have attained a dangerous excess.

The drawback of limiting the application of the rack to lines of easy curvature is a serious one, as it is just in the mountainous regions where such a contrivance is required that sharp curves are wanted to lessen works and to provide length, so as to moderate excessive grading. The Abt Company strongly recommend a minimum radius of 9 chains for 1 in 12½ grade on our standard gauge, and this is the limit on the Abt standard gauge line Eisenerz to Vordenburg in Styria, where the grade is 1 in 14·7. However on the Visp Zermat 1 in 8 line in Switzerland, and the Nilgiri in India, both on the metre gauge, push-up engines are used on 5 chain curves, which is much smaller in proportion than 9 chains on the 4 ft. 8½ in. gauge, and there are other similar cases.

On the Bhore ghât and Thul ghât adhesive inclines, where the ascent is from the Bombay flats to the tableland of the Deccan, there used to be, when I was there many years ago, frequent safety or catch sidings at intervals with reverse grades, the points of which were kept normally open to the siding, and were only closed by a pointsman, when the signal of the descending driver indicated that he had full control of his train, but whether this practice is now continued since the introduction of the more powerful modern brakes, I am not aware; and in this country of high wages, it would add considerably to the working expenses of the section.

The Government Consulting Engineer in the case of the Nilgiri line, reported against the adoption of safety sidings, except in a modified form. His report states, "I am of opinion that, except when the features of the country are such as to make it possible at reasonable cost, to make a guard siding at the upper end of a station, of sufficient length and grade to stop a runaway with absolute safety, it is wiser to rely on the brakes, and to make quite sure of their efficiency. I believe I am correct in stating that catch sidings do not exist on any rack railway elsewhere. They cannot be laid in at any place where there is a rack. They were not ordered by the Board of Trade after the Snowdon accident."

I do not understand the statement that catch sidings cannot be laid where there is a rack, as points and crossings, as already described, are in use on several rack lines.

As to speed on the rack, it is stated that a velocity of 17 to 20 miles per hour, is easily and comfortably attained, but it is evident that on such a comparatively short length as ordinarily is required for the rack ascent, this matter is of minor importance.

Two systems have been adopted in lines of which a rack section forms a part, firstly, that in which one or more rack engines are employed, only on the rack length, taking up trains brought to the foot of the incline by the ordinary adhesion engines, and delivering them over to other ordinary engines at the top, and *vice versâ*, or possibly where the grade is not very severe, for the ordinary engine also to go through, assisting the rack one by adhesion only, even if the power exerted by the latter is only sufficient to take itself up. This system only works economically when the traffic is sufficient to employ fully the special rack engines, and if the grade is severe, it has the disadvantage of isolating from one another, as far as ordinary locomotive stock is concerned, the railway systems, if there are such, at each end of the incline.

The other plan is to provide locomotives which combine the pinion and the adhesion principles, so as to be thoroughly effective in both, in order that they may go through, gearing the pinion when required in addition to their adhesion work, which latter up fairly steep grades will share the work to a small extent, in good weather. This system appears to gain more favour, as it is subject only to the comparatively minor defect of carrying the useless mechanism of the pinions, and the weight incident to them, over a possibly considerable mileage of easy grading where it is not wanted.

In many cases the alternative presents itself of adopting for the ascent of a given height, a comparatively long adhesion line, or a short and steep rack one, and this is the phase of the question which only, up to the present, has had to be considered in this Colony. So that it becomes interesting to ascertain as nearly as possible, where both these methods are practicable, which is economically the best.

An actual comparison from experience which would be trustworthy is out of the question for no two lines have the same data or are under similar conditions. An attempt was made at this in a paper by Mr. R. Wilson[1] as regards the cost of raising and hauling 1,000 foot tons by the rack system on the Hartz Mountain Railways, and on the Semmering incline with adhesion

1 Institution of Civil Engineers, Min. Proc., Vol. xcvi.

respectively, both on the standard gauge, and shewing that the cost of this work, on the former line, was only 76·6% (mark the decimal) of that on the latter. But such comparisons as these as well as those on which so much ink has been wasted, and which are so frequently turning up with regard to the gauge and other questions, are, I think, not of much value, unless we know much more of the details than the writers ever give us, and even if we had every possible detail their application to widely different local circumstances would probably mislead us seriously.

Comparisons, deduced from trials, between rival garbage destructors, pumps, oil engines, etc., etc., are being constantly put before the profession, but are very misleading as a rule, for the reason just given. There was a trial, some years ago, between a compound and a simple locomotive, for which a special length of double line of railway was set apart. The two engines were provided with the same class of fuel and water, and ran side by side at the same time along the parallel roads, with the same speed, load, grades, curves, and wind resistance, and yet with all this, as nothing was said about the experience, ability, or even temper, of the respective drivers, on which the economical working of a locomotive so much depends, the results as to fuel consumption etc. could not be regarded as absolutely decisive. Moreover if severer grades, or other circumstances not met with in the trial, were encountered, the results might have been reversed. So, in the Hartz Mountain and Semmering case, where the other conditions were nothing like so similar, we ought to know all about the delicate question as to whether the respective traffic and locomotive superintendents in each case were capable men or otherwise, apart from all questions of grades or racks. Such a knowledge might upset the whole calculation, and turn the exact figure 76·6 into something very different, and possibly over to the other side of the comparison.

It is evident that the mechanical effort of raising a given weight, to a given height, in a given time, is not affected by the adoption of a rack, as it is not a power in itself but only a means of applying power. If therefore we suppose a choice to be required between two proposed lines which have to surmount 1,000 feet, one 10,000 feet long with a rack grade of 1 in 10, and another 60,000 feet long with an adhesion grade of 1 in 60, the same load to be taken up in the same time, in each case, the expenditure in running, wages, and in consumption of fuel and water, will be practically the same in each case. On the rack line the journal and rail friction, apart from brake action, will be less, owing to the lesser number of revolutions of the wheels and of the shorter length of road, and the general maintenance of the road, apart from that caused by the rack, will be much less, but on the other hand there are the extra repairs to the locomotive due to the pinions and gear, the wear and tear due to extra braking, the maintenance of the rack itself as well as the extra care required in that of the whole road, due to the proper working of the rack system, the cost of working the shunting stations at each end, and the indefinable extra expense always to be looked for in dealing with special apparatus inserted in the general ordinary system.

On the whole, I should be inclined to think that the determining factor must be mainly the comparative cost of construction of the two lines, and the question of the method by which they are proposed to be worked. It is clear that if the rack section is, or is to be in the future, a link between two extensive railway systems, one in the low and the other in the high country, different working conditions would arise from those which would exist if the rack line was a branch one pure and simple, with little or no possibility of extension beyond.

In fact, the problem which would have to be solved in such an alternative as that just referred to, would be one in which the traffic and locomotive departments would have to be consulted as well as the engineer.

This paper might fitly conclude with the following extract from a report by a Commission appointed by the Italian Public Works Department, on this matter a few years ago, in which the leaning evidently is towards the rack in the case of such an alternative:—

"After having thoroughly studied this subject, we have come to the final conclusion, (1) That rack railways offer an excellent means of overcoming steep inclines, which are beyond the limit of adhesion, and that they make railway communication profitably possible in mountainous regions, where adhesion lines would require the investment of too much capital, and would not pay.

"(2) That the slow speed of the rack locomotives is favourable for working the engines economically, and that the speed, though in itself slow, is relatively considered, about the same as the average speed on adhesion lines.

"(3) That it is practicable, considered from a mechanical stand point, for cog-wheel locomotives to ascend grades from 3½ to 25 per cent. (1 in 40 to 1 in 4) but that from an economical stand point considered, the grade on combination rack railways with large traffic should not exceed 7 per cent. (1 in 14·28).

"(4) That the Abt system, for lines with large passenger and goods traffic is preferable to any other rack system.

"(5) That the efficiency of a rack railway, even on very steep grades is considerable, but on grades of 6 to 7 per cent. (1 in 16·66 to 1 in 14·28) its efficiency is equal to that of an adhesion line of 2½ per cent. (1 in 40).

"(6) That the total operating expenses of a combination rack railway are smaller than those of an adhesion one between the same points, hence that rack systems can favorably compete with adhesive lines.

"(7) That Italy contains many locations where the application of the Abt system would be advisable from a technical as well as from an economical point of view."

NOTES ON DAMAGE CAUSED BY LIGHTNING TO SEAL ROCKS LIGHTHOUSE ON 10TH JULY, 1900.

By C. W. DARLEY, M. Inst. C.E.

[With Plate II.]

[*Read before the Royal Society of N. S. Wales, August 8, 1900.*]

THE Seal Rocks Lighthouse which is situated one hundred and seven miles north of Sydney stands on a bold projecting headland at an elevation of two hundred and fifty-eight feet over sea level. The lighthouse stands by itself on a well defined conical hill, the keeper's quarters being built on a lower plateau, and distant about three hundred feet.

The day the lightning occurred had been fine, but for two days previously heavy thunder clouds hung low over the locality, and there had been frequent peals of thunder, but apparently this condition was quite local, although it extended some distance inland, for at Bungwall six miles, and Bullahdelah about twenty miles inland, a similar atmospheric state was reported. At 3 p.m. the light tower was struck by lightning.

The tower is fitted with a solid copper lightning conductor $1\frac{1}{2}$ in. by $\frac{3}{4}$ in. half round, and is attached at top to the copper roof of lantern. It passes down outside the lantern to the gallery, and then passes in through the lantern base, and down the inside of the tower, being secured to the wall with copper screws in lead plugs. Upon reaching the floor of the lamp room in basement, it passes out under the wall, and is then taken underground to earth, but where or how has not yet been ascertained.

The electric fluid entered the vane on top of lantern dome (the ends of the feather being bent and fused and the base mold lifted 3 in.) thence passing down the lightning rod. A portion of the current was communicated to the electric bell wires on the middle or green-light floor. These bell wires which lead from the lamp room to the principal and assistant keepers' quarters are laid underground within 1 in. galvanised iron gas pipe for a distance of about 300 ft. The current apparently tried to make earth at three places, for the pipe was burst out and the sockets split, the earth overlying the pipe at these places being blown away. At the houses the wires lead up verandah posts within a wood casing which was torn off and split into fragments. A sheet iron covering where the wires entered the houses was blown off, and in one case with such force that it cut a passage for itself through the top of a paling fence six feet away. Some stone flags on the verandah round the post were displaced, and generally there were many indications of the efforts of the lightning to make earth.

To return to the lighthouse. The iron flooring, ceiling, and staircase of lantern must have been thoroughly charged, as numerous spots appear where the paint has been blown off, varying in size from about $\frac{1}{4}$ to 1 in. diameter, the bare iron underneath being fused and in some cases pitted, the iron ceiling underneath this floor is fastened to the iron girders with iron set screws, and the heads of eight of these screws have been blown off. The battery for the electric bells (which stood on top of the lobby framing at entrance to the green light room) was destroyed and the wires leading downwards through the store room below have disappeared, one side of the lobby framing was shattered and the entire framing was wrenched away from its fastenings and moved some 4 in. out of place, the writing desk which was fixed on two iron brackets against the side of lobby was broken up as also was one of the iron brackets, the ink pot which stood on the desk was driven with such force against the reflector of the green light on the other side of the room, as to dent the reflector, but not to seriously damage it; the clock was destroyed; the glass in all the windows of this room was blown out, and four panes of glass in the main lantern were badly fractured. No injury was done to the dioptric apparatus or lamps of either the main light or the green light, and both remain in good working order. A copper screw which held the lightning conductor to the wall was blown out and shows traces of fusion.

In the oil-store in basement (which opens to the outside only and has no direct connection with the green light room by staircase or otherwise) stood an open bucket containing about two gallons of kerosene oil, and in four tanks was stored about one hundred and fifty gallons of seal oil. The flash from the fused bell wires may have communicated with the kerosene oil and caused an explosion, for the entrance door was blown out and destroyed, also the door leading into small store under outer stone staircase, and the glass from all windows. The weight tube which is 11 in. diameter and constructed of stout zinc about 9 gauge or .147 in. thick was blown to pieces for a length of about eight feet, part passing through the doorway and landing about forty feet from the building; the weight chain was clogged in places with fused metal.

The lids of the oil-tanks were blown off and destroyed, and most of the draw-off cocks were injured, but the oil inside did not escape. The arched concrete floor between the cil room and the green-light room above appears to have been bodily driven upwards as it is cracked all round some three or four inches from the wall. The skirting and weight tube indicate that it lifted up at least a quarter of an inch. The floor of oil room is paved with asphalt, and this has been melted and destroyed. All the copper measures, buckets, oil-pump etc., which were in the room were injured, and one spare lamp for the main light was found embedded fast in the asphalt paving. The fire which followed destroyed all the work tables, tool chest, tank stand, etc.

Probably the whole cause of the damage is due to the lightning conductor not making an efficient earth connection. No doubt it was unwise to lead the conductor part of the way down the inside of the tower, but this appears to have been occasionally adopted in English practice, and in the case of the Eddystone Lighthouse, and the Nash Low Lighthouse, where this was done, the towers were struck by lightning and damaged internally.

Another lesson to be learnt from this occurrence is the necessity for insulating the bell wires. The whole of the lantern is a metal structure with a copper roof, and the modern lighthouse practice is to attach the lightning conductor not directly to the vane on top, or the copper roof, but to attach it to the base of the lantern and thus depend upon the lantern collecting the current and conveying it to the conductor.

The bell wires are invariably in metallic contact with some portion of the lantern, and therefore just as liable, as in the case in question, to be charged with lightning as the proper conductor.

It is proposed to attach a copper band $1\frac{1}{2}$ in. by $\frac{3}{16}$ in. to Seal Rocks Lighthouse from the copper dome of lantern, and lead it down outside and take it to earth, taking steps to so bury the earth plate and maintain it in a state of efficiency by leading the discharge from overflow and down water pipes over the pit where the plate is sunk.

When replacing the bell wires steps will be taken to carefully insulate them from any metallic contact in the lantern.

The following reports as to the state of the weather on the coast north and south of Seal Rocks on the 10th July, have been kindly supplied to me by Mr. H. C. Russell, C.M.G., the Government Astronomer. The matter is of special interest inasmuch as it is most unusual for thunderstorms to occur on the coast in the month of July:—

Port Macquarie, sixty-five miles north. Pilot reports—I neither saw or heard thunder that day.

Manning River, thirty-four miles north. Pilot reports—Nothing of any consequence took place near this station, but thunder was heard previous evening.

Port Forster, Cape Hawke, eighteen miles north. Pilot reports—On day lighthouse was damaged the weather was very threatening to the south-east, heavy squalls passing out to sea with distant rolling thunder, and at night there was bright lightning in the direction of Seal Rocks. About 11 p.m. a very heavy clap of thunder.

Stroud, about thirty-three miles inland, almost due west. Postmaster reports—Heard no thunder about 3 p.m., but from 6 to 9 p.m. that evening I heard thunder and saw several flashes of lightning in the east towards Seal Rocks, and it struck me at the time it was a somewhat unusual thing to have storms in July.

Port Stephens, forty-four miles south. Lighthouse keeper reports—That lightning and thunder were severe for about ten minutes on that day.

From the foregoing notes it appears the storm was very local, the centre apparently passing inland over Sugarloaf Point, on which the Seal Rocks Lighthouse is erected.

Added 3rd September, 1900.—Since the foregoing paper was read, the earth terminal of the lightning conductor has been opened up, and found to be in apparently good order, the surrounding soil being damp. The position of the earth plate is shewn on the accompanying drawing (*Plate* 2). A defective joint has been found in the copper conductor, which escaped notice during the first examination, being situated in the green-light room behind the iron stairs. This was a lap joint, the two parts being held together by a screw passing through into a lead plug in the wall. It now transpires that the screw has been loose for some time, and when painting the walls, which is done almost every second year, the paint got in between the laps of the copper rod and thus broke continuity, causing the electric current to escape and thus do all the damage reported.

THE LANGUAGE, WEAPONS AND MANUFACTURES OF THE ABORIGINES OF PORT STEPHENS, N.S.W.

By W. J. ENRIGHT, B.A. *Syd.*

(Communicated by R. H. MATHEWS, L.S., Memb. Corres. Soc. d'Anthrop. de Paris.)

[With Plates III., IV.]

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LAST year I contributed a short paper to this Society on "The Initiation Ceremonies of the Aborigines of Port Stephens."[1] On the present occasion it is intended to supply a grammar and vocabulary of the Kutthung, one of the tribes dealt with in my former article, and it is hoped that this attempt to preserve the language of the native tribes on this part of the coast of New South Wales may be found of some value. Two photographs, showing a number of weapons and other articles collected by me amongst these natives have been added, together with a short description of each.

My best thanks are due to my old and valued friend, Mr. R. H. Mathews, of Parramatta, for introducing me to the principal men of the tribe, and for many practical suggestions whilst I was occupied in carrying on the work.

In the system of spelling adopted, all the consonants have the same value as in English. The sounds of the vowels are represented in the following words :—

a = fate	*i* = wit	*u* = gun
ă = fan	*ī* = mite	*ū* = sure
â = far	*o* = dot	*ou* = now
e = let	*ô* = note	*oy* = coy
ee = meet	*oo* = moon	

[1] Journ. Roy. Soc. N. S. Wales, xxxiii., 115 – 124.

The letter *g* is hard in every case. *Dh* is pronounced nearly as *th* in that, with however, a slight, initial *d* sound. *N* preceding *y*, as in Nyee, has the sound of *ñ* in cañon, thus Nyee is pronounced nearly as in-yeé, but quickly as one word. The final *h* is guttural, and somewhat like the *ch* in the German, but is not so marked. The accented syllable is shown in the usual way throughout the paper, and where there are two accented syllables in the same word, they are both marked.

THE KUTTHUNG GRAMMAR.

1. The Kut′-thung dialect is spoken amongst the Aborigines living along the southern bank of the Karuah River and the south shore of Port Stephens. It was at one time spoken amongst the tribes lying between Port Stephens, West Maitland and Paterson, but with the exception of the Kutthung, they are now extinct.

The adjoining tribes were the Gummigingal,[1] inhabiting the territory on the north shore of Port Stephens and the Karuah; the Warringal,[2] living between Telegherry and Pipeclay Creeks; the Warrimee, living between Telegherry Creek, Port Stephens, the Sea Shore and the Hunter River: the Garawerigal,[3] between the Myall River and the sea shore; the Yeerunggal,[4] about the Myall Lakes; the Birrimbai, in the neighbourhood of Bungwall Flat; and the Birroonggal,[5] on the Myall River.

2. There are only two numbers, the singular and plural, and each number has three persons. The personal pronouns are used for the present tense of the verb "to be," which has no real existence in that form *e.g.* "Nut′-wâ" is the equivalent, not only for "I," but also of "I am." "Yeé-nū-âr" is the Kutthung term for "thou art" as well as for "thou," and in this latter sense in forming the future and past tenses.

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[1] People of the Spear. [2] People of the Streams—(In Proc. Roy. Soc. N.S.W., Vol. xxxiii., p. 124, I have erroneously called this tribe the Doowalligal) [3] People of the Sea. [4] People of the long and narrow place. [5] People of the deep river.

Present Tense—Mur′-rook = Good.

Nut′-wâ mur′-rook,	I am good
Yeé-nū-âr mur′-rook,	Thou art good
Nū-âr mur′-rook	He is good
Nyeé-un mur′-rook	We are good
Noó-râr mur′-rook	You are good
Bâră mur′-rook	They are good

Past Tense—Yer′-ră-kee = Bad.

Yer′-ră-kee nut′-wâ gut′-tâ-lă,	I was or have been bad
Yer′-ră-kee yeé-nū-ar gut′-tâ-lă	Thou wast or hast been bad
Yer′-ră-kee nū-âr gut′-tâ-lă	He was or has been bad
Yer′-ră-kee nyeé-un gut′-tâ-lă	We were or have been bad
Yer′-ră-kee noó-râr gut′-tâ-lă	You were or have been bad
Yer′-ră-kee bâ′-ră gut′-tâ-lă	They were or have been bad

Future Tense.

Mur′-rook nut′-wâ gun′-yee	I will or shall be good
Mur′-rook yeé-nū-âr gun′-yee	Thou wilt or shalt be good
Mur′-rook nū-âr gun′-yee	He will or shall be good
Mur′-rook nyeé-un gun′yee	We will be good
Mur′-rook noo′-râr gun′-yee	You will or shall be good
Mur′-rook bâ′-ră gun′yee	They will be good

3. The articles "a" and "the" are not translated.

4. Personal pronouns; possessive.—These are always placed before the noun they agree with.

Example I.—1. Bee-num′-bâ Băr-ră-kun′. 2. E-goó-bâ Kun′-nī. 3. Bur′-rub-bă gum′-mī. 4. Noon′-gum-bâh mir′-ree.

Translation—1. Your boomerang. 2. This yamstick. 3. My spear. 4. Her dog.

5. Nouns.—The nominative is generally placed foremost in the sentence, the objective usually follows it, and the verb governing the object is placed last.

Example II.—1. Mir′-ree goo bud-jeé-lă. 2. Nut′-wâ bâ-ră bun-yil′-ă. 3. Nut′-wâ koor′-ee toó-ree-ăl′-lă. 4. Mut′-too koor′-ee bud-jeé-lă.

Translation—1. The dog bit him. 2. I struck them. 3. I speared a man. 4. The 'black snake' bit a man.

6. Nouns, possessive.—The possessive is formed by adding "goo′-bă" to the possessing noun.

Example III.—1. Koó-noong-goo-bă băr-ră-kun′. 2. Wam′-bo-gn-goo-bă nimbik. 3. Bing′-hī-goo-bă gum′-mī. 4. Kidn-goo-bă mir′-ree.

Translation—1. The old man's boomerang. 2. The kangaroo's (doe) bone. 3. The eldest brother's spear. 4. The woman's dog.

7. Nouns, ablative.—The ablative is formed by adding "oo" to the noun. In cases where the final letter of a word is a vowel, the vowel is dropped.

Example IV.—1. Nut′-wâ koor′-ee băr′-ră-kundoó bun-yil′-lă. 2. Nut′-wâ koor′-ee goot′-the-roo bun-yil′-lă.

Translation—1. I struck a man with a boomerang. 2. I struck a man with a club.

8. Verbs.—The verb is without any change in the present tense for either number or person. The same rule applies to the past, which is formed by adding "llă" or "lă" to the present tense. The present participle is formed by adding "llin" or "lin" to the present tense. Euphonic changes are also occasionally made in the final syllable to meet this addition. There is no separate form of the verb for the future, which is indicated by suffixing "nuh" to the nominative agreeing with the verb.

Present.	Past.
Mur′-roo-ma (make)	Mur-roo-má-lă (made)
Bun′-yee (strike)	Bun-yil′-lă (struck)
Yăl′-lô-wâ (sit down)	Yăl′-lô-wăl′-lă (sat down)
Bud-jeé (bite)	Bud-jeé-lă (bit)
Boon′-mâ (steal)	Boon′-mâ-lă (stole)
Boo-bâ (lie down)	Boo-bâ′-lă (laid down)
Bit′-yee (drink)	Bit'-yeel-lă (drank)

Present Participle.

Mur′-roo-má-lin (making)
Bun-yil′-lin (striking)
Yăl′-lô-wăl′-lin (sitting down)
Bud-jeé-lin (biting)
Boon′-mâ-lin (stealing)
Boo-bâ′-lin (lying down)
Bit′-yeel-lin (drinking

The verbs have no passive, but the sense of the passive is rendered by means of the indicative.

Example V.—1. Wut′-tâ koor′-ee win′-yăl-lâ. 2. Toó-mul-lă kidn ku′-reel-lâ. 3. Bud′-jee nū′-âr-nuh. 4. Kut′-tī nut′-wâ-nuh[1] wun′-dă doo′-kun kut′-tī băr′-ee-â. 5. Nut′-wâ gum′-mī mur′-roo-má-lin. 6. Bing′-hī-goo-bă băr-ră-kun′ goo bun-yil′-lă. 7. Nut′-wâ beé-yâr-goo-bă yuk′ree boon′-mâ-lă. 8. Noó-kwum-bâ nur′-rin kidn-goo-bă bor-tâ′ dun-yil′-lă.

Translation—1. A man was burnt in the fire (*lit.* fire burnt a man). 2. The woman was drowned in the creek (*lit.* creek drowned the woman). 3. I will bite. 4. I will go when the sun sets (*lit.* I will go when the sun goes from me). 5. I made a spear. 6. I struck him with the eldest brother's boomerang. 7. I stole my father's wommera. 8. His eldest sister ate the woman's food.

9. Adjectives.—Adjectives are generally placed after the noun they qualify—

Koor′-ee mur′-rook, a bad man; kidn yer′-ră-kee, a bad woman.

The comparative is formed by adding "bing" to the adjective, and the superative by the addition of "beé-rang," signifying "very"—

mur′-rook, good; mur′-rook-bing, better; mur′-rook-beé-rang, best
yer′-ră-kee, bad; yer′-ră-kee-bing, worse; yer′-ra-bee-beé-rang, worst.

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[1] *h* is guttural, see explanation hereinbefore.

10. Abverbs.—Adverbs may be formed from adjectives by means of the suffix "boo"—

Yer'-ră-kee, bad;	yoó-râ, slow;
Yer'-ră-keé-boo, badly;	yoó-râ-boo, slowly.

11. Prepositions.—Prepositions are placed after the nouns they govern. Some are separate words, and others are simply suffixes. Examples of the latter are "oo," which has been previously referred to as forming the ablative, and "gwa" meaning among, also "numbar" meaning at, and "in-ge-râ" signifying with.

Example VI.—1. Beé-yâr mur'-rook koop'-păl-eé-â-gil-lin goog'-e-roo. 2. Nū-ar gum'-mī gâ'-băl-lin nyeé-un num'-bâ. 3. Nyeé-un nur'-râ gub'-bee-rung kut'-tī. 4. Koop'-păl-eé-â bâ-ră-nuh yoon'-go goó-âr. 5. Wot'-too mur'-rălin dheer'-ră-gwâ. 6. Nut'-wâ băr-in-ge-râ kut'-tī. 7. Kidn koor'-ee boo-larng' kut'-tī. 8. Wot'-too pur'-rupă wok'kă yăl'-lô-wal'lin. 9. Dârn'-dee yăl'-lô-wăl'-lin wit-tuk bâ-ră. 10. Ky'-in-dub'-bă yăl'-lô-wăl'-lin wit'-tuk bâră.

Translation—1. The good father is running to the hut. 2. He is throwing a spear at us. 3. We go from the camp. 4. They will run up to the mountain. 5. The opossum is sitting among the branches. 6. I go with them. 7. The man and woman go together. 8. The opossum is sitting on top of the hut. 9. They are sitting on this side of the creek. 10. They are sitting on the other side of the creek.

12. Conjunctions.—Conjunctions are "dil'-ling," meaning also, and "yâ-ree," meaning or.

Example VII.—1. Noó-kâ băr'-ee-â băr-ră-kun' gum'-mī dil'-ling. 2. Nâ'-nă wom'-mô koor'-ee yâ'-ree kidn yâ'-ree.

Translation—1. Give me a boomerang and also a spear. 2. Who is the fatter—the man or the woman?

13. The negative is expressed by means of "gooran" (not) and the imperative is expressed by adding "yung" or "nī" to the verb.

Dun'-yee, eat;	Koop'-păl-eé-â, run;
Dun'-yee-yung', don't eat;	Koop'-păl-ee'-â-nī, don't run.

14. The interrogative is expressed by means of "weé-yuh," *e.g.* Weé-yuh mur′-rook, is it good?

This word appears to be used in asking a question concerning the quality of anything. There are other words which are used to inquire concerning time, manner, place, etc., which will be found in the vocabulary in the succeeding pages.

15. Numerals.—The numerals are really only two, viz. "wok′-kool," one, and "bul-ló-râ," two; but by compounding these the Kutthung is able to count as far as five. Any greater number than five he expresses by "doocalla," a great many.

Vocabulary of the Kutthung Language.

The words in the following vocabulary have all been spelt phonetically and the translation of them into English is given as literally as possible. In some instances the English word will be found to have two equivalents in the Kutthung. This I think has been caused through tribes coalescing, as their numbers dwindled away and tribal boundaries were effaced before the march of civilization. By this means each new addition to the tribe would inevitably mean a slight addition to the language. The reader will please note that "*d*" and "*t*" are interchangeable as also are "*g*" and "*k*."

Kutthung. English equivalent.	Kutthung. English equivalent.
Beé-yâr, *father*	Ber′-ri-ma, *the teal*
Boor′-ī, *baby boy*	Broó-ee-gee, *to swim*
Boor′-ī Toó-kal, *boy* (lit. *big baby*)	Broó-ee-gal′-it, *whip snake*
Bit-theé, *old woman*	Bung-hí, *to-day, now*
But-tong′, *black*	Buk-oo-ee, *meat*
Bur-rá, *white or light coloured*	Bud-geé lă, *bit* (past tense)
But′too, *smoke*	But-tig-yee′, *wattle tree*
Bur′-rī, *earth, territory belonging to a tribe*	Bur-roó-ma, *mahogany*
Bin′-dul, *beard*	Be-lorn′, *stingaree*
Bee, *the wrist*	Bun-yeé, *to strike*
Buk-â, *the knee*	Bunn-yil′-lă, *struck*
Băr-ră-kun′ *returning boomerang*	Boo-bâ, *to lie down*
Bur-rid′, *the wallaby*	Bur′-rung, *red*
Book′-ut, *bandicoot*	Boó-mer-ī, *grass tree*
Bul′-boo, *kangaroo rat*	But-teé-yuk, *white ant*

Kutthung.	English equivalent.

Bir′-rum Bir′-ra, *bird's nest fern*
Boó-ra, *short*
Bir′-rin, *wide*
Buk′-koo-wee, *short*
Bir′-roon, *to break*
Boon-dheé-la, *to fall*
Bin′-dhee, *stomach*
Bur′-rin, *a net*
Buk′-ă Buk-â, *savage*
Bur′-oo-lit′, *rosella parrot*
Buk′-ă, *angry, to quarrel*
Bun-bee-al′-la, *to drop on ground*
Bum-′bee wut′-tâ, *to make fire*
Boó-took, *soft, smooth*
Boon′-mâ, *quiet*
Bar′-koon, *a coward*
Bir′-ree-wel, *brave*
Boó-ī, *breath*
Bing′-hī, *youngest brother*
Bool′-bung, *the larger circle at the keeparra ground*
Bar′-rô-wa, *a large bullroarer used in keeparra ceremony*
Bort-tâ, *food*
Beé-rang, *very*
Bun-dă-leel′-lâ, *cut*
But′-thoon, *a dilly bag*
Bir′-roo-yee, *fish-hook*
Boo-ee-buh, *to copulate*
Bil′-lung-ree, *the black oak tree*
Boor′-rool, *heavy*
Bun′-ga Bug′gun, *flock pigeon*
Bool′gee, *dry*
Bor Bor, *a circular piece of bark cut off a tree and used as a flying target*
Boor′-ro-wang, *female of the Macrozamia*
Bul-lo′-râ, *two*
Bul-lo′-râ Wok′-kool, *three*
Bul-lo′-râ Bul-lo′-râ, *four*
Bul-lo′-râ bul-lo′-râ wok′-kool, *five*
Bâ-ră, *they, them, those*
Bâ′-lee, *to*
Bâr-in-gin-in′-dâ, *their*
Bâr-in-gin-in′-dă-wee, *these*

Kutthung.	English equivalent.

Bee-num′-bâ, *your*
Bum-bâ′-lă, *married* (past tense)
Boon′-dhee, *a club used both for throwing and striking*
Bool′-gee bur-rī, *a drought* (lit. *dry earth)*
Boo-larng′, *together*
Boon′-ma, *to steal*
Bee-ram′-mer, *marks made at Keeparra on the body of the initiate*
Bur′-run gee, *the native squirrel*
Boom′-be-ră, *the testicles*
Bir′-ree-wel goo-ran, *weak* (lit. *not strong)*
Bit′-yee, *to drink*
Ba-rel′-la, *a fly*
Bur′-rin, *a net*
Boon′-ger-ăl, *a fight*
Bot′-yee, *to carry*
Boon-dâ′-gee, *to swallow*
Bâ-râ, *down*
Bân, *aunt*
Bil′-lin, *yellow*
Beé-yar Goó-ran, *fatherless*
Bur′-rub-bă, *my*
Buk-kin′, *half*
Din′-nâ, *the foot*
Doon′-gâ, *the right arm*
Doó-kăl or toó-kăl, *great, big, large*
Doon′-dee, *small coolamon*
Dir′-râ, *a tooth*
Doon′-git, *carpet snake*
Dut′-tee, *dead*
Doon′-ge-râ, *pelican*
Doó-nong, *the eel*
Dur′-râ-ra, *dry*
Dun′-yee, *eat*
Dhur′-ra, *the leg*
Dhap-pee, *the chin*
Doó-mu, *to keep*
Dhun′-bârn, *strong*
Dun′-gee, *to tie*
Dhur′-oo-bal-lee, *to leak*
Dhum′-but, *thirsty*

Kutthung.	English equivalent.
Dun′-gâ,	*to shew*
Doon′-găl,	*tears*
Dhur′oo-bal-lee kun′-ge-ră,	*to bleed* (lit. *to leak blood)*
Dhir′-ră-bwee,	*oyster*
Dheé-ra,	*a branch*
Dun′dul,	*between*
Dârn′-dee,	*on this side of*
Dhub′-ba,	*whilst*
Dir′-ree Dir′-ree,	*rough*
Doó-ping,	*a mosquito*
Dip-oon′-gâ,	*a stone used for sharpening shell fish-hooks*
Dheé-kâ,	*the native companion*
Dhur′-ī-ee,	*thin*
Dul′dee,	*to kick*
Dhook-kee,	*to rise*
Dool′-bee,	*a pointer consisting of a stick lashed crosswise to an upright and pointing in the direction that people have gone*
Dhal′-gi,	*a minor initiation ceremony*
Dir′-răwâ,	*a rib*
Doó-kăl-lă,	*a lot, great many*
Dreé-ăl-ung,	*speared*
Dun′-dul-lă,	*narrow*
Dheé-wee,	*the navel*
Doó-roong,	*brown*
Dung′-gă,	*the vagina*
Dhoo-ree,	*straight*
Doó-wâ-kee,	*to search*
Doon′-gă,	*to know*
Dhir′-roo-la,	*dangerous*
Dhur′-roo-me-ree,	*a rainbow*
Dil′-ling,	*also*
E-goó-bâ,	*this*
Ek′-ū-ba,	*good-bye*
Gă-roó-wâ,	*sea*
Gô-on,	*mangrove tree*
Gool′-be ree,	*a few*
Goó-lâ,	*the native bear*
Gá-long,	*going*
Gum-mī,	*a spear*
Gool-gâ,	*the penis*
Gă-lun-gun′,	*the green tree-snake*
Goó-bâ,	*of*
Gun′-gul-bâ,	*black comorant*
Gă′-ra,	*the schnapper*
Grâ′-bun,	*groper*, (a fish)
Gur′-râ wur′-ră,	*jew fish*
Gur-um′-bee,	*white gum*
Goó-ee-wee,	*shark*
Gir′-um-bit,	*salt water*
Gir′-ra-gâr,	*honey*
Gip′-pee,	*wet*
Goó-jee ik′koo,	*come here* (the expression of greeting used among the Kutthung)
Goó-râ,	*long*
Goó-nood,	*old*
Goó-roo-mul,	*young*
Gul′-lu,	*cheeks*
Gur′-rī,	*to choke*
Ghin′-doo-ee,	*turkey*
Gir Gir,	*king parrot*
Goó wok,	*hard*
Gun′-yâ,	*hut*
Goó-bree-gī,	*hungry*
Goó-rum-bă,	*to tell lies*
Gool′-bee,	*a noise*
Grâ-bī-nâ,	*to steal*
Gir′-ru,	*alive*
Gun′-gil-lee,	*to weep*
Gir-ree-boo,	*to lose*
Goó-ee-wut,	*shower of rain*
Gur′-rel-bool′-lin,	*to dig*
Goo,	*him*
Gool-gă,	*pathway leading from Boolbung to Goonambung*
Goo-lum′-brâ,	*the first man, now the presiding genius of the Keeparra*
Goó-nan-duk′-yer,	(lit. *stercum humanum edens) the small bullroarer*
Goon′-dâ-ree,	*the apple tree (angophora)*
Gir′-ree-poot,	*spotted gum*

Kutihung. English equivalent.

Gir′-rum-bô, *dying*
Gir′-rung, *green (unripe)*
Goor′-rum-bâl′-in, *no gammon*
Gir′-rungh, *a leaf*
Gul′-bee-meé-nung, *silent*
Gun′-dim-mur′-ră, *barbed spear made of hard wood*
Gut′-tâ-lă, *was or have been*
Gun′-yee, *shall or will*
Goó-reel, *the large shield*
Goó-ge-ree, *hut*
Gub′-bee-rung, *from, from the direction of*
Gwâ (also kwa), *a suffix indicating among*
Goó-âr, *up to*
Găl, *a people, a tribe*
Gun-′dee-wī, *the flying fox*
Goó-ran, *no, not*
Gur′-rool, *perspiration*
Gin′-du, *whilst*
Jik′-ker-â, *white ironbark*
Kit′-chung, *hair*
Kidn, *woman*
Koor′-ee, *man*
Koó-noong, *old man*
Koong-un′, *flood*
Koó-ee-wun, *rain*
Kur′-ru-won, *summer*
Kir′-ră-kur′-ră, *autumn*
Koor′-râ, *night*
Keé-wong, *moon*
Kun′-ge-ră, *blood*
Kreé-pun, *spotted gum*
Kur′-ree-kī, *myrtle*
Keé-la, *to micturate*
Koó-yuk, *canoe*
Kur′-run-gī, *black duck*
Kow′-wer-ree, *brown snake*
Kow′-ăl-gă-lit, *diamond snake*
Kur′-roon-gee, *to jump*
Kur′-ree Kur′-ree, *fast*
Kur′-ră-kă, *mouth*
Kut′-yee, *to cut*
Kut′-tâ, *to drop out of your hand*

Kutthung. English equivalent.

Kok′-ă-too, *cockatoo*
Kut′-te-râ, *fast*
Kur′-rup-pă, *loins*
Kur′-run-gee, *a fool*
Kur′-roo-mâ, *to climb*
Kut′-tī, *to go*
Ky′-in-dub′-bă, *on this side of*
Kup′-pô-ee, *an egg*
Kup′-poon-dee, *hut*
Kun′-nī, *a yam stick*
Kô-kee-dun, *come here*
Kil′-lung, *a feather*
Kup′-pô, *bye and bye*
Kur′-ră-gun, *soon*
Koó-ye-roo, *a bone used for combing the hair*
Kur′-re-kī, *bush myrtle*
Koon′-dool, *root of a tree*
Kun′-dâ, *a bird's nest*
Kur′-re-keé, *to fetch, to carry*
Koot′-thee wit′-tee, *to sing*
Krum′-moon, *clouds*
Kor′-oo-bâ, *the fortescue fish*
Keé-păr-ră, *the initiation ceremony of the Kutthung*
Kit′-tee, *the large coolamon*
Koot′-the-râ, *a nullah or club*
Kin′-yârngh, *pleased*
Koom′-ba, *to-morrow*
Koom′-bug-gă, *day after to-morrow*
Kur′-reel-lâ, *drowned*
Ky′-in-goo, *over*
Kow′-wăn, *uncle*
Kut′-thung, *to spit*
Kâ′-pee, *to throw*
Khir′-roodn, *itching*
Koó ee-puk′-kee, *to smell*
Kup′-paw, *stop*
Koó lâ-hee, *to snare*
Kyin, *across*
Koop′-păl-eé-â, *runs*
Mir′-ree, *dog*
Mur′-re-kun, *girl*
Mich′-ee-găn, *little girl*
Mul′-boo, *thunder*

Kutthung.	English equivalent.
Mun′-nī,	*star*
Mut′-te-râ,	*hand*
Mik′-kong,	*the eye*
Min′-gin,	*the liver*
Mur′-rook,	*good, happy*
Mur′-rung,	*nice, beautiful*
Mun′-um-bâ,	*red gum tree*
Mun′-nung,	*sand*
Mil′-lhin,	*mud*
Mun′-noong,	*a hill*
Mun′-yil-lâ,	*gave*
Má-ning,	*to take*
Mur′-roo-ma,	*to make*
Mâ′-ril-lâ,	*caught*
Mâ,	*the finger*
Mit′-tee,	*small*
Mur′-ro-má-lă,	*made*
Min′-â-gô,	*why*
Mut′-too,	*black snake*
Moó-nul-gook,	*death adder*
Mim′-mô,	*blind*
Mur′-râ-lin,	*climbing*
Mur′-rom-boó,	*thank you*
Min′-yâ-pô,	*something*
Mâ′-poo,	*widower*
Mâhl′-gun,	*a spider*
Mâ-koom-băl′-lin,	*nodding the head*
Mak′-ree,	*porcupine*
Muk′-kee muk′-kee,	*lazy, useless*
Moó-ree-ung-gub-bâ,	*how far*
Mut′-tuk,	*the fishing spear*
Muk′-kun,	*small species of lizard*
Mug′-gin,	*a bulb found growing with wild potatoes*
Mur-reen′,	*a star*
Mit′-tuk,	*sore*
Mur′-rin,	*sharp*
Mur′-ra-yung,	*don't go*
Mil′-lin Mil′-lin,	*a swallow*
Mâh′-poon-gun,	*a widow*
Mī-kin,	*a long time ago*
Mī-poo-yoo,	*a mullet*
Mī-ee,	*the point of a spear*
Num′-bâ,	*suffix signifying "at"*
Ná-yâ,	*mother*
Nut′-yoon,	*fresh water*
Nur′-rin,	*eldest sister*
Nun′-nâ,	*elbow*
Nim′-bik,	*bone*
Nârng,	*nose*
Nur′-ree-ăn,	*ear*
Noó-ree-on,	*hot*
Nut′-wâ,	*I*
Noó-â,	*he*
Nyeé-un,	*us (we)*
Noó-yâ,	*to ask*
Nâ-nă,	*who*
Nâ-nă, yee,	*who there?* lit. *what who are you*
Nâ-num-bá-yee,	*whose*
Noó-kwum-bâ,	*his*
Noon′-gum-bâ,	*her*
Noó-koo-wom′-bâ,	*that*
Nup′-pun,	*breasts (female)*
Nup′-pung,	*milk*
Nun′-doo,	*grass tree*
Nyeé-hu,	*yes*
Nur′-run,	*a hole*
Nâh′-kâ	*to see*
Nur′-rewin,	*the lyre bird*
Nur′-roon,	*kidneys*
Noó-ree,	*noisy*
Nur′-râ,[1]	*a camp*
Năp-poo,	*sleep*
Núj-ee-leé-la,	*possessed*
Nur′-ree,	*the leg*
Nô-yâ,	*at once*
Nook′-kil′-lâ,	*to swap*
Nur′-rô-win,	*flat piece of country*
Nuj′-ee-roo,	*a small bag for holding piece of colourless quartz given to initiates*
Nun′-nâ-yook,	*there*
Noon-ghee,	*nephew*

[1] In Journ. Roy. Soc. N.S. Wales, Vol. XXXIII., p. 119, I have erroneously called this "ulra."

Kutthung.	English equivalent.
Noon′-ghâ-gun,	*niece*
Ná-yâ Goó-ran,	*motherless*
Nyee Nyee,	*merry*
Nut′-tâ,	*shallow*
Noot′-tâ,	*to taste*
Nur′-run-geé,	*remember*
Noó-kâ,	*give*
Oó-pep-poo,	*again*
Oó-pik-kee,	*to send*
Pur′-ru-pă,	*a hut*
Pook′-kul,	*a knot*
Poor′-roo-pung,	*smooth*
Poó-ee-pir′-râ,	*tired*
Poó-pur-ră,	*close*
Ping′-gun,	*lightning*
Por′-oo-look,	*a flea*
Pup′-puh,	*close*
Toó-ra-kee,	*at*
Tur′-roo-kâ,	*handle of stone tomahawk*
Toó-toong,	*narrow*
Tū′-ree,	*the fighting boomerang*
Tuk′-ke-râ,	*cold*
Tul′-lun,	*the tongue*
Tá-ral-leé,	*hail*
Toó-kee Wăr′-ree,	*soon*
Toó-kun,	*the sun*
Toó-mul-lă,	*a creek*
Tuk′-kut,	*a perch*
U-lit′-tin,	*after*
Wun′-dă,	*where*
Wol′-long,	*for*
Way′-in-gun,	*will walk*
Wot′-too,	*an opossum*
Wok′-kă,	*on top of*
Woor′-roon,	*loud*
Wung′-gă,	*to dance*
Wor′-rīne,	*flat*
Wot′-thee,	*mad*
Wor′-ră-keé,	*to see*
Wom′-mô,	*fat*
Wâh-kun,	*a crow*
Wy′-yee,	*a pup*
Wăr′-ră-pă-meé-nung,	*be quiet*
Weé-yâ,	*to tell*
Wong′-ghâ,	*a corroboree*
Wol′-lun,	*the head*
Wol′-lun yer′-ră-kee,	*a head-ache*
Weé-yuh,	*was it?* (word of interrogation)
Wol′-loo-yâ,	*a large kangaroo*
Woong′-un,	*the youngest sister*
Wok′-khâ,	*air*
Win′-nô, weé-nâ,	*spring*
Wil′-ling,	*the lip*
Wur′-ring,	*the left arm*
Wok′-kul,	*the shoulder*
Wut′-tâ,	*fire*
Win′-yăl-lâ,	*burnt* (past tense)
Wam′-boyn,	*kangaroo*
Wit′-too,	*the neck*
Wor′-rin,	*a stream*
Wok′-kool,	*one*
Wit-tă-kit,	*the emu*
Wăl′-lin-gul′-gă,	*the native bee*
Woó-yâ,	*to hear*
Wil′-lâ,	*a stone*
Wī-lâ,	*black cockatoo*
Won′-gul-lin,	*a corroboree*
Woo-roó-mâ,	*the westerly wind*
Wor′-ree-â,	*a young swan*
Wun-′gī,	*how*
War′râ gub′-bă gud,	*pregnant*
Woor′-roó-bung,	*the jew lizard*
Weé-ree,	*to sweep*
Wor-rung′,	*frost*
Wun′-nă,	*to listen*
Wun′-yim-bô wun-yim-bô,	*always*
Wăd-yee-mâ,	*to mimic*
Yer′-ră-kee,	*bad, ill, sick*
Yoon′-goo,	*a mountain*
Yal′-lô-wal′-lin,	*sitting*
Yâ-ree,	*or*
Yăr′-rin,	*light* (in weight)
Yar′-ruh,	*to swim*
Yur′-reel,	*a cloud*
Yăl′-lôwâ,	*the north-east*
Yer-reé-â,	*evening*
Yoó-kul,	*the heart*
Yup′-pee,	*the ti-tree*
Yuk′-ree,	*the wommera*

Kutthung. English equivalent.	Kutthung. English equivalent.
Yur′-râ, *the sky*	Yeé-boo, *to finish*
Yum′-bīne, *the scrotum*	Yoó-lun, *to skin*
Yū′-kâ, *the flathead fish*	Yâ-kâ, *mahogany*
Yun′nâ, *to walk*	Yâ-ree, *or*
Yoó-ră Yoo-râ, *slow*	Yoom′-broo, *in*
Yen′-dhee-ree, *the eyebrows*	Yar′ ree-num′-bâ, *our*
Yăl-lôwă, *to sit down*	Yit′-tuh, *blunt*
Yoó-râ-bă-leé-lâ, *to hide*	Yoon′-nur-ră, *awkward*
Yăn-dă-meé-nor, *right*	Yer′-ă-kee Yer′-răkee, *painful*

Weapons etc. of the Kutthung.

The whole of the articles here described with the exception of Fig. 20 *Plate* 3, have been collected during wanderings amongst the aboriginals upon the shores of Port Stephens.

Plate No. 3.

Figs. 1, 2, 3, 4, 5 and 6, are boomerangs of the returning variety. They are about eighteen inches in length from point to point and have a maximum width of two inches.

Fig. 7 is a fishing spear composed of a shaft made from the stem of the grass tree, seven feet six inches in length, and four pieces of hardwood twenty-five inches in length lashed together, but with the points separated by means of pieces of wood thrust in between them, and fastened into the shaft by means of gum and twine. They use this spear in catching the large fish. Going into the water as far as he can to use the spear with effect, the native stands like a statue holding the spear obliquely in poised hands ready to strike his prey as it passes. Standing motionless, he is soon surrounded by fish, and the first that passes his feet is pierced by a certain powerful thrust. Sometimes they make use of a boat (the bark canoe is never used nowadays) from which they spear the fish.

Fig. 8 is the wommera or throwing stick used for the purpose of throwing spears. It is made of two pieces of wood the larger of which is thirty-two inches in length, with a breadth of three inches at the end which is held in the hand and tapering to a point at the other end, whereon is lashed a sharpened piece of wood, three and a half inches in length, projecting at a slight angle. The point of this smaller piece of wood is inserted into the end of the shaft of the spear, which is held between the thumb and forefinger of the thrower, the broad flat end of the wommera all the while resting in the palm of the hand.

Fig. 9 is the Bar′-ro-wa or large bullroarer used in the closing part of the Keeparra[1] ceremony. It is twenty four inches in length with a maximum breadth of three and one half inches.

Fig. 10 is a spear composed of three pieces, a sharpened hard-wood point twenty-four inches in length, thrust into thin stem of grass tree about thirty-four inches in length, and this in turn is fastened into a shaft of like material about six feet four inches in length. It is thrown at game or other objects by means of the wommera previously described.

Figs. 11 and 12 are heads of basaltic rock.

Fig. 13 is also of basaltic rock, but unlike the two former implements appears to have been used without the usual wooden handle, and is probably a chisel.

Fig. 14 is a whet stone used for sharpening the points of the shell fish hooks, and is of hard eruptive rock. It is four and a half inches in length, one and three-quarter inches in breadth at one end, and tapers at the other end to a point, which has unfortunately been broken off the specimen in my possession. It has a uniform thickness of five-eighths of an inch.

Fig. 15 represents a shield of mangrove wood. It is thirty inches in length with a breadth of nine inches. The handle which is a green twig of the mangrove is fastened by boring two holes three inches apart in the centre of the shield, and inserting into each hole an end of the twig, the fibres of which are then separated on the face of the shield. This instrument is covered with pipe-clay and adorned with three red stripes.

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1 See "Initiation Ceremonies of the Aborigines of Port Stephens, New South Wales."—Journ. Roy. Soc. N.S. Wales, Vol. xxxiii., p. 121.

Figs. 16 and 17 are waddies used not only as clubs, but for throwing at small animals. The former called "Boon'-dhee" is twenty-six inches in length, and made of the wood of the ironbark. The latter called "Goothera," is made of the wood of the myrtle and is thirty-five inches in length.

Fig. 18 is a Coolamon made of mangrove wood. It is seven inches in diameter with the same depth internally, and is used for carrying water or holding liquid of any kind.

Fig. 19 is the Koo-pin' and is made of the wood of the black oak. It is used for warding off spears, and also to hinder the flight of an opponent.

Fig. 20 is a fighting boomerang, made of myall wood, and I believe is from the north-western part of New South Wales.

Plate 4.

Fig. 1 A boomerang (tū-ree) of the type that does not return when thrown.

Figs. 2, 3, 4, 5 and 6, Boomerangs (Băr-ră-kun') of the kind which can be made return when thrown.

Fig. 7 Yamstick (kun'-nī) used by the "gins" in digging for roots, and is also their favourite weapon.

Fig. 8, Shield (Ben'dool-gun).

Fig. 9, A waddy called "Bin'-nă-pin" by the Kutthung.

Figs. 10, 11, and 12, Stone axe heads.

Figs. 13 and 14, Stone axes with heads of a dark eruptive rock and handles made of a piece of vine, which is doubled around the head and the two portions are then fastened together with bark, and the head made more secure with wax or gum.

Fig. 15, Koó-ye-roó, a sharpened kangaroo bone used for combing the hair.

Fig. 16, A waddy of one of the Hunter River, (N.S.W.) tribes.

Fig. 17, The Goó-nan-duk'-yer whose use will be found described in "The Initiation ceremonies of the Aborigines of Port Stephens N.S. Wales," herein before referred to.

The other articles manufactured by the Aborigines are the canoe, fishing net, dilly bag, stone knife, belt of spun opossum hair, barbed spear of hardwood, fish hook of shell, and a small bag used for carrying the pieces of crystal bestowed on the young men when they have been initiated at the Keepara.

For the arrangement of the weapons, and the preparation of the two plates attached hereto, I am indebted to Mr. W. J. P. Craik of West Maitland, N. S. Wales.

Note on an OBSIDIAN "BOMB" from NEW SOUTH WALES.

By R. T. Baker, F.L.S.,

Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, September 5, 1900.*]

At the present time much attention is being given by Scientists in Europe in regard to the origin of Moldavites (the generic name by which obsidian "bombs" or "buttons" are now generally known), and this is one of the reasons I must give for bringing the specimen under the notice of this Society. Another reason is that this specimen of obsidian "bomb" differs in shape from those usually found in Eastern Australia, a fact that may be of some interest and use to the savants in their researches on these remarkable bodies.

The specimens which have been recorded from Eastern Australia are (with one exception) button-shaped, with one, two or three flanges, although occasionally an elongated form of these occurs.

The one obtained by Charles Darwin when visiting Australia in the *Beagle* 1832-6, was a particularly good specimen of this type of "button or bomb." It was presented to him by Sir Thomas

Mitchell, who probably found it in the interior of New South Wales. Messrs. W. H. Twelvetrees, F.G.S. and W. F. Petterd, C.M.Z.S.,[1] record a "bomb," which from their description somewhat resembles the one recorded in this note, for "it is without the flange or beading, which is apparently characteristic of the buttons obtained on the east coast."

My specimen from its shape etc., therefore, is also comparable to those known from West Australia, but unfortunately it is not perfect—one-third or more of the whole having been broken off, so that more correctly speaking it is only a portion of a "bomb" that is now to be macroscopically described. It is worthy of note that of the two belonging to this type of bomb, and now recorded from Eastern Australia and Tasmania, one should have been found in Tasmania *(loc. cit.)*, and the other in New South Wales. This latter specimen, the subject of this note, is rather bright looking, and not so dull as those I have examined from Western Australia, although however, it strongly resembles them in every other respect.

It has a blackish, very dark bottle-green, glassy appearance, particularly so at the large fracture, which shows a little fire on the edge. It measures about 1 inch in diameter and $\frac{5}{8}$ inch in thickness, and might be described in general terms as sub-globose in shape. There is quite an absence of concentric rings, flanges, or flutings round the edges, which are very thick and rounded. The whole of the surface is irregularly indented with gas pores and broken globulites of varying size, and these no doubt occur throughout the mass, although only a few are exposed on the big fracture above referred to. Viewed under a lens, the surface has much the appearance of that of many meteorites, such as for instance, the Thunda meteorite from Queensland and others. The specific gravity is 2·456 at 15° C., almost identically the same as the one described from Tasmania, *(loc. cit.)* and showing it to be "Obsidian" (glassy varieties of rhyolitic and trachytic rocks) and

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[1] Roy. Soc., Tas., 1897, p. 42.

not basaltic-glass which is usually classed as tachylyte and has a higher specific gravity.

This specimen was discovered about twenty feet below the surface about a mile and a half from O'Connell near Bathurst, by Messrs. B. Walker and Lester, when sinking for gold.

I am indebted to Messrs. Rumsey and Tremain of the Technical College for the photograph, and to Mr. Henry G. Smith for the specific gravity.

MARRIAGE AND DESCENT AMONG THE AUSTRALIAN ABORIGINES.

By R. H. Mathews, L.S., Corres. Memb. Anthrop. Soc., Washington, U.S.A.

[*Read before the Royal Society of N. S. Wales, October 3, 1900.*]

In describing the social structure of a native Australian community the first matter calling for attention is the classification of the people into two primary divisions, called phratries, or groups—the men of each phratry intermarrying with the women of the opposite one, in accordance with prescribed laws. 1. The natives of some tracts of country are segregated into the two phratries referred to, without any further subdivision. 2. In other localities there is a partition of each phratry into two sections, making four divisions of the tribe. 3. Among the inhabitants of other districts there are four subdivisions of each phratry, giving a total of eight sections. 4. In some parts of Australia, instead of employing the sharply defined divisions referred to, the marriages are arranged by the elders of the tribe, who are well acquainted with the genealogy of the people around them. This I have designated the *Tooar* organisation, and is elsewhere dealt with.

Owing to the different methods of subdividing the phratries, the details of the rules regulating the intermarriage of the men and women, and the descent of the progeny, are somewhat varied in each system, but the fundamental principles are the same in them all. Whether there are two, or four, or eight partitions of the community, every division has an independent name by which its members are easily recognised. Frequently, but not invariably, the men are distinguished from the women by means of a masculine and a feminine form of the name of each division.

In dealing with the subject it will be necessary to supply tables giving examples of the divisions of a tribe in each type of organisation. Table No. 1 represents the Parn-kal'-la system, composed of the two phratries only; Table No. 2 shows the Kam'-il-a-roi method of four divisions; and Table No. 3 illustrates the Wom-by'-a type, containing eight divisions.

Table No. 1.

Phratry.	Father.	Mother.	Son.	Daughter.
A.	Kirraroo	Matturrin	Matturri	Matturrin
B.	Matturri	Kirrarooan	Kirraroo	Kirrarooan

Table No. 2.

Phratry.	Father.	Mother.	Son.	Daughter.
A.[1]	Murri	Butha	Ippai	Ippatha
	Kubbi	Ippath	Kumbo	Butha
B.[1]	Kumbo	Matha	Kubbi	Kubbitha
	Ippai	Kubbitha	Murri	Matha

Table No. 3.

Phratry.	Father.	Mother.	Son.	Daughter.
A.	Choolum	Ningulum	Palyarin	Palyareenya
	Cheenum	Nooralum	Bungarin	Bungareenya
	Jamerum	Palyareenya	Chooralum	Nooralum
	Yacomary	Bungareeny	Chingulum	Ningulum

[1] In the Kamilaroi tribe each phratry is distinguished by a proper name—A is called Dilbee, and B is known as Kuppathin, but I have used the letters A and B so as to preserve uniformity in the three tables, for purposes of reference.

Table No. 3—*continued.*

Phratry.	Father.	Mother.	Son.	Daughter.
B.	Chingulum	Noolum	Yacomary	Yacomareenya
	Chooralum	Neenum	Jamerum	Neomarum
	Bungarin	Yacomareenya	Cheenum	Neenum
	Palyarin	Neomarum	Choolum	Noolum

A glance at the foregoing three tables shows that each system is exactly alike as regards the partition of the community into the phratries A and B. It will also be observed that each phratry is composed of certain aggregates of women, who have perpetual succession among themselves. We will take an example from the column headed "mother" in phratry A in each table. In Table No. 1, Matturrin produces Matturrin from one generation to another. In Table No. 2, Butha produces Ippatha, and in the next generation Ippatha is the mother of Butha, and these sections reproduce each other in continuous alternation. In Table No. 3 we see that Ningulum has a daughter Palyareenya; Palyareenya produces Nooralum; Nooralum is the mother of Bungareenya; Bungareenya has a daughter Ningulum, and this series is continually repeated in the same order. If the examples had been taken from phratry B, similar results would have been obtained. The brothers of the girls, in every case, belong to the same phratry and section as their sisters.

We have therefore seen that the women never pass out of the phratry to which they belong, and that where it consists of more than one denomination, they pass successively through each of the sections of which it is composed, in the same number of generations. It is also apparent that the daughters of each phratry become the wives of the men born in the opposite one. For example, in Table No. 3, the women of phratry A are the mothers of sons and daughters belonging to the same phratry as themselves; and their boys on reaching manhood must take their wives from phratry B. In a similar manner the daughters of the women of phratry A must obtain their husbands from among the sons of the women in phratry B. For the reasons above stated, I have found it convenient to enunciate that the phratries are formed and maintained by the women.

Having illustrated the structure of the phratries, I will now pass on to very briefly show the rules of marriage among the subdivisions, and the descent of the resulting offspring. The three tables explain themselves—the father, mother, son and daughter of each division being shown on the same line across the page. In Table No. 1, where the phratry is undivided, the offspring take their mother's denomination direct. In Table No. 2, in which the phratry is bisected, the progeny take the name of the complementary division in the mother's phratry, thus,—Butha's children are Ippai and Ippatha, and Ippatha's progeny are Kumbo and Butha. In some districts, instead of the marital laws following the order set out in the table, there are what I have termed "alternative" marriages, for example—a Murri, male, marries an Ippai, female, and *vice versa;* a Kubbi, male, takes a Kumbo, female, as his partner, and *vice versa.* The descent of the children, however, is not affected by this variation—the offspring of an Ippatha, for example, being always Kumbo and Butha, no matter whether she is united to a Kubbi or a Murri husband.

Table No. 3 shows the Wom-by'-a organisation, in which the phratry is divided into four sections. By the ordinary or "direct" rules of marriage, Choolum takes Ningulum as his spouse, and the issue of the union are Palyarin and Palyareenya. But Choolum can exercise the alternative right of marrying a Nooralum woman, and in such case the offspring will be Bungarin and Bungareenya. Again, Cheenum takes Nooralum as his regular mate, and his "alternative" wife is Ningulum, the name of the resulting progeny being determined by the mother, as before. Similarly, Jamerum can marry either a Palyareenya or a Bungareenya woman, and Yacomary's wife is Bungareenya, with the alternative of Palyareenya. In the pairs of sections, Chingulum and Chooralum, Bungarin and Palyarin, in phratry B, marriage and descent follow the same alternative rules, *mutatis mutandis.* In consequence of polygamy being sanctioned, it is possible for a man to take one wife from the "direct" section, and another spouse from the "alternative" division—the nomenclature of the progeny being regulated as above explained.

It has been stated in an earlier page that the children belong to the same phratry as their mother, and in many tribes the totem is also handed down in the same way. In carefully examining tables of genealogies, however, it is quite clear that marriage, relationship and descent, depend mainly on the father's side of the house—a law which applies with the same cogency to the Wombya, Kamilaroi and Parnkalla systems. The rule is equally persistent in the Tooar type of organisation, which I have described elsewhere.

The people of both sexes marry an individual belonging to the same phratry as their father. Taking an example from Table No. 3, we see that Chingulum marries Noolum, of the same phratry as his father Yacomary. Noolum takes as her husband a Chingulum man, belonging to the phratry of her father Palyarin. By employing Table No. 2, for our example, it is observed that Ippai marries a Kubbitha woman belonging to the same phratry as his father Murri. And Kubbitha marries Ippai, a man of her father Kumbo's phratry.

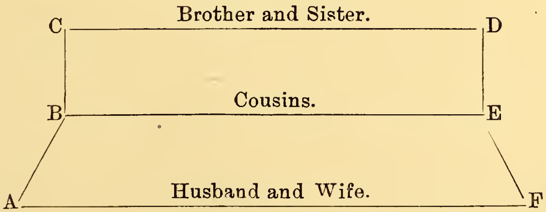
All the people, men and women alike, marry an individual belonging to the same section of their father's phratry as that to which his mother belongs. By taking our example from Table No. 3, we find that Choolum's father is Palyarin, and Palyarin's mother is Ningulum. Choolum marries a Ningulum woman, who therefore belongs to his father's mother's section. Again, Ningulum's father is Yacomary, and Yacomary's mother is Noolum. Noolum mates with Chingulum, the name of her father's mother's section. Using Table No. 2, for an example, it is seen that Murri's father is Ippai, and the mother of Ippai is Butha; Murri marries Butha, his father's mother's section name. Also, Butha's father is Kubbi, and Kubbi's mother is Matha. Butha is married to Murri, the section name of her father's mother.

The children of both sexes take the section name of their father's father. By employing an example from Table No. 3, it is seen that Choolum has a son Palyarin, and Palyarin is the father of Choolum, the section of his father's father. Again, Choolum has a son Palyarin, and Palyarin has a daughter Noolum, the name of the section to which her father's father, Choolum, belongs. Taking an example from Table No. 2, we observe that Murri's son is Ippai, and Ippai has a son Murri, the section name of his father's father. Also, Kumbo has a son Kubbi, and Kubbi has a daughter Butha, the section to which her father's father belongs. In the Kamilaroi and Parnkalla systems, the children, in addition, take the section name of their mother's mother, (which in their case is identical with that of their father's father); but this does not apply to the Wombya, owing to their more perfect system of subdividing the phratries.

In the three last preceding paragraphs, examples have not been supplied from Table No. 1, illustrating the Parnkalla system of marriage and descent, it being thought that the simplicity of the table renders explanation unnecessary.

A man takes a wife who is the daughter either of his father's cousin, or of his mother's cousin; and a woman likewise marries a man who is the son of a cousin of her father or of her mother. The cousin here meant is the child of one's father's sister, or of one's mother's brother. This statement can be illustrated by using a diagram, with distinctive letters, which can be referred to, as follows :—

Diagram No. 1.



I will commence with examples from the Wombya organisation, represented in Table No. 3. The pedigree of a man's wife, traced through his father, is as follows:—A = Choolum; B = A's father, Palyarin; C = B's father, Choolum; D = C's sister, Noolum; E = D's son, Yacomary; F = E's daughter, Ningulum. By the table we see that A = Choolum, marries F = Ningulum, the daughter of his father's father's sister's son—that is to say, the daughter of his father's cousin. By following the pedigree of any given man's wife through his mother, it can be shewn that Chingulum, for example, marries Noolum, the daughter of his mother's mother's brother's daughter, or in other words, the daughter of his mother's cousin.

The pedigree of a woman's husband, if traced through her father, can be run out as follows:—A = Ningulum; B = A's father, Yacomary; C = B's father, Chingulum; D = C's sister, Ningulum; E = D's son, Palyarin; F = E's son, Choolum; then A = Ningulum marries F = Choolum, who is the son of her father's father's sister's son—that is, the son of her father's cousin. In a similar way it can be represented, by running out a woman's husband's pedigree through her own mother, that she herself marries the son of her mother's mother's brother's daughter, or in other words, the son of her mother's cousin.

The same rules hold good in the Kamilaroi organisation, as the following example from Table No. 2 will explain:—A = Kumbo; B = A's father, Kubbi; C = B's father, Kumbo; D = C's sister, Butha; E = D's son, Ippai; F = E's daughter, Matha. Then A = Kumbo marries F = Matha, the daughter of his father's father's sister's son—that is, the daughter of his father's cousin.

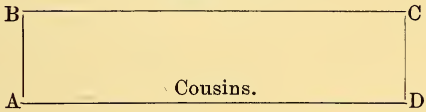
An example from Table No. 1 will illustrate that the same laws also apply to the Parnkalla organisation:—A = Kirraroo; B = A's father, Matturri; C = B's father, Kirraroo; D = C's sister, Kirrarooan; E = D's son, Kirraroo; F = E's daughter, Matturrin. Then, A = Kirraroo marries F = Matturrin, the daughter of his father's father's sister's son, or, the daughter of his father's cousin.

One example each in the Kamilaroi and Parnkalla systems has been thought sufficient, because the rules are analogous to those given in the Wombya organisation, which has been illustrated more fully, in order to avoid repetition.

In the Kamilaroi and Parnkalla systems, according to the tables, the men, as well as the women, can marry the offspring of their father's sister, or of their mother's brother, subject to conditions to be mentioned presently. This also applies to the "alternative" marriages of the Wombya. By using a diagram this can be made more clear:—

Diagram No. 2.

Brother and Sister.



Taking an example from the Kamilaroi system it can be demonstrated that A = Kubbi; B = A's father Kumbo; C = B's sister Butha; D = C's daughter Ippatha. Kubbi marries Ippatha, the daughter of his father's sister. If we had traced the blood through Kubbi's mother Matha, it could have been shown that he married his mother's brother's daughter. Again, if A be a female, the genealogy of her husband can be followed, in the same way, through her father's sister, or her mother's brother, showing that she marries a son of one of these. If we further consider Kubbi = A, and assume that his father, Kumbo = B, is an emu, then B's sister C is also an emu.[1] Referring to diagram No. 2, it is apparent that A is the son of an Emu man, B; and that D, his wife, is the daughter of an Emu woman, C.

Putting the above example in another form, it will be seen that the son of a brother marries the daughter of a sister; and not only so, but the son of an emu marries the daughter of an emu. To prevent the union of persons of such consanguinity there are customary laws in aboriginal society which make it incumbent that the brother and sister relationship here referred to shall be collateral or tribal only, and not of the full blood. It may not

[1] Proc. Roy. Geog. Soc., Q., Vol. x., p. 22.

be unnecessary to state here that by following the ordinary rules of marriage in the Wombya organisation, as represented in Table No. 3, a brother's children's children intermarry with a sister's children's children—a relationship sufficiently wide not to require any further restrictions.

Selecting an illustration from the Wombya system we can show by Diagram No. 2 that A = Choolum; B = A's father Palyarin; C = B's sister Palyareenya; D = C's daughter Nooralum. Then Choolum, as his "alternative" wife, marries Nooralum, the daughter of his father's sister. It can easily be shown that Choolum's alternative spouse may also be the daughter of his mother's brother. And if A be a female, the genealogy can be varied as in the Kamilaroi example last given. It also appears that if A's father Palyarin, B, is an eaglehawk, then B's sister, Polyareenya, is likewise an eaglehawk. According to the diagram, A is the son of an eaglehawk man, B; and A's wife, D, is the daughter of an eaglehawk woman, C. As in the Kamilaroi example, this brother and sister relationship must be titular instead of direct.

It is not thought necessary to furnish an example of the marriage rules, according to diagram 2, in the Parnkalla system, because they are similar to those of the Kamilaroi.

In examining each pair of sections in Table No. 3, it is observed that Choolum is Cheenum's father's (Bungarin's) female cousin's (Neomarum's) son, and also that Cheenum possesses the same relationship to Choolum. Again, Choolum marries Cheenum's cousin, and Cheenum marries Choolum's cousin. It is likewise apparent that Jamerum is Yacomary's father's (Chingulum's) female cousin's (Neenum's) son; and that Yacomary is related in the same manner to Jamerum. Also, Jamerum marries Yacomary's cousin, and Yacomary maries Jamerum's cousin. Similarly it can be shown that the pairs of sections, Chingulum and Chooralum, and also Bungarin and Palyarin, are respectively related to each other in the same way. The relationships referred to in this paragraph account for certain pairs of sections, (*e.g.*, Choolum and Cheenum), being placed together in the table.

As indicated in Table No. 3, Choolum and Palyarin are related to each other as father and son in continuous alternation, and I have found that they have certain totems which descend with them. Thus, Choolum bandicoot is the father of Palyarin bandicoot, and in the next generation Palyarin bandicoot is the father of Choolum bandicoot. The other pairs of sections have aggregates of totems in the same manner, as enumerated in Table No. 4, hereunder :—

Table No. 4.

Moiety A.	Choolum Palyarin	Black-snake, death-adder, bandicoot, eagle-hawk, bloodwood, currant bush, tiger-snake.
	Cheenum Bungarin	Fire, opossum, black-duck, emu, rain, corella, scorpion, thunder.
Moiety B.	Jamerum Chooralum	Iguana, kangaroo, spinnifex, dingo, lightning, crow, carpet-snake, pipe-clay.
	Yacomary Chingulum	Common hawk, yam, frog, white crane, mopoke, galah.

In treating of the "alternative" marriages in an earlier page it was shown that Cheenum could also marry Ningulum, in which case his son would be Palyarin ; and in a similar manner Choolum could be the father of Bungarin. With totems descending from the father to his offspring, in tribes where polygamy is practised, Cheenum's totem could be transmitted to both Bungarin and Palyarin, supposing he takes a wife from each of the sections over which he possesses potential marital rights. I have discovered that, in consequence of the close blood-relationship referred to in the last few paragraphs, the divisions Choolum, Palyarin, Cheenum and Bungarin, are very friendly amongst themselves, and the same totems are more or less in use among these four sections, whom I have accordingly called Moiety A. In other words, the totems particularized in Table No. 4 as belonging primarily to Choolum and Palyarin, are also to some extent common to Cheenum and Bungarin, and *vice versa*. The same remarks will apply in all respects to the remaining four sections, who are distinguished as Moiety B, in Table No. 4. The men and women of Moiety A are related as brothers-in-law and sisters-in-law respectively to the people of Moiety B, and conversely. In general, the progeny, boys and girls alike, take the totem of their male parent.

Marriage between persons of the same totem is forbidden, if they belong to families residing in neighbouring hunting grounds, but where the parties to the union come from remote districts, and therefore cannot be any blood connection, I have observed individuals of the same totem living as man and wife. Mr. T. M. Sutton, in speaking of the Adjadurah tribe in 1887, refers to a man who was a ghardie (emu), being married to a ghardie woman.[1]

The following are a few of the principal tribes inhabiting the country about Elsey Creek, Katherine and Roper Rivers, reaching northerly to Wilton and Goyder Rivers, and onward to Glyde's Inlet on the north coast of Arnheim's land, Northern Territory. Their names are the Yungmunnee, Charmong, Mungerry, Yookull, Hongalla, and Koorungo. They have an organisation containing eight sections, similar to those given in Table No. 3, but bearing a nomenclature more or less different. These eight sections, how they intermarry, and the names of the resulting offspring is represented in tabular form hereunder:—

Table No 5.

Phratry.	Father.	Mother.	Son.	Daughter.
A	Eemitch	Inkagalla	Uwallaree	Imballaree
	Uwannee	Imbawalla	Uwungaree	Imbongaree
	Unmarra	Imballaree	Urwalla	Imbawalla
	Tabachin	Imbongaree	Yungalla	Inkagalla
B	Yungalla	Immadenna	Tabachin	Tabadenna
	Urwalla	Imbannee	Unmarra	Inganmarra
	Uwungaree	Tabadenna	Unwannee	Imbannee
	Uwallaree	Inganmarra	Eemitch	Immadenna

These are the divisions of the Yungmunnee tribe about Elsey Creek, and their equivalence to those of the Wombya is as follows: Eemitch is equal to Choolum, Uwannee to Cheenum, Unmarra to

[1] Proc. Roy. Geog. Soc., S.A., Vol. ii., 3rd Session, p. 17.

Jamerum, and Tabachin to Yacomary in phratry A. Again, Yungalla corresponds to Chingulum, Urwalla to Chooralum, Uwungaree to Bungarin, and Uwallaree to Palyarin, in Phratry B. All that has been said in the foregoing pages in regard to the Wombya tribe, represented in Tables Nos. 3 and 4, applies equally in every respect to the sections and phratries illustrated in Table No. 5.

A brief reference to the geographic distribution of the tribes adopting each type of organisation dealt with in this article may not be without interest. The country inhabited by the people of the Wombya type of division comprises about three-fourths of the Northern Territory of South Australia, with extensive regions in Queensland and Western Australia. The territory occupied by tribes possessing the Kamilaroi system extends over about two-thirds of New South Wales, the greater part of Queensland, a wide zone through the centre of South Australia, and more than half of Western Australia. The Parnkalla organisation includes nearly the whole of Victoria, about a third of New South Wales, part of Queensland, and a considerable portion of Western Australia and South Australia.

Among the tribes on the south-east coast of New South Wales and Victoria, the southern coast of South Australia, part of the west coast of Western Australia, and a tract of country reaching inland easterly and southerly from Port Darwin, in the Northern Territory, the *Tooar* type of organisation is in force, with various modifications.

APPENDIX.

Some Tribes of Cape York Peninsula, Queensland.

That portion of Cape York Peninsula extending from the Cape to about the fifteenth parallel of south latitude, is occupied by a considerable number of tribes, out of which may be enumerated the Yandigan, Merrikaba, Kowanatty, Gametty, Joonkoonjee, Tannagootee, Yeldivo, Kokinno, Kamdheu and Kookeealla. Of these I am best acquainted with the Joonkoonjee tribe, on the

Batavia River, whose organisation is after the Kamilaroi type, possessing four sections, with rules of marriage and descent as in the following table—the males and females using the same names for their respective divisions. The dialects spoken from the Jardine to the Batavia River and Pioneer Downs, or farther south, are similar in many respects. My best thanks are due to the Rev. N. Hey, of Mapoon, and other gentlemen on the Peninsula, for assisting me whilst engaged in obtaining the following information.

Table No. 6.

Phratry.	Father.	Mother.	Offspring.
Jamakunda	Lankenamee	Pakwickee	Pamarung
	Namegooree	Pamarung	Pakwickee
Kamanutta	Pakwickee	Lankenamee	Namegooree
	Pamarung	Namegooree	Lankenamee

The pair of sections forming the phratry Jamakunda invariably marry the Kamanutta pair, but the rules of intermarriage of the individual sections constituting the phratries vary in different parts of the tribal territory. For example, in some districts instead of the rules of marriage following the order laid down in Table No. 6, a Lankenamee, male, provided there is no blood relationship, may marry a Pamarung, female, and *vice versa.* The descent of the offspring is not disturbed by this irregularity—the children of a Pakwickee mother being always Pamarung, irrespectively of the section name of her husband. These rules apply, *mutatis mutandis*, to all the other sections.

Athough marriages are generally regulated by the order of names in Table No. 6, and the rules given in the last paragraph, there are, further, what I have designated "family, or sectional" regulations, under which a man may, in certain cases only, take a wife bearing his own section name, but of a different totemic nomenclature. For example, a Lankenamee shark, belonging to a distant lineage, might be permitted to take as his wife a Lankenamee grasshopper.

The sons and daughters of certain women are betrothed in infancy to the daughters and sons of other women—these betrothals being of course in accordance with the laws illustrated in Table No. 6. For the purpose of providing against contingencies, two or three girls are usually betrothed to the same boy ; or more boys than one may be allotted to the same girl. *Meeoogoo* is a mutual term of relationship between the mother of the girl and the mother of the boy.

The totems, called by the natives *eedeete*, belonging to each phatry are common to the two sections of which it is composed; thus, the totems attached to Jamakunda are common to the sections Lankenamee and Namegooree; and the Kamanutta totems are common to the Packwickee and Pamarang sections. The following are some of the totems attached to the phratry Jamakunda :—black snake, shark, emu, native dog, bush rat, rock, stone, ironbark tree, wattle tree, north wind, black cloud, yams, native cat, kangaroo-grass, carpet snake, kangaroo, crow, common hawk, dove, white fish, silver fish, bronze pigeon, sea, fresh water, a dead man, grasshopper, green ants, bloodwood tree, fire, and wind. Among the totems of the Kamanutta phratry may be enumerated the tea-tree, sun, moon, iguana, plain turkey, opossum, pelican, common grass, bee, fly, frog, black duck, lizard, bark of a tree, gum, thunder, water-lily, sea-shell, turtle, butterfly, ibis, crab and beetle.

The children take the phratry and totem name of the mother; they do not, however, belong to her section, but take the name of the other section in their mother's phratry, as exemplified in Table No. 6.

When the boys are about twelve years of age, they are taken from the control of their mothers by the chief men, and are passed through a course of initiatory formalities, analogous in their main features to those practised by the Kamilaroi,[1] Dippil,[2] and Koom-

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[1] Proc. Roy. Soc., Victoria, Vol. IX., N.S., pp. 137–173.

[2] American Anthropoligist, Vol. II., N.S., pp. 139–144.

banggary[1] tribes, described by me elsewhere. Scars are raised upon their bodies, the septum of the nose is pierced, and a front tooth is punched out of each youth, during the ceremonies. The novices are required to pass through the ordeal of inauguration at not less than three meetings of the tribes for that purpose, extending perhaps over a period of several years, and at the conclusion of the proceedings they are presented with spears and other weapons and released from certain prohibitions regarding food—for example they may now eat eggs, iguana, &c., which were before forbidden to them.

A "bullroarer,"[2] called by the natives *pipe-ra-chy*, is used by the tribes on these occasions; it is generally made of bloodwood, of the usual shape, with a hole drilled in the smaller end, through which a long string is fastened, to enable the operator to swing it round his head. The size of the instrument varies from about sixteen to twenty inches, and is often ornamented with one longitudinal and several transverse bars painted in red ochre on one or both sides.

Until a youth has graduated in all the inaugural ceremonies of his tribe, and been admitted to the rights and privileges of aboriginal manhood, he cannot take a wife, or be present at any of the councils or deliberations of the men.

Message sticks[3] are used in summoning tribes for festive or hostile corroborees, and as friendly reminders to relatives at a distance. They consist of small pieces of wood, four or five inches in length, with quadrilateral designs and other rude markings cut upon their surface. Sometimes a bunch of feathers, bound into a cylindrical form by means of string, and about ten inches long, is used for the same purpose.

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[1] Proc. Amer. Philos. Soc., Philad., Vol. xxxvii., pp. 53 – 66.

[2] See my article on the different kinds of "Bullroarers"—Journ. Anthop. Inst., Lond., xxvii., 52 – 60.

[3] The reader is referred to my paper on "Message Sticks"—American Anthropologist, x., 288 – 297.

Infanticide, abortion, and cannibalism are largely practised among all the tribes on the Peninsula in those districts where the natives are still in a comparatively wild state. The bones of adult victims, rolled in strips of the bark of the tea-tree, and fastened with string passed around, are frequently carried by the relatives of the deceased for considerable periods.

The same divisional system, but with different names for the sections, extends from Cape York southerly till it adjoins the Koonjan and other tribes, who use the four divisions reported by me in Table No. 3, contained in a paper[1] contributed to this Society in 1899. The equivalence of the four sections of the Koonjan, Warkeemon, Goothanto, Mykoolon and Kogai communities may be tabulated as follows:—

Table No. 7.

Koonjan Community.	Warkeemon Community.	Goothanto Community.	Mykoolon Community.	Kogai. Community.
1. Ajeereena	Karpungie	Erainyer	Jimalingo	Woongo
2. Arenynung	Cheekungie	Arara	Bathingo	Koobaroo
3. Perrynung	Kellungie	Loora	Maringo	Bunburri
4. Mahngale	Koopungie	Awonger	Yowingo	Koorgilla

[1] Journ. Roy. Soc., N.S.W., xxxiii., pp. 108 - 111.

On the CONSTITUENT of PEPPERMINT ODOUR occurring in many EUCALYPTUS OILS.—Part I.

By Henry G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Received and read before the Royal Society of N. S. Wales, October 3, 1900.*]

Among the Eucalypts of Australia there are many species known vernacularly as Peppermints, on account of the marked peppermint odour given by the leaves when crushed, or from the odour of the oil when distilled.

The first Eucalyptus oil was obtained from a New South Wales' species known as the Sydney Peppermint, *Eucalyptus piperita*, Sm., which species grows plentifully in the neighbourhood of Sydney. The following quotation is from page 227 of "White's Voyage to New South Wales," published 1790 :—"The name of Peppermint Tree has been given to this plant by Mr. White on account of the very great resemblance between the essential oil drawn from its leaves and that obtained from the peppermint, *Mentha piperita*, which grows in England. This oil was found by Mr. White to be much more efficaceous in removing all cholicky complaints than that of the English peppermint, which he attributes to its being less pungent and more aromatic. A quart of the oil has been sent by him to Mr. Wilson."

Although the leaves of this species have a well marked peppermint odour, yet, the constituent giving this odour is only present in very small quantity in the oil; this is also the case with many other species, the type *E. amygdalina*, for instance, which is also known in some localities as peppermint. From our experiments we find that this peppermint constituent occurs in greatest amount in the oil obtained from the leaves of *E. dives*, next in that of *E. radiata*, and in somewhat lesser amount from the leaves of

E. Sieberiana, and from *E. coriaceæ* and several others. If subsequent investigation should show this constituent to have special value for medicinal or other purposes, it can be obtained commercially from the leaves of both *E. dives* and *E. radiata*, so that the supply can be assured. In the oils of those species mentioned, this peppermint constituent occurs with phellandrene as the principal terpene, and in many of them with an almost entire absence of eucalyptol. Although occurring principally with phellandrene, yet, this terpene need not necessarily be present, as the peppermint constituent has been found occurring in the oil of at least one species in which phellandrene is quite absent; but generally, it may be stated as occurring in the oils of those species which are pronounced phellandrene bearing ones, and which make such a well defined group of Eucalyptus trees.

The yield of oil obtained, on a commercial scale, from the leaves and terminal branchlets of *E. dives* ranges from two to three per cent.; the oil is usually almost colourless, owing to the small quantity of free acid present. The crude oil has a low specific gravity 0·882 to 0·888 at 15° C., only a trace of Eucalyptol appears to be present at any time, but there is always much phellandrene. The optical rotation of the crude oil in a 100 mm. tube ranges from – 55·7° to – 63·9° the higher rotation occurring during the Australian spring months, the lower during the winter months.

On rectifying a sample of the oil of *E. dives* distilled in October, only two per cent. distilled below 172° C.; between 172° and 200° C.[1] 60 per cent. was obtained; between 200° and 227° C. 13 per cent. came over, and between 227° C. and 240° C. 20 per cent. distilled. The peppermint constituent occurs in greatest amount in the fraction 227° to 240° C., and it was thus possible to obtain it in a crude condition by ordinary distillation.

The specific gravity at 15° C. of the fraction 172° – 200° C. was 0·8593, of that obtained between 200° and 227° C. 0·8936, and of that between 227° and 240° C. 0·9318.

[1] These temperatures are corrected to the nearest whole degree.

The optical rotation of the first fraction in a 100 mm. tube was – 73·85°, while that of the third fraction had been reduced to – 9·4°. A larger quantity of the oil (two litres) was then distilled when practically the same results and percentages were obtained.

The constituents in the fraction 227° – 240° C. suffered slight decomposition when distilled under atmospheric pressure, as indicated by the odour and the darkening on keeping. When the oil was distilled under reduced pressure no decomposition took place. The oil when thus obtained under reduced pressure is of a slight yellowish colour, having a strong taste and odour of peppermint, and for commercial purposes might be used as thus obtained, or, the same result may be brought about by steam distillation of the fraction 227° – 240° C. When placed upon the tongue it has a hot and penetrating effect, quickly diffusing a sense of warmth over the chest. When taken in small quantities it appears to act efficaciously in the early stages of a cold. Whether it has value in this or other directions is worthy of determination by the medical profession.

The peppermint constituent when obtained as pure as possible, possesses an odour of peppermint which is much more pronounced when diffused, but the peppermint taste is increased exceedingly, and it is also much more pungent than the oil of the fraction from which it was obtained. It is most probably, owing to the strong odour given by this constituent when diffused, that has caused the name "peppermint" to be attached to so many different species of Eucalyptus. The oil of many of these species, however, does not contain the constituent in sufficient quantities to enable it to be isolated, or even readily detected; and it is probable that many of the constituents found in larger amount in some Eucalyptus oils are also present in minute quantities in a great many others, their characteristic odour being more readily detected in the leaf than in the oil after extraction.

The only chemical references to this peppermint constituent, that I can find are in Messrs. Schimmel & Co's. semi-annual reports for April 1888, and April 1890, where referring to the oil of *E. hæmastoma*, they say, that probably this contains menthone. There appears to be but one constituent in Eucalyptus oils having this peppermint odour. We have distilled the oil from the leaves of *E. hæmastoma* from two localities and failed to detect this peppermint constituent in the oil. This species grows plentifully in New South Wales, and is known as "White or Scribbly Gum." Mr. Smith, the author of this species, named *E. hæmastoma* in 1797, no doubt from trees growing at Sydney, in the neighbourhood of which it occurs plentifully, and as the characteristic constituents of identical species of Eucalyptus appear to be constant, there can be no doubt that the oil referred to by Schimmel & Co. was not obtained from *E. hæmastoma*, but from another species.

The question of constancy of chemical constituents in oils of the same species of Eucalypts will be fully discussed in the forthcoming work by Mr. R. T. Baker and myself.

Now that this peppermint constituent has been isolated it is found not to be menthone, as it has a much higher specific gravity, a higher boiling point, has probably no rotation, and the crystalline product obtained on reduction by sodium in alcoholic solution is not menthol, but quite a distinct substance and most probably new. Its taste and odour also differ from menthone. In boiling point and specific gravity it more closely resembles pulegone, but the same differences present themselves as with menthone. We are indebted to Messrs. Schimmel & Co. of Leipzig for samples of both menthone and pulegone, that firm having presented to the Technological Museum a very fine collection of the several constituents occurring in essential oils. It is probable that the peppermint constituent found in Eucalyptus oils is a new ketone, and in the second part of this paper I purpose dealing more fully with its chemical reactions and peculiarities.

Experimental.

Purification of the constituent.

The fraction 227° – 240° C. was frequently agitated for about three weeks with a saturated solution of sodium bisulphite, adding a little alcohol. The combination did not readily take place. After some days a crystalline compound formed which continued to increase. On adding water the crystals dissolved, the unacted upon oil separating. The aqueous portion was removed and decomposed with caustic soda solution. An oil at once separated in good quantity showing that a compound had been formed. The separated oil was well washed and then steam distilled. As thus obtained it is almost colourless, and has an intense peppermint taste and peppermint odour; it is soluble in alcohol, ether, and ordinary solvents, and is slightly soluble in water.

Optical rotation.

The rotation in a 100 mm. tube was $-0{\cdot}35°$. It is probable that the constituent itself is inactive, and that the slight rotation was caused by the presence of a minute quantity of the aromatic aldehyde present in these oils, previously supposed to be cuminaldehyde; this itself is lævorotatory and would be extracted with sodium bisulphite together with the peppermint constituent, and be present in the final product. That a small quantity of an aldehyde is present is indicated by the slight pink colour obtained when tested by Schiff's reaction, but the quantity present can be but small as this aldehyde answers to Schiff's reaction readily, besides easily forming a crystalline oxime. It has not been possible so far to form a crystalline oxime with the peppermint constituent, it remaining persistently as a thick oil; when dissolved in alcohol it had no rotation.

The presence of a small quantity of this aldehyde in the oil of *E. dives* again illustrates the persistency with which minute quantities of the several constituents maintain their presence in these oils.

Specific gravity.

The specific gravity of the purified material was ·9393 at $\frac{17° C.}{15° C.}$

Boiling point.

The purified material boils at 224 – 225° C.

Molecular value.

1·1816 gramme in 27·3 grammes of glacial acetic acid gave a depression in the freezing point of 1·085 degrees ; the molecular value from this is 155.

$C_{10}H_{18}O = 154$.

The crystalline substance formed on reduction.

On treating a solution in alcohol with metallic sodium, and afterwards adding water, the thick oily substance which separated was seen, after some time, to contain crystals. The aqueous portion was removed and the oily mass treated with slightly diluted alcohol in the cold. The crystals were but slightly acted upon and it was thus possible to remove the adhering oily impurities by dilute alcohol alone. That the crystals can be thus purified, was seen by the fact that as thus obtained, they melted at the correct temperature. The crystals are but slightly soluble in ether, so that they can be thus purified also. The crystals were found to be exceedingly soluble in chloroform from which on evaporation oblique needle crystals were obtained. The best method of purification was found to be to remove all adhering impurities by alcohol and ether, drying, and afterwards dissolving in chloroform, filtering, and allowing to crystallise. The crystals were colourless, they were slightly soluble in acetic ether, insoluble in acetone, and insoluble in alkalis.

The melting point was 155 - 156° C.; the substance did not decompose on melting, and on cooling crystallised very finely in long prisms of radiating crystals, which polarised exceedingly well. Its slight solubility in both alcohol and ether may be characteristic.

Determination of the alcohol in fraction 227 – 240° C.

An attempt to isolate an alcohol from this fraction with phthalic anhydride was not successful, no alcoholic substance being obtained. A portion of the oil of this fraction was then boiled for three hours with acetic anhydride and anhydrous sodium acetate, treating in the usual way and saponifying the product, 1·3236 grammes of the oil thus obtained was heated half an-hour with 10 cc.

alcoholic potash of known value, and titrated with semi-normal sulphuric acid, the saponification figure was 42·3 from which, taking the molecular weight of the ester as 196, we obtain 14·8 per cent. of ester or 12·0 per cent. of alcohol originally existing in this fraction, considering the molecular formula to be $C_{10}H_{18}O$. Only a very small quantity of ester is present originally in the crude oil of *E. dives*, so that an aromatic alcohol is shown to be present in small amount in this oil.

I wish to express my thanks to my colleague Mr. R. T. Baker, F.L.S., for botanical assistance in the preparation of this paper.

On an EUCALYPTUS OIL containing 60 Per Cent. of GERANYL ACETATE.

By Henry G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, November 7, 1900.*]

In a paper by Mr. R. T. Baker and myself, "On the Darwinias of Port Jackson and their essential oils," read before this Society, December 6th, 1899, we showed that geraniol occurs in large quantities in the oil distilled from the leaves of *Darwinia fascicularis;* this alcohol can, therefore, be obtained in commercial quantities from plants belonging to the Myrtaceæ.

The indigenous flora of Australia is exceedingly rich in plants belonging to this natural order, and it is thus probable that we shall eventually find other plants belonging to the Myrtaceæ, besides *Darwinia fascicularis* and the present Eucalyptus, from which geraniol may be obtainable on a commercial scale.

During the research on the Eucalypts of New South Wales and their essential oils, now being undertaken at this Museum, the presence of aromatic alcohols has often been detected; either free or combined as esters, and in a paper before this Society[1] it was shown that in the oil of *E. patentinervis*, either geraniol or linalol was present as free alcohol; from the results of this research it was probably geraniol.

The species of Eucalyptus now being described, the oil of which contains such a large percentage of geraniol, is known locally as 'Paddy's River Box'; its botanical name is *Eucalyptus macarthuri*. It grows plentifully in the Wingello district of this colony, on the banks of Paddy's River it is found as a fine foliaceous tree. The oil obtained from this species has no resemblance to ordinary Eucalyptus oil, and belongs to none of the well defined chemical groups of these oils. It thus becomes still more difficult to define in a simple sentence what Eucalyptus oil really is.

The crude oil of *E. macarthuri*, obtained by steam distillation from fresh material of leaves and terminal branchlets, is reddish in colour owing to the presence of a small amount of free acid in the original oil. In appearance, odour, etc., it resembles more than anything else, the crude oil of *Darwinia fascicularis*, but the higher boiling portion consists largely of eudesmol, the stearoptene of Eucalyptus oil, which constituent is absent in *Darwinia*. Although containing this stearoptene no crystals were obtained when the crude oil was placed in a freezing mixture, eudesmol being so exceedingly soluble in the oil.

The free acid present could not be determined in the usual way because it was found during the research on the oil of *Darwinia fascicularis*, that saponification of geranyl acetate takes place readily in the cold, if alcoholic potash be used. Full description of the rates of saponification is given in the paper referred to. The free acid was readily removed from the oil of *E. macarthuri*, by agitating with a very dilute aqueous solution of potash, the ester not being saponified by this treatment; the oil was afterwards well washed and dried. Saponification of the oil before

[1] Proc. Roy Soc., N. S. Wales, 1900, p. 74.

and after this treatment gives the amount of free acid present. The crude oil, after removal of the free acid, was but slightly coloured, it had a slight rotation to the right, and formed a clear solution with two volumes of 70 per cent. alcohol.

The oil was distilled in October 1900, and the yield obtained at that time of the year from leaves and branchlets was 0·112 per cent., 500 lbs. of material giving nine ounces of oil. The leaves were obtained from the neighbourhood of Wingello. The yield is only one-third that obtainable from the leaves and terminal branchlets of *Darwinia fascicularis*, and may be considered as about equal in amount to that obtained for geranium oil *(Pelargonium sp.)*. It would, however, be necessary to cultivate *Darwinia* for its oil, but the leaves of *E. macarthuri* are ready to hand. The mode of collection and distillation need not differ in any respect from that followed with ordinary Eucalyptus oil, except that it seems wasteful in the extreme to cut down the trees simply for their leaves, when by topping the trees, fresh material might again be obtained from the same trees in a few years. As the actual cost of obtaining crude Eucalyptus oil per pound from various species is well known, the cost of manufacturing any crude Eucalyptus oil can be calculated, providing the percentage yield (on a commercial scale) of any species is known. The method of preparing the oil of *E. macarthuri* for market is purely a commercial matter, but the saponification of the total ester in the oil takes place in the cold when alcoholic potash is used, the delicacy of the geraniol is thus not impaired in the slightest, as it is unnecessary to use heat, and the stearoptene, (eudesmol), having scarcely any odour does not interfere. The separated oil after cold saponification is light yellowish in colour, its odour is fresh and aromatic, and when diffused the rose odour is very marked. The acetic acid present in the ester might also be recovered if desired.

It is probable that slight differences may be found in the composition of the oil at different times of the year, but judging from the results obtained for *Darwinia* these differences should not be great. Some free alcohol was found to be present in the oil of *E. macarthuri*, most probably geraniol.

The oil separated after saponification is readily oxidised to citral, using potassium bichromate. The pure aldehyde was obtained by agitating the oxidised product with sodium bisulphite, separating the crystals formed, purifying and decomposing them in the usual way. The tests applied, together with the odour, showed the product to be citral.

Pure geraniol was obtained by treating the saponified oil with dry calcium chloride, removing the unacted upon oil with benzene, allowing the benzene to evaporate, and decomposing the compound with water; the washed oil was then steam distilled. The product was a colourless oil of a fine rose odour, it boiled at 224 – 225° C. (uncor.), and had a specific gravity 0·885 at 20° C.

On distilling the oil under atmospheric pressure only a few drops came over below 172° C.,[1] between 172 and 219° C. 10 per cent. distilled; between 219 and 229° C., 63 per cent. was obtained; the thermometer then rapidly rose to 266° C., between 266 and 282° C., 16 per cent. came over. Some decomposition of the ester had taken place under atmospheric pressure, the odour of acetic acid being detected. The first fraction contained neither eucalyptol nor phellandrene, but a green coloration being obtained with the sodium nitrite, indicated that a small quantity of pinene was present. The second fraction contained most of the geraniol. The third fraction consisted largely of eudesmol, the oil crystallising to a solid mass in the bottle soon after distilling.

The optical rotation of the crude oil after removal of the free acid was +3·6° in a 100 mm. tube, and the fraction 219 – 229° C. had a rotation in the same tube of +1·0°. The specific gravity of the crude oil at 15° C. was 0·9245, this comparatively high specific gravity was due to the presence of the stearoptene. The specific gravity of the fraction 172 – 219° C. was 0·8823; of the fraction 219 – 229° C. 0·9111; while that of the fraction 266 –

[1] Temperatures corrected to the nearest whole degree.

282° C. was 0·9511. The high specific gravity of this portion of the oil raises the specific gravity of the crude oil above that of *Darwinia fascicularis.* The specific gravity of the oil after saponifying was 0·9115 at 15° C.

Determination of the ester.

The amount of ester present was determined by heating the oil on the water-bath for one half hour (using upright condenser) with 20 cc. of semi-normal alcoholic potash, and then titrating with semi-normal sulphuric acid in the usual way.

(1) 2·9725 grammes oil required ·5124 gramme potash; saponification figure = 172·38.

(2) 3·0125 grammes oil required ·5194 gramme potash; saponification figure = 172·4.

As the ester consists entirely of geranyl acetate with a molecular weight of 196, the amount of ester present in the crude oil is 60·34 per cent.

After removing the free acid in the oil an ester determination gave the following result:—

1·945 grammes oil required ·3332 gramme potash; saponification figure = 171·3.

this gives the saponification figure for the free acid as 1·1, so that the amount of ester as geranyl acetate in the oil was 59·95 per cent. and the free acid represented an ester value of 0·39 per cent.

Determination of ester by cold saponification.

The oil taken was that from which the free acid had been removed by aqueous potash, one and a half hours elapsed after addition of the alcoholic potash before titration.

1·65 grammes oil required ·2828 gramme potash; saponification figure = 171·4

this is equal to 59·99 per cent. and it shows that the whole of the ester present in the oil is saponified in the cold in one and half hours.

It appears thus certain that the ester present in this oil is wholly geranyl acetate and that the other esters present in

Eucalyptus oils, determined during the research, are absent, viz., the amyl ester of eudesmic acid present in largest amount in the oil of *E. aggregata;* the iso-valeric acid ester present in greatest amount in the oil of *E. saligna*, and the acetic acid ester present in the oil of an Eucalyptus sp. at present undetermined. It is thus probable that this method might be used quantitatively for the determination of geranyl acetate occurring in other essential oils together with other esters.

Determination of the free alcohol.

The acetylation of the free alcohol in the oil was performed by gently boiling for one and a half hours with acetic anhydride and anhydrous sodium acetate, decomposing the remaining anhydride with water and washing the oil until the water ceased to react acid.

1·5066 grammes of this oil required ·3164 gramme potash; saponification figure = 210

equal to 73·5 per cent. geranyl acetate. As 60·34 per cent. existed as ester in the original oil we have 13·16 per cent. of ester formed from the free alcohol present. The free geraniol in the oil was thus 10·64 per cent.

Determination of the acid of the ester.

The aqueous portion after saponifying the oil was evaporated to small bulk and distilled with sulphuric acid, adding water until it ceased to distil acid. The distillate gave the reactions for acetic acid. A portion of the distillate was exactly neutralised with barium hydrate, evaporated to dryness, heated to render the salt anhydrous, and ignited with sulphuric acid. 0·828 gramme gave 0·754 gramme barium sulphate = 91·06 per cent. A second determination gave identical results. Barium acetate requires 91 37 per cent. of barium sulphate, so that but a minute quantity of a higher volatile acid than acetic acid can be present. An odour of valeric acid was at first detected and it may be that it had been derived by oxidation of the trace of valeraldehyde detected when distilling the oil. It is not likely to be present as free acid, because the free acid present in Eucalyptus oils is entirely acetic acid, no other acid being present, at any rate in those oils which have been exhaustively investigated.

The remainder of the acid distillate was neutralised with soda and evaporated to crystallising point; very fine crystals of sodium acetate were thus obtained.

I wish to express my thanks to my colleague, Mr. R. T. Baker F.L.S., for botanical assistance in preparing this paper.

THE SUN'S MOTION IN SPACE.

Part I. History and Bibliography.

By G. H. Knibbs, F.R.A S.,
Lecturer in Surveying, University of Sydney.

[*Read before the Royal Society of N. S. Wales, November 7, 1900.*]

Apart from its intrinsic interest, the determination of the direction and quantity of the sun's motion in space is important, as being the condition of further progress in developing a satisfactory system for defining the places of stars. The establishment of such fixed planes of reference as will be unaffected by the relative or absolute motions of the sun and stars, even for great periods of time, is clearly a desideratum, if not essential, in any thorough scheme of analysis of such movements. It is proposed in this paper to give an account of the history and bibliography of the development of this idea, of a motion of translation of the sun through space, and also of the determinations of its direction and amount, indicating briefly at the same time the general principles underlying the determinations. The different references are numbered for the sake of convenience. This is a step preliminary to a further consideration of the whole question, and since no such bibliography has yet been published, nor has any complete review of the existing state of knowledge on the subject been attempted, the present sketch will not be without value in further prosecuting the attack on the problem. As to the necessity of reaching the best solution, difference of opinion cannot, of course, exist.

(1) *Giordano Bruno, 1584.*—The conception of an indefinitely extended stellar universe, in which the sun and its planetary system is but a single and perhaps insignificant member, is one the world owes to the marvellous intuitions of Giordano Bruno, the immortality of whose memory was doubly assured when his noble mind and indomitable spirit vanished from the world in the flames of martyrdom on the 17th February 1600. "The magnificent stars and resplendent bodies" constituted, according to Bruno, "innumerable systems of worlds not much unlike our own,"[1] scattered through the ether of a boundless universe,[2] the suns being visible, but the planets invisible[3] through their smallness.

Copernicus had imagined the centre of the universe, as it were, to be in the sun and immovable.[4] Bruno to whom the sun was merely the father of life[5] for its own system, placed the centres in each star,[6] that is to say, they were centres merely for the systems of bodies about them; there was no general centre.[7] The innumerable worlds like ours "throned and sphered amidst the ether" free in space,[8] having the principle of intrinsic motion, attract one another and move by their own inward spiritual power.[9] It is in

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[1] . . ." questi magnifici astri e lampeggianti corpi . . . che sembrano e sono innumerabili mondi non molto dissimili a questo."—De la causa, principio et uno, Vol. I., p. 234, Opere di Giordano Bruno. Wagner. Leipsic, 1830.

[2] "In questo modo diciamo esser un infinito, cioè una eterea regione immensa. ne la quale sono innumerabili et infiniti corpi come la terra, la luna et il sole, li quali da noi son chiamati mondi composti di pieno e vacuo; per che questo spirito, quest'aria, questo etere, non solamente è circa questi corpi, ma ancora penetra dentro tutti, e viene insito in ogni cosa."—De l'infinito universo e mondi, Vol. II., p. 34, *op. cit.* [3] *Ibid.*, p. 52.

[4] See *op. cit.*, Vol. I., p. 163. [5] "Padre di vita." *Ibid.*, p. 51, last line.

[6] De Immenso. Bk. VII., p. 600. See also De l'infinito, Vol. I., p. 163.

[7] Centum et sexaginta articuli adversus hujus tempestatis mathematicos c 4 x., Art 160. Prague 1588. [8] Gfrörer 14, p. 159.

[9] See La Cena de le Ceneri.—Opere di Giordano Bruno, Vol. I., pp. 165 –166 etc. Wagner, 1830.

the totality of the infinite expanse of the ether that they all move.[1] There are also many other passages in Bruno's writings that shew most unmistakably the idea of a general motion among the stars to be at least as old as 1584, when the supposed 'Venice' edition of Bruno's works appeared.[2]

(2) *Schyrleus de Rheita (Antonius Maria) 1645.*—About sixty years after the publication of Bruno's works, appeared a curious treatise by Schyrleus de Rheita, published in Antwerp under the date 1645, and entitled *Oculus Enoch et Eliæ* etc.[3] This expresses with great justice the idea of a general motion among the stars. "These," said Schyrleus, "possibly have their proper motion, but the enormity of their distance prevents its being perceived." Doubtless the inspiration of this passage came from his predecessor Bruno.

(3) *Fontenelle, 1686.*—In his celebrated discourses on the plurality of worlds published in 1686, Fontenelle recognised, in a modified way at least, the possibility of stellar motion, if not also that of the sun as one of the stars.[4] Teaching that the stars were like our sun,[5] each being at the centre or in a vortex[6]—the idea of Descartes—it was possible for them to have true movement of their own, and to carry their planets along with them.[7] He recognised also the perpetual motion of the matter of the universe.[8]

(4) *Halley, 1717.*—Bruno's, Schyrleus' and Fontenelle's opinions were of course purely conjectural; the first significant recognition

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[1] "Uno dunque è il cielo, il spazio immenso, il seno, il continente unversale, l'eterea regione, per la quale il tutto discorre e si muove."—*Ibid.*, Vol. II., p. 50.

[2] Although Bruno's work is noted "Stampato in Venezia, Anno MDLXXXIV.," it was actually printed in London. Other works supposed to have been printed in Paris were also printed in London.

[3] Oculus Enoch et Eliæ sive radius sidereo-mysticus 2 pt. Antverpiæ 1645 fol.

[4] Entretiens sur la pluralité des mondes, 1686.

[5] Une étoile fixe est lumineuse d'elle-même comme le Soleil . . la centre et l'âme d'un monde, *loc. cit.* p. 106, edition 1719, Amsterdam.

[6] Soleils des . . tourbillons, *ibid.* p. 107.

[7] d'autres dont le soleil n'etant pas au centre, ait un veritable mouvement, et emporte ses planetes avec soi, *ibid.*, p. 108. [8] *ibid.*, p. 119.

of the existence of evidence that the so-called *fixed* stars did *not* really occupy fixed positions, but were subject to movement, is to be found in Edmund Halley's "Considerations on the change of the latitudes of some of the principal fixed stars" published in 1717.[1] Comparing recent star places with Ptolemy's, Halley was astonished to find that the latitudes of Aldebaran, Sirius, and Arcturus, directly contradicted the greater obliquity of the ecliptic indicated by the latitudes of most of the rest, and conjecturing that in all probability these conspicuous stars are nearest to the earth,[2] he remarked :—"if they have any particular motion of their own, it is most likely to be perceived in them," that is to say, in the nearer stars. Since the problem of solar motion, is a problem of motion in relation to other stars, Halley must be considered in the passage quoted, to have, implicitly at least, raised the whole question. Its full significance however does not appear to have occurred to him.

(5) *Bradley, 1747.*—With Bradley[3] the conception took still more definite shape, for in his paper in the Phil. Trans. of the Royal Society in 1747, he discussed the consequences, in respect of star places, of the alternative suppositions, viz., that the stars are in motion, and the sun fixed; and that the stars are fixed and the sun is in motion. Bradley clearly recognised that the problem would, if at all, be solved by taking account of the large proper motions of the nearer stars, and that a more exact knowledge of precession, aberration, and nutation, was necessary, before the problem could be properly attacked. That very knowledge, viz., of the fundamental constants of astronomy, was afterwards attained with a remarkable degree of precision, by the reduction of Bradley's own observations and the comparison of them with Bessel's observations and with others.

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[1] Phil. Trans. Reprint, Vol. VI., pp. 329–330, Orig. Vol. XXX., 1717. Halley was then Sec. Roy. Soc. [2] p. 330.

[3] James Bradley, D.D., F.R.S., Astron. Roy.—Phil, Trans. Reprint Vol. IX., pp. 417–438, Orig. Vol. LV., 1747-8.

(6) *Wright, 1750.*—In 1750 Thomas Wright of Durham published "An original theory or new hypothesis of the universe, etc."[1] in which the sixth 'letter' bears the title "of general motion amongst the stars, etc." He requires it to be granted that "all the stars are, or may be, in motion." These speculations of Wright's, on the nature of the stellar universe, were known to Kant prior to the production of his work on the same subject.[2]

(7) *Kant, 1755.*—It was however not till a period of about five years after the appearance of Wright's theories, that Kant published anonymously, his remarkable "Allgemeine Naturgeschichte und Theorie des Himmels,"[3] in which he sketched his view of the development and mechanics of the entire sidereal system, one feature of which was the "nebular hypothesis" of the genesis of planetary systems. It was through these offices that the human mind was familiarized with the larger conception of general stellar movement.

(8) *Mayer, 1760.*—Five years later again, that is after the appearance of Kant's work, Tobias Mayer, in 1760, in a memoir presented to a Göttingen Society,[4] compared the places of 80 stars observed by Roemer in 1706 with his own observations in 1756 and Lacaille's in 1750. Out of these, from 15 to 20 shewed differences in declination or right ascension exceeding 15″; and in the cases of Arcturus, Sirius, Procyon, Altair, Piscis Austrinus, the differences were so great that there could be no question as to the reality of the stellar motion. Mayer pointed out that the sun, as well as the stars, might be conceived as having absolute motion.

(9) *Lambert, 1761.*—In 1761 Heinrich Lambert[5] published some speculations concerning the universe, surmising that "everything *revolves*," the earth round the sun, the sun round the centre of his

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[1] Lond. 4to. pp. xii.+84, plates 32. See also Phil. Mag., April 1848, pp. 241 – 252.—De Morgan's account of Wright's speculations.

[2] Kant, according to Struve, obtained his knowledge of Wright's view from the Hamburgische freie Urtheile of 1751.

[3] Leipzic, 8vo 1755. [4] Opera Inedita, 1775.

[5] Cosmologische Briefe, Augsburg 1761.

system, this group round still another centre, and so on. However wild such surmises may now appear they were efficient in stimulating inquiry as to the nature of the evidence of general stellar movement, and of course cannot even now be proved to be utterly false.

(10) *Michell, 1767.*—Six years later, an "inquiry into the probable parallax and magnitude of the fixed stars, from the quantity of light which they afford us, and the particular circumstances of their situation," was sent forth by Michell.[1] In this it was argued that the apparent change of place might be due to either solar or stellar motion, or to both combined,[2] and Michell observed that if the annual parallax of a few of the stars should at any time be ascertained, it might serve as a basis for the calculation of the distances of others. He regarded the sun as merely one member of a great system of stars.

(11) *Lalande, 1776.*—Lalande[3] in 1776, applied, to the theory of the sun's motion, the somewhat fanciful doctrine, that a force, causing a revolution of a body about its centre, impelled the body onwards through space. He did not however, contribute anything of moment to the question.

(12) *Prévost, 1781.*—The first attempt to definitely calculate the direction of the solar motion was, I believe, made in Germany by Prévost, and published in the Nouveaux Mémoires of the Berlin Academy for 1781.[4] Prévost's investigation, based upon the proper motions in Tobias Mayer's table, led him to an opposite conclusion to that drawn by Mayer himself; for he, Prévost, was satisfied, contrary to Mayer's view, that the table afforded distinct indication of motion, and selecting 26 stars for discussion; he fixed the coördinates of the point towards which the sun must, from their apparent motions, be supposed to really move, as

$$\text{R.A.} = 230^\circ, \ \text{D.} = +25^\circ$$

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[1] Rev. John Michell, B.D., F.R.S.—Phil. Trans. Reprint Vol. XII., pp. 423–440, 1767. [2] p. 433.

[3] Mem. l'Acad. Sc., Paris 1776.

[4] p. 418. See also Berl. Astr. Jahrb. 1786, 259.

a result nearly agreeing with the deduction of Herschel two years *afterwards.*[1] Prévost raised the question as to whether, assuming comets to enter our system from without, more ought not to appear from the advancing than from the opposite quarter.

(13) *Herschel, 1783.*—In 1783 Herschel's paper "On the proper motion of the sun and solar system etc.," appeared in the Philosophical Transactions of the Royal Society.[2] Using Dr. Maskelyne's account of the proper motions of a number of stars, he formed two tables, one containing 32 stars; the other 12. He concluded that the solar motion cannot be less than that which the earth has in her annual orbit, and assigned a point near λ Herculis, with the coördinates, according to Galloway, (1847),

$$\text{R.A.} = 257^\circ, \;\; \text{D.} = +25^\circ$$

as the positive direction of the motion at that date. In the postscript to his paper he says, that out of 44 stars, the apparent movement of which were examined, 32 agree with the hypothesis, and the remaining 12 cannot be accounted for by it. This "must therefore be ascribed to a real motion of the stars themselves, or to some more hidden cause of a still remoter parallax." Herschel's method of solution depended upon the *direction* of the proper motion of the stars, the intersections of which on the celestial

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[1] The Encyclopædia Britannica 9° Edit. xi., p. 767, the article being by Prof. Pritchard, by implication rather than specific statement credits Herschel with being the author of the idea of solar motion. Although he, Herschel, made no acknowledgments, Prévost's work was probably widely known. Proctor also fails to recognise Prévost's result. see Encyc. Brit. ii., p. 819. It may be mentioned that Galloway writing on 4th March, 1847 says, (Phil. Trans. Reprint, Vol. lxv., p. 83):—"In the same year (*i.e.*, 1783) in which Sir W. Herschel's paper appeared in the Transactions, Prévost communicated the results of a similar inquiry to the Berlin Academy in a memoir which was published in the Nouveaux Mémoires of that Society for 1781." It may be further remarked that in 1894 in the Abh. d. k. Leop.-Carol. Akad., Bd. 64, p. 215, Kobold says, "William Herschel im Jahre 1783 zuerst das Vorhandensein einer fortschreitenden Bewegung unseres Sonnensystems darlegte und die Richtung dieser Bewegung bestimmte . . ." That is to say Kobold has failed to notice Prévost's claim to priority.

[2] William Herschel—Phil. Trans. Reprint, Vol. xv., pp. 397 – 409. The remainder of the title is:—"With an account of several changes that have happened among the fixed stars since the time of Mr. Flamsteed. See also Berl. Astr, Jahrb. 1787, p. 224.

sphere are of course considered as the points to and from which the sun is moving.

(14) *Du Séjour, 1786.*—It is stated in the Connaissance des Temps for 1809,[1] that Duséjour occupied himself with the problem of solar motion. This would probably be found in his analytical treatise of the movements of celestial bodies.[2]

(15) *Klügel, 1789.*—The Berlin ephemeris in 1789 contained formulæ by Klügel,[3] for deducing the direction of the sun's path in space, the point which he assigned having for its coördinates the values

$$R.A. = 260°, \quad D. = +27°$$

The deduction was also based on the proper motions of Mayer's table.

(16) *Wurm, 1795.*—The Berlin Astronomical Yearbook was in 1795 again the repository of a discussion of the trend of our system in the stellar universe; viz., in Wurm's article on the degree of certainty of our knowledge of the movement of our system through space.[4]

(17) *Prévost P. and Maurice, F., 1801.*—In the memoirs of the Berlin Academy in 1801, a determination by Prévost and Maurice,[5] based on a discussion of the proper motion from 1756 to 1797 of 39 stars, of the point to which the motion of our system is directed, was given. The result was also published afterwards in the Berlin Ephemeris, viz., in 1805.[6]

(18) *Biot, 1805.*—Jean Baptiste Biot in his Traité élémentaire d'astronomie physique,[7] published in 1805, also deduced formulæ

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[1] Sur le mouvement du système planétaire, pp. 377 – 382.

[2] Traité analytique des mouvemens apparens des corps célestes, Paris 1786-9, 2 tomes 4°.

[3] Trigonometrische Formeln zu der Untersuchung über die Fortrückung der Sonne und der Sterne.—Berl. Astr. Jahrb. 1789, 214.

[4] Ueber den Grad der Zuverlässigkeit unserer Kenntniss von einer eigenen Bewegung unserer Sonnensystems.—Berl. Astr. Jahr 1795, p. 175.

[5] Mém. Berlin Acad. 1801, pp. 118 – 131.

[6] Bode, Berl. Astr. Jahrb,, 1805, pp. 113 – 126.

[7] The edition to which I have access is 1811. The treatment of the problem is entitled "Sur le mouvement de translation du systême planétaire," t. III., additions pp. 114 – 129.

for the computation of the coördinates of the direction of the sun's path. He computed the intersections of great circles determined by the proper motions of Aldebaran, Capella, Sirius, Procyon, Pollux, Arcturus, α Lyræ, and α Aquilæ, as given by Zach[1] from comparisons of Bradley's places with Maskelyne's, and of Mayer's with Piazzi's. Biot's system of axes was identical with Airy's hereinafter mentioned. His theoretical expression for the "secular parallax," analogous to that for parallax in altitude, contained the factor,—the solar motion divided by the distance of the star. The absolute values of these he said, were impossible of determination. Selecting Sirius, Procyon, and Arcturus as stars whose proper motions were most suitable for a determination, he found the point towards which our system tends, to have the following coördinates, viz.

$$\text{R.A.} = 245{\cdot}^\circ0, \quad \text{D.} = +36{\cdot}^\circ4$$

Biot shewed that the evidence indicated displacements among the stars themselves: *i.e.*, the changes of apparent place could not be wholly due to the sun's motion.

(19) *Herschel, 1805.*—In May of the same year (1805), William Herschel[2] returned to the problem, Dr. Maskelyne's proper motions of 36 stars, the table of which he published in 1790, affording the necessary material for a more elaborate computation than he had at first undertaken. Herschel stated that the possibility of solar motion had been shewn upon theoretical principles by Dr. Wilson of Glasgow, and the probability, by Lalande, to which latter reference has already been made. He assigned for the point of direction, the position

$$\text{R.A.} = 245{\cdot}^\circ9, \quad \text{D.} = +49{\cdot}^\circ6$$

this being based upon the proper motions of 6 stars only, and so determined that the sum of the true proper motions should be a minimum. He discussed also the quantity of the motion.

(20) *Herschel, 1806.*—On February of the year following, (viz., 1806) Herschel read a further paper "on the quantity and velocity

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[1] Tabulæ speciales aberrationis et nutationis, etc.
[2] Phil. Trans. Reprint Vol. XXIII., pp. 233 – 256, 1805. Also Berl. Astr. Jahrb., 1811, p. 224.

of the solar motion."[1] He gave—p. 233—its value calculated for the distance of Sirius as 1·″117, and remarked on the possibility of the sun forming a unit in a very extensive stellar system. He also pointed out that it could not possibly be one member of a binary combination, as for example, with Arcturus. It may be mentioned further, that he assigned the following values for the relative distances of Sirius, Arcturus, Capella, α Lyræ, Aldebaran and Procyon, viz., 1, 1·2, 1·25, 1·3, 1·4 and 1·4.

(21) *Prévost, 1808.*—In 1808 a further attempt of Prévost's to deduce the solar motion appeared in the Bibliothèque brittanique.[2]

(22) *Burkhardt, 1809.*—Herschel's scheme for deducing the solar motion in space was objected to by Burkhardt in a memoir published in the Connaissance des Temps of 1809. Burkhardt gave formulæ for the solution of this problem, and applied these to several of the stars in Maskelyne's catalogue. The discrepancy among the results led him to conclude that we were not in possession of sufficient information to justify any deduction. His contention that the Herschelian method of solution, based on the assumption that the sum of the true proper motions of the stars must be a *minimum*, was equivalent to supposing that the stars are inclined to rest rather than to motion, shews a singular misapprehension of the nature of the problem.

(22A) *Gauss, 1810?*—According to Ludwig Struve,[3] Gauss assigned the values

$$\text{R.A.} = 259\cdot^\circ 2, \quad \text{D.} = +30\cdot^\circ 8$$

for the direction of the solar motion. No reference is given so that the date is uncertain.

(23) *Bessel, 1818.*—In 1818 it was again, this time more elaborately, investigated by Bessel in the 12th section of the *Fundamenta astronomiæ.* After discussing the proper motions of 71 stars, each being not less than 0·″5 annually, and finding that

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[1] Phil. Trans. Reprint Vol. xxiv., pp. 205 – 237.

[2] t. xxxix., pp. 192 – 210, 1808.

[3] Mém. Acad. St. Petersb., 7me série, t. xxxv., (3).

this number gave no certain result, Bessel concluded that a considerable period must elapse before the true theory of solar motion can be made out. The Besselian method depended upon the principle that the poles of the proper motions give a reliable indication of the sun's path in reference to the stars considered.

(24) *Olbers, 1821.*—In 1821 Olbers calculated the direction of the path in space of our system from the proper motion of 82 stars.[1] This was published in connection with his correspondence with Bessel.

(25) *Argelander, 1837.*—Argelander's great memoir "On the proper motion of the solar system," presented to the Academy of St. Petersburg in 1837[2] may be said to be the first systematic attempt to discuss the problem with anything like the thoroughness it deserved; 390 stars with proper motions sufficiently large were available, by comparing Bessel's reductions of Bradley's observations with Argelander's own '1830' catalogue.[3] These stars were divided into classes as follows, and with the following results for the year 1792·5:—

Class I.	P.M. > 1″[4]	21 Stars	R.A.	260·°8	D.	+ 31·°3
„ II.	„ 1·″0 – 0·″5	50 „	„	255·°2	„	37·6
„ III.	„ 0·5 – 0·09	319 „	„	261·°2	„	31·0

The general result corrected to the beginning of this century (1800·0) was R.A. = 259·°9, D. = + 32·°5[5]

Argelander's fundamental assumption was that the distances of the stars varied inversely as their proper motions. His reduc-

[1] Point vers lequel se dirige le système solaire, d'après les mouvements propres de 82 étoiles. Olbers u. Bessel.—Briefwechsel, herausg. von A. Erman II., 1852, p. 220.

[2] Ueber die eigene Bewegung des Sonnensystems.—Mém. d. sav. étr. de l'acad. impér. St. Petersb., t. III., pp. 561 – 605.

[3] DLX Stellarum fixarum positiones mediæ, ineunte anno 1830. Ex observationbus Aboæ habitis deduxit—Kelsingforsiæ, 1835.

[4] P.M. denotes as usual, proper motion.

[5] The values given for the second calculation and final result are in the St. Petersburg Memoirs— I. 255·°9; 37·°8 } II. 258·2; 39 2 } 1792·5 III. 262·0; 29·2 }
For mean, 1800 – 260·°8; 31·°3.—Vide pp. 589 – 590. Argelander corrects these in the memoir published in the Astron. Nach.: the corrected values are those above given.

tion was as follows:—The angles ψ made by the P.M's. with circles of declination were first computed, and then, assuming a point Q for the direction of the solar motion, the angles ψ' which the stars's path made with the meridians thereof, were also calculated. The value of ψ' was differentiated on the supposition that the R.A. and D. of Q are variables. In the resulting expression the value of the differences of ψ and ψ' were substituted for $d\psi'$, and thus an equation was obtained in which there are two undetermined quantities dA say, and dD. These equations on being solved by the method of least squares, gave values to be applied as *corrections* to the assumed values of the R.A. and D, of Q. The successive application of this process with recomputed values of R.A., D. and ψ' gave that position of Q which most nearly represented the whole of the observations.

(26) *Struve, F. G. W. von, 1837.*—A report by Struve on Argelander's work appeared in the Bulletin of the St. Petersburg Academy of Science in 1837,[1] and some correspondence between him and H. C. Schumacher, the founder of the Astronomische Nachrichten, also took place, in the same year,[2] relative to the solar motion.

(27) *Wartmann, L. F., 1837.*[3]—In the same year also, an article was contributed by Wartmann to the Society of Switzerland, on the general motion of translation of our whole system in space.

(28) *Taylor, T. G., 1838.*[4]—The Madras Literary and Scientific Journal for 1838 contained a reference to the solar motion in space by Taylor of the Observatory of that place.

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[1] Rapport sur le mémoire de F. Argelander: Ueber die eigene Bewegung des Sonnensystems hergeleitet aus den eigenen Bewegungen der Sterne. Petersb. Bull. Scient. Acad. II., 1837, pp. 113, 129.

[2] Auszug aus einem Schreiben an H. C. Schumacher, Astr. Nach. XIV., 1837, 315; Bibliothèque universelle de Genève (2) X., 1837, 161.

[3] Sur le mouvement général de translation de tout l'ensemble de notre système solaire.—Soc. Helvét. Act., 1837, pp. 71–74.

[4] Result of astronomical observations made at the Madras Observatory: Motion of the Solar system in space.—Madras Journ. Lit. and Sci., (1) VII., 1838, pp. 387–399, 479.

(29) *Cauchy, 1839.*[1]—In 1839 Cauchy cursorily remarked in connection with a brief discussion on the effect of motion on the behaviour of luminous rays, that " if our sun move in space it translates with it the whole planetary system"; and he points out that on the supposition that the system to some extent carries the ether with it, there is nothing extraordinary in the fact that the refractions of luminous rays from stars in opposite points of the heavens, viz., the points from which and to which we are moving, are equal. This is probably one of the earliest recognitions that the solar motion in space may perhaps produce optical effects of an important character : a question however which has recently been exhaustively discussed. See for example "Aether and Matter," by Larmor, Cambridge University Press, 1900.

(30) *Gruithuisen, 1840.*[2]—In 1840 Gruithuisen, in a memoir in the Astronomisches Jahrbuch for that year, pointed out that meteors afford evidence of the path of the sun in space.

(31) *Lundahl, 1840.*—The Abo catalogue, by Argelander, did not contain the whole of Bradley's stars given in the Fundamenta Astronomiæ. On comparing the latter work with Pond's catalogue of 1,112 stars reduced at the beginning of 1830, Lundahl found as many as 147 stars with P.Ms. not less than 0·″09 annually, which had not been included in Argelander's investigation. The reduction of these gave the result

$$R.A. = 252{\cdot}^\circ 4, \quad D. = +14{\cdot}^\circ 4$$

for the epoch 1792·5. Combining this result with those previously obtained by Argelander, and having regard to the weight of each, gave for 1800

$$R.A. = 257{\cdot}^\circ 9, \quad D. = +28{\cdot}^\circ 8$$

This investigation was published by Argelander in the Astronomische Nachrichten.[3]

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[1] Note sur l'égalité des réfractions de deux rayons lumineux qui émanent de deux étoiles situées dans deux portions opposées de l'écliptique.—Comptes rendus, VIII., 1839, pp. 327 – 329.

[2] Die Sternschnuppen zeigen, wohin die Sonne den Weg im Weltraum nimmt.—Astr. Jahrb. 1840, 1 (Gruithuisen).

[3] Astr. Nach., No. 398, pp. 209 – 216.

(32) *Wolfers, 1841.*—Wolfers contribution on the proper motion of our system appeared in the monthly notices of the Geographical Society of Germany for 1841.[1]

(33) *Richter, Ed., 1842.*[2]—In the following year the proceedings of the Dessau Natural History Society contained Richter's paper upon the same subject, and on the velocity of the motion.

(34) *Struve, O., 1842.*—The determination of the solar motion was next undertaken in 1841 by Otto von Struve, his researches being published in 1842 at St. Petersburg.[3] It was based upon the proper motion of 392 stars, whose mean places according to Bessel's catalogue were compared with their positions in 1825 deduced from observations made at the Dorpat Observatory. Of these only about 134 had been iucluded in Argelander's series; about 260 were new. Struve's fundamental hypothesis was that the distances of the stars were in the inverse order of their magnitudes; and dividing stars from the first to the seventh magnitude into twelve classes, he assigned unity as the distance of the first and 11·34 as that of the twelfth class, following the indication of the elder Struve[4] in the introduction to his catalogue of double stars.[5] Otto Struve's result reduced to 1792·5 was

$$\text{R.A.} = 261\cdot^\circ 4, \quad \text{D.} = +37\cdot^\circ 6$$

and combining these values with the three determinations by Argelander and one by Lundahl, he obtained for the same epoch,

$$\text{R.A.} = 259\cdot^\circ 2, \quad \text{D.} = +34\cdot^\circ 6.$$

(35) *Bravais, 1843.*[6]—In 1843 Bravais communicated to the French Academy of Sciences, two notes on the solar-motion deter-

[1] Ueber die eigene Bewegung unseres Sonnensystems.—Monatsber. Gesell. Erdkunde II., 1841, pp. 37, 38.
[2] Ueber die eigene Bewegung der Sonne und deren Geschwindigkeit.—Dessau Verhandl. des Naturh. Vereins I., 1842, pp. 14–17.
[3] Mém. l'Académie, t. V., 1842, pp. 17–124.—Bestimmung der Constanten der Præcession, mit Berücksichtigung der eigenen Bewegung des Sonnensystems. See also Astr. Nach., Bd. XXI., 1844, pp. 65–74.
[4] Friedrich Georg Wilhelm von Struve—Recueil Pétersb. Acad., 1832. Introd. in Cat. nov. Stell dup.
[5] See Dunkin, 1863, hereinafter.
[6] Memoire sur le mouvement propre du système solaire dans l'espace. —Journ. de Math. pur et appliq., t. VIII., 1843, p. 435. Comptes rendus, t. XVI., 1843, pp. 494–498; t. XVII., 1843, pp. 888–889.

mined upon the assumption that the 71 fundamental stars, whose proper motions were discussed, belonged to the one dynamic system, whose centre of inertia was supposed to be at rest. Bravais recognised the great disadvantage of insufficient information as to proper motions of stars in the southern hemisphere, and discussed the effect of taking into account the distances of the stars and their distribution in the celestial sphere.

In the second note he found that, basing fresh calculations on the proper motions of 62 stars of the first and second magnitudes in the 1755 and 1830 catalogues, the sun's trajectory was directed to a point nearly coincident with η Herculis, and that its path annually was 0·″28 at the mean distance of stars of the first magnitude. The position of η Herculis for 1843 would give

$$\text{R.A.} = 249{\cdot}^\circ 4, \quad \text{D.} = +39{\cdot}^\circ 2 \quad \text{R.} = 0{\cdot}''28$$

as the coördinates of the direction of the sun's motion at that date: R denotes mean distance of stars of first magnitude.

(36) *Bolzano, 1843.*[1]—Doppler had conceived and published the idea that when a source of light, as a star, has a velocity as high as thirty-three miles a second, to or from the observer, a sensible consequent variation should exist, as he believed, in its colour.[2] Bolzano imagined that the changes of the light of the stars, taking place through such movement, could be made to afford some indication of its velocity, the distances between the stars and so on. It will be necessary to refer to this matter later; when the nature of Doppler's misconception will be further adverted to.

(37) *Otto Struve and Peters, 1844?*—Faye in 1859 quotes Struve and Peters as having assigned the coördinates

$$\text{R.A.} = 259{\cdot}^\circ 75, \quad \text{D.} = +34{\cdot}^\circ 55$$

as specifying the direction of the path of our system in space for the epoch 1859.[3]

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[1] Eine Paar Bemerkungen über die neue Theorie in Herrn Doppler's Schrift "Ueber das farbige Licht der Doppelsterne."—Pogg. Annal., Bd. LX., 1843, pp. 83–88.

[2] Abhandl. der k. böhm. Gesell., Fol. v., Bd. II., 1841-2, pp. 465–482.

[3] Comptes rendus, 5 Dec. 1859, p. 873.

(38) *Mädler, 1846.*—In 1839 Mädler succeeded Friedrich Struve at Dorpat; the latter having been assigned the directorship of the Pulkova Observatory, then the best organized observatory in the world, and in 1840 he discussed the present state of our knowledge of the System of the Universe,[1] following on in 1846 with his own theory of the position of the "central sun,"[2] about which our sun and its neighbours were supposed to revolve. The idea was by no means a new one. Long before the architecture of the stars had been systematically studied, Kant, to whose work reference has already been made, had speculated on the possibility of Sirius being the centre of revolution. Lambert, was inclined to regard the vast nebula in Orion as the controlling centre: Herschel the great cluster in Hercules, estimated by him to contain 14,000 stars:[3] Argelander selected a point, R.A. = 49° D. = +54½°, in Perseus:[4] Boguslawski gave preference to Fomalhaut in Piscis Australis. Mädler's idea was that the sidereal system revolved about its common centre of inertia, and from the direction and quantity of rotation he concluded that Alcyone (η Tauri) was, in a passive sense, this centre. The distance thereto he computed to be thirty-four million times the radius of the earth's mean distance from the sun, and the great revolution to be made in 18·2 million years, with a velocity of thirty miles per second. Later Mädler published[5] a more complete exposition, which will be more fully referred to hereinafter.

(39) *Mitchell, 1847.*—In 1847 an article by Mitchell appeared on the proper motion of the solar system[6] in the Sidereal Messenger.

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[1] Ueber den gegenwärtigen standpunkt unseres Kenntniss der Weltsysteme.—Oken, Isis, 1840, pp. 823 – 835.

[2] Die Central Sonne—Astr. Nach. 566, 567, pp. 213 – 237. Bibl. Univ. Archives III.. 1846, pp. 5 – 29. See also, Uebersicht der neuesten Erweiterungen und des gegenwärtigen Standes unserer Kenntniss des Sonnensystems.—München, Gelehrte Anz. XXII., 1846, pp. 755 – 792.

[3] Phil. Trans. Reprint Vol. XXIV., p. 230, 1806.

[4] Mem. St. Pétersb. Acad. t. III., p. 603, 1837.

[5] Die Eigenbewegungen der Fixsterne in ihren Beziehungen zum Gesammtsystem, Dorpat, 1856.

[6] I., 1847, p. 70.

(40) *Galloway, 1847.*—On the year following the appearance of Mädler's memoir on a "Central Sun," Thomas Galloway,[1] secretary of the Royal Astronomical Society, studied the solar-motion problem with new material. He selected 81 stars in the southern hemisphere, observed by Johnson and Henderson, comparing their places with the catalogues of Lacaille and Bradley. These stars had a P.M. of at least 0·″1 per annum, 65 depending on Lacaille and 16 on Bradley's results. In respect of the principle of computing the solar motion, Galloway argued that each equation should have equal weight since we know nothing of the absolute velocity of a star's motion, or of its distance. His final deductions, based on the assumption indicated, were :—

81 stars, general result :—	R.A. =	263·°8	D. =	+37·°3
79 stars, re-calculated with two stars rejected	,,	257·°1	,,	34·°3
78 stars, re-calculated with a further rejection of one star	,,	260·°0	,,	34·°4

The coördinates are for the epoch 1790.

Galloway considered the possible error of the catalogues, and shewed that the annual P.M. 0·″1, was greater than the probable error of the catalogue. The close accord with the results of Argelander and Struve he regarded as considerably enhancing the probability of the conclusions reached.

(41) *Encke, 1847.*[2]—In an article on von Struve's study of stellar astronomy, Encke discussed Gauss' representations respecting the uncertainty of our knowledge of the direction of the sun's movement.[3] Struve had, according to Encke, assigned a point in the line joining the two third-magnitude stars π and μ Herculis, one-fourth of the whole distance from the former—that is a point whose coördinates in 1847 would be

R.A. = 259·°3, D. = +34·°7

This is obviously the result previously given, see (34).

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[1] On the proper motion of the Solar System by Thomas Galloway, M.A., F.R.S.—Phil. Trans. Reprint Vol. LXV., pp. 79 – 109, March, 1847.

[2] Ueber die "etudes d'astronomie stellaire" von Struve.—Astr. Nach. XXVI., 1848, pp. 337 – 350.

[3] Gauss, Darstellung hinsichtlich der Ungewissheit in der Bestimmung der Richtung der Sonnenbewegung.—*Loc. cit.*, p. 348.

(42) *Fleury, 1852.*[1]—In 1852, Fleury indicated what he believed to be a suitable experimental method for determining the amount of motion of the solar system.

(43) *Plana, 1852.*[2]—Plana, discussing in the Astronomische Nachrichten of 1852, Galloway's results, gave as the result from 81 stars, computed by stricter methods,

$$\text{R.A.} = 260{\cdot}^\circ 2, \quad \text{D.} = +36^\circ{\cdot}9$$

Epoch 1790. In his solution he applied the method of least squares and discussed Galloway's solution at same length.

(44) *Struve, F. G. W., von, 1853.*[3]—The first volume of the collection of Memoirs (1852 or 1853) of the Pulkova Observatory contains one by Friedrich Struve on "Results relating to the proper motion of the Solar System."

(45) *Arago, 1855.*[4]—Arago, in his popular astronomy, refers at some length to the work done by different astronomers, on the computation of the sun's path in space; he however contributes nothing original, and as a bibliography his chapter is incomplete.

(46) *Mädler, 1856.*[5]—In 1856 Mädler made a second and much more thorough determination based on the proper motions of no less than 2,163 stars. This gave—

$$\text{R.A.} = 261{\cdot}^\circ 6, \quad \text{D.} = +39{\cdot}^\circ 9$$

for the direction of the sun's motion, a direction which it has since been shewn is probably the prevailing one for several stars near our system.[6]

(47) *Airy, 1859.*—In March 1859, Airy also investigated the question under discussion.[7] Pointing out what he conceived to be

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[1] Méthode expérimentale propre à déterminer le mouvement absolu de Soleil.—Cherbourg, Mém. Soc. Sci. I., 1852, pp. 336.

[2] Mémoire sur la direction probable que Mr. T. Galloway assigne au mouvement propre du système solaire, etc.—Astr. Nachr. XXXIV., 1852, pp. 301 - 326.

[3] Résultats relatifs . . *au mouvement propre* du système solaire.—Poulkova, Recueil de Mém. I., 1852 or 1853.

[4] Mouvements propres des étoiles et translation du système solaire.—Astronomie populaire II., 1855, p. 19.

[5] Détermination de la direction suivant la quelle se meut le système solaire.—Dorpat, Beob. XIV., 1856, p. 223.

[6] See Klinkerfues, 1878, hereinafter.

[7] On the movement of the Solar system in Space.—Monthly Notices, Roy. Astr. Soc., Vol. XIX., pp. 175 - 180, 1859. See also Memoirs, Vol XXVIII., pp. 143 - 172, 1860.

the impracticability of Herschel's graphic method when the number of proper motions to be considered was large, and the impropriety of assuming the point to be determined, he proposed a method of rectangular coördinates, with a general weight multiplier to be attached to any class of stars defined by brilliancy or any characteristic, other than the magnitude of the proper motion itself. His system of axes, identical with Biot's, was—x, the sun's centre at a fixed epoch (an equinox); y, the point whose R.A. was 90°, the xy plane being parallel to the earth's equator; z was parallel to the earth's axis and + to the north. The proper motions reduced on this system were treated as chance quantities by the theory of errors. Airy clearly saw that the probable inequalities of motion, in the stars forming the cluster to which we may be supposed to belong, limited in some measure the strictness of this method, and he directed the attention of future investigators to the point. He also considered the influence of the systematic error, which may have crept into the computations by which the proper motions themselves were determined. Those used in his discussion, were taken from Main's papers in the Monthly Notices and the Memoirs of the Royal Astronomical Society, giving altogether the proper motions of about 1,200 stars, from comparisons of Bradley's places computed by Bessel, with the places given in the Greenwich 12-year, and subsequent 6-year catalogues.[1] In the analysis, two extreme suppositions were considered: (a) that the irregularities of proper motion were entirely due to chance errors of observation: (b) that they were due to the motions peculiar to the stars themselves, the latter supposition being regarded as in the main the true one. Airy was guided by F. von Struve as to assumptions respecting the supposed relation between the magnitude and distance of the stars. It is worthy of special remark that he, Airy, seems to have been the first to clearly recognise what may be called the relativity of the problem.

[1] Rev. R. Main—Proper Motions of 875 stars, etc. Monthly Notices, Vol, x., pp. 118, 122, (1850). Proper motions, Greenwich 12-year catalogue, etc. Memoirs, Vol. xix., (1851). Proper motions, Greenwich catalogue of 1,576 stars, etc. Memoirs, Vol. xxviii., pp. 127 – 142, 1858, published 1860.

He points out that we may arbitrarily take as the zero of our space coördinates, the place of one body or the mean of the places of many bodies; and in computing the sun's motion we are really referring that motion to the mean place of the stars included in the investigation, considered as a fixed point, or more strictly as a point of reference. Denoting by R the sun's proper motion as seen from the distance of a star of the first magnitude, Airy found the elements of the solar motion for suppositions (*a*) and (*b*) to be as follows, for the epoch 1840 (?):—

(*a*) R.A. = 256·°9, D. = +39·°5, R. = 1·″269
(*b*) 261·°5, +24·°7, 1·″912

Struve had, in his 'Bestimmung der Constante der Præcession,' found only 0·″339 for the quantity of the solar motion, just about one sixth of Airy's estimate. This will serve to indicate the uncertainty as to the velocity of translation through space, deduced in this way.

(48) *Carrick, 1859.*[1]—Carrick's paper on the sun's orbit plane, in the proceedings of the Literary and Philosophical Society of Manchester, discussed, I believe, the solar motion. [As there is no available copy in Sydney I cannot verify this however].

(49) *Faye, 1859.*[2]—In discussing the effect of the motion of the solar system through space, upon Fizeau's then recent attempt to determine whether the azimuth of the polarisation of a refracted ray is affected by the movement of the refracting body,[3] Faye quoted the value assigned by Otto Struve and Peters for the year 1859, as being

R.A. = 259·°7, D. = +34·°5, V. = 7·9 kilometres per second.

(50) *Liagre, 1859.*[4]—Liagre's memoir to the Brussels' Royal Academy of Sciences in 1859, furnished references to the results obtained by different investigators and discussed the significance

[1] Proc. Lit. Phil. Soc., Manchester, Vol. I., p. 187, 1860.

[2] Sur les expériences de M. Fizeau, considerées au point de vue du mouvement de translation du systéme solaire.—Comptes rendus XLIX., 1859, pp. 870 – 875. [3] *Ibid.*, pp. 717 – 723.

[4] Sur les mouvements propres des étoiles et du soleil.—Brux. Bull. Acad. VIII., 1859, 158.

of the question, but he contributed nothing fundamental to the then existing material. His memoir gives however a fair idea of the state of knowledge of the question in his day, but is meagre from a bibliographical or historical point of view.

(51) *Gautier, A., 1859.*[1]—Gautier contributed in the same year a notice on the later researches of Mädler.

(52) *Peters, 1860.*—In 1860 Peters again discussed the nature of the proper motion of the fixed stars, with reference to the hypothesis of Mädler, that the stellar system revolved round Alcyone as a central sun.[2]

(53) *Babinet, 1862.*—In a paper on the influence of the motion of the earth on optical phenomena,[3] in October 1862, Babinet quotes the coördinates of the direction of our motion in space as

$$\text{R.A.} = 260°, \ \text{D.} = +34{\cdot}°5, \ \text{V.} = 0{\cdot}25 \ \text{S.}$$

S being the annual orbit of the earth. These are evidently Struve's results for the direction.

(54) *Carrington, 1863.*—Carrington discussing very briefly the consequence of motion of translation of our whole system through space, concludes that any attempt to deduce the direction of motion from the apparitions of non-periodic comets is nugatory.[4]

(55) *Ångström, 1863.*—Ångström in 1861 suggested to the Royal Scientific Society of Upsala a purely optical method of determining the motion of translation of the solar system, which was practically identical with Babinet's, previously briefly referred to. In 1863, he published results of an attempt to thus deduce proof of the motion, experiments shewing that the influence of

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[1] Notice sur les dernières recherches de M. Mädler relatives au mouvement général des étoiles autour d'un point central.—Archiv. d. Sci. phys. et nat. IV., 1859, p. 305.

[2] Ueber die Eigenbewegungen die Fixsterne, mit Bezug auf Herrn Mädler's Hypothese der Bewegung der Sterne um Alcyone als Centralsonne.—Peters, Zeitschrift I., 1860, pp. 88 – 130.

[3] Comptes rendus, t. LV., 1862, pp. 561 – 564.

[4] Monthly Notices, Roy. Astr. Soc., Vol. XXXIII., pp. 203-204.

the earth's annual motion appears to be verified, but the evidence of solar motion was doubtful.[1]

(56) *Dunkin, 1863.*—In 1863 Dunkin computed the solar motion from the proper motions of 1,167 stars.[2] These he arranged in seven groups according to Struve's magnitude-parallax theory, the distribution in right ascension being nearly uniform, and about two-thirds of the stars being in the northern hemisphere. The assumed relative distances, and the number of stars corresponding to each were :

Distance	1·0	1·71	2·57	3·76	5·44	7·86	11·34
[3]Proctor's Dist.	1·0	4·7	3·2	4·1	2·0	4·5	5·0
No. of Stars	9	55	146	238	330	368	21

The results on Airy's two suppositions were—

(*a*)	R.A. = 261·°2,	D. = + 32·°9,	R. = 0·″335
(*b*)	263·°7	25·°0	0·″410

Dunkin remarked that probably a few stars of the fourth, fifth, and sixth magnitudes with large proper motions, are after all near stars, and notwithstanding that his values for the quantity of solar motion were sensibly the same as Struve's, 0·″339, he regards the fundamental assumptions as resting upon a very slender basis.

(57) *Stone, 1863.*—On 11th December, 1863, E. J. Stone, contributed a discussion merely on the quantity of the solar motion. Accepting R.A. = 260° N.P.D. = 55·°37′ as the direction thereof, he found, rejecting stars within 10° of the pole, from the proper motions in R.A. 0·″434, and from those in N.P.D. 0·″341. The mean 0·″403 would represent the motion at the mean distance of the group of stars considered. Stone alleges that if Bradley's

[1] Ny bestämning af ljusets våglängder jemte en method att på optisk väg bestämma solsystemets progressiva rörelse.—Oefv. Vetensk. Akad. Förhandl., Stockholm, Bd. xx., p. 41, 1863. See also Pogg. Annal., cxvii., p. 290, and Phil. Mag. Vol. xxix., 4 Ser., 1865, pp. 489 – 501.

[2] Monthly Notices.—Roy. Astr. Soc., Vol. xxiii., pp. 166 – 169.

[3] See hereinafter.

[4] On the motion of the solar system in space.—Month. Not. Roy. Astr. Soc., Vol. xxiv., pp. 36 – 39, 1864.

R.A. required a correction in the form of x cos R.A. + y sin R.A. the apparent drift would be at once accounted for.

(58) *Reddie, 1864.*—The Astronomical Register of 1864 contained an article by Reddie, expressing disbelief as to the motion of the solar system in space. The paper provoked some anonymous discussion in the pages of that journal,[1] but neither the paper nor discussions contribute anything of permanent interest.

(59) *Babinet, 1864.*—Babinet, in an article in Cosmos in 1864, discussed the possibility of the solar motion being that of one component of a double star.[2]

(60) *Stone, 1867.*—In 1867 Stone considered the question of the probability of the existence of solar motion, from the number of cases of mere agreement or disagreement of the signs of the proper motion and parallactic displacement.[3] His conclusion was that the preponderance over the number required by mere proper motion was sufficient evidence of the reality of the displacement, but that on the whole the parallactic displacement due to the motion of our system through space was much smaller than the independent proper motion of the stars.

(61) *Hoek, 1868.*—In reply to a query of Delaunay's as to whether there was evidence of solar motion in the inclinations, with the plane of the earth's orbit about the sun, of the planes of the non-periodic comets, and also in their excentricities, Hoek stated in 1868 that, subject to some uncertainty, the proper motion of the sun would from such evidence appear to be insignificant as compared with the mean initial motion of the comets, and from a study of the excentricities it might be deduced, that the annual path of the sun is probably inferior to three-tenths of the mean radius of the earth's orbit.[4] It is fully recognised that such deductions are essentially precarious. If the motions of non-

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[1] Astron. Register, Vol. II., pp. 37 – 39, 59 – 61, 82 – 84, 87-88, 164-165, 1864.

[2] Cosmos, t. XXV., p. 429, 1864.

[3] Motion of the Solar System in Space.—Month. Not., Roy. Astr. Soc., Vol. XXVII., pp. 238-239, 1867.

[4] Comptes rendus, t. LXVI., pp. 1200 – 1207, 1868.

periodic comets have no general tendency, the effect of translation of our system through space on their apparent motion would be seen in the elements indicated, provided the number considered was sufficiently large. Hence evidence of this character is valuable qualitatively. Quantitatively it is of course of inferior precision.

(62) *Hurst, 1869.*—Some correspondence on the motion of the universe appearing in a London daily, it was republished in the Astronomical Register as being of sufficient interest. One letter by Hurst, in reply to an article in Fraser's Magazine, points out that the motion is more than "guessed at." Hurst seemed to think that Alcyone had been shewn to occupy the centre of gravity of the sidereal system to which the sun belongs, that the direction of motion was toward π Herculis, and its quantity in one year 33,350,000 miles.[1] This would be for 1869—

R.A. = 257·°6, D. = + 37·°2, V. = 1·06 miles per second.

(63) *Proctor, 1869.*—The second letter, by Proctor, severely criticises Hurst, and merely offers a somewhat fuller, but still very incomplete statement of the state of knowledge on the question at the time of writing.[2]

(64) *Proctor, 1869.*—In the Monthly Notices of the Royal Astronomical Society, November 1869,[3] Proctor discussed the theory of a combination of the solar motion together with the stars own motion. From a somewhat full examination of Main's list of 1,167 stars, he points out that the evidence is apparently strongly antagonistic to the accepted view that stars of small magnitude are at greater distances, as the following table shews :—

Division according to magnitude.		Appt. P.M. ″	Resultant Distance.	Struve's Distance.	No. of Stars.
I.	1	0·857	1	1·0	9
	2	0·182	4·7	1·71	55
	3	0·268	3·2	2·57	146
II.	4	0·208	4·1	3·76	238
	5	0·433	2·0	5·44	330
	6	0·191	4·5	7·86	368
	7	0·173	5·0	11·34	21

[1] The Motion of the Universe.—Astr. Reg., Vol. VI., p. 236.
[2] Astr. Reg., Vol. VI., pp. 237-238.
[3] Monthly Not. R. A. Soc., Vol. XXX., pp. 8 – 18, 1869.

The mean result from I. was 0·″3015, from II., 0·″3022, that is to say the mean distance of the stars of the first three magnitudes is slightly less than the mean distance of those of the next three or four magnitudes! Proctor argues that large proper motion is an argument for proximity; that since there is no apparent agreement with proper motions and brightness, we are forced to accept the former, rather than the latter, as the best available evidence.

(65) *Flammarion, 1872.*—Flammarion treats upon the motion of our translation through space in the third volume of his studies published in 1872.[1]

(66) *Villarceau, 1872.*—In a note to the French Academy of Sciences in 1872, Villarceau discusses theoretically the velocity of light and the aberration constant in relation to the absolute movement of the solar system in space.[2] The paper is obviously important from the theoretical point of view, in respect of the accurate determination of star places, from which the proper motions are ascertained.

(67) *Doppler, Fizeau, Huggins, Zöllner, 1873, etc.*—The progress of science about 1873 opened up an entirely new possibility of investigating the sun's motion in space. In 1841, Doppler of Prague had pointed out that the system of waves in the luminiferous medium emanating from a luminous point, must be affected by its motion to or from an observer,[3] the consequence of which he erroneously (Bolzano previously referred to erring with him) thought would be a perceptible change of colour. The genius of Fraunhofer[4] had opened up a way of detecting the shift of the spectrum, since the lines crossing it, measured by him with such amazing diligence, really do shift with motion of the light-source,

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[1] Translation du système solaire dans l'espace et relation du soleil avec les étoiles les plus proches.—Etudes et lectures, t. III., p. 59, 1872.

[2] Sur la constante de l'aberration et la vitesse de la lumière, considérées dans leurs rapports avec le mouvement absolu de translation du système solaire.—Comptes rendus, t. LXXXV., pp. 854 – 860.

[3] Abhandl. d. kön. böhm. Ges, d. Wiss., Bd. II., p. 467.

[4] Bibl. Univ. VI., 1817, pp. 21 – 26.

an aspect of Doppler's principle noticed by Fizeau[1] in 1848. It was not till April 1868 however, that definite estimations of movements to or from our system were made : they were then communicated to the Royal Society of England by Huggins.[2] It is evident that the motion in the line of sight affords a perfectly independent method of computing the solar motion. Eighteen months after Huggins had reported his results, Zöllner[3] devised his ingenious reversion-spectroscope, which by doubling the line displacements increased the possibility of their accurate measurement.

(68) *Villarceau, 1875.*—In 1875 Villarceau contributed a second note, in continuation of the subject referred to in his note of 1872.[4] No further remark is here necessary.

(69) *Maxwell-Hall, 1876.*—By 1876 not only had some considerable advance been made in the determination of velocities in the line of sight, a similar progress had also been made in the estimation of the parallax, and therefore in the *distance* of stars. In September of that year, Maxwell-Hall published his first memoir[5] commenced in 1869, on the sidereal system, in which the sun, and some of the nearer so-called 'fixed' stars were regarded as bound together in a great dynamical system, assumed to be subject to the ordinary laws of gravity. Hall supposed the stellar orbits to be circular, and employing the same axes as Biot and Airy, used heliocentric polar coördinates in the developments of his equations. In adopting the direction of solar motion for the purpose of examining the evidence of the existence of a dynamical stellar system, Hall remarks that the mean of the results from

[1] Paper read before Soc. Philomathique, Paris, 23 Dec. 1848. See Annal. de Chim. et de Phys., t. XIX., pp. 211 – 221, 1870.

[2] Further observations etc., with an attempt to determine whether stars are moving to or from the earth etc.—Phil. Trans., Vol. CLVIII., pp. 529 – 564, (1868).

[3] Leipzig, Ber. math. phys., Bd. XXIII., pp. 300 – 306, 1871.

[4] Recherches sur la théorie de l'aberration, et considérations sur l'influence du mouvement absolu du système solaire, dans le phénomène de l'aberration.—Comptes rendus, t. LXXXI., pp. 163 – 171, 1875. See also Conn. des Temps. Additions 1878.

[5] Mem. Roy. Astr. Soc., Vol. XLIII., pp. 157 – 197, Sept. 1876.

Airy's two suppositions is *prima facie* the most probable, *i.e.*,

R.A. = 259·°2, D. = + 32·°1 for the epoch 1840.

Reducing to 1850 the mean of Argelander's, Lundahl's, and O. Struve's results as I.; putting Galloway's reduced result from southern stars as II.; and the mean of Airy's two results also reduced to 1850 as III., he adopted the general mean for 1850, as shewn hereunder,

	R.A.	D. +.
I.	259°·41′	34°·33′
II.	260·33	34·20
III.	259·18	32·05
Mean	259·51	33·39

or say R.A. = 259°·85, D. = + 33·°65

Hall considered the possible case of the sun and nearer stars revolving about a gigantic central body, and also of their revolving about their common centre of inertia. Using the parallaxes of α Centauri, and 61 Cygni, assumed as 0·″936 and 0·″422 respectively, to determine the constants of his equations, and comparing the observed with his computed motions, he concluded that the centre lies towards Andromeda, instead of toward Hydra, and that the motion is about a common centre of inertia rather than about some gigantic mass. The place assigned for the centre was for 1850,

RA = 10·°4, D. = + 27·°8

A second calculation gave

R.A. = 9·°2, D. = + 26·°5

The angular velocity of the sun about this centre was 0·″06612 per annum, 20 million years constituting the 'Annus Magnus' required to complete a revolution, whose radius was 31 million times the earth's mean distance from the sun. The whole gravitative mass was estimated to be 78 million times that of the sun, although the distribution at $\frac{3}{4}$ of a sidereal unit apart would indicate only 34 million. It should be added that in his discussion, Hall availed himself of existing knowledge of the radial velocities of stars, which, taken with parallax and proper motion, permitted of the absolute velocities being computed.

(70) *Leo de Ball, 1877.*—From the proper motions of 67 stars, Leo de Ball found for the epoch 1860, the values

R.A. = 269·°0 D. = + 23·°2

as defining the direction of the apex of the solar motion.[1]

(71) *Preston, 1878.*—In 1878, Tolver Preston raised the question whether the motion of the sun in space is not due to the reaction of the mechanical energy of the developed heat, this not being produced uniformly throughout its surface.[2]

(72) *Klinkerfues, 1878.*—In 1878, Klinkerfues applied Bessel's method of calculating and cartographically representing the poles of the proper motion in considering the fixed-star system, and the parallaxes and motions of its members.[3] He concluded that the stars Vega, Capella, Sirius, and Fomalhaut have parallel motion and belong to one system, or at least move as if they did ; a conclusion which Kobold points out loses its significance, if it be remembered that the computed radiation-point of the convergence, is very nearly identical with the antiapex of Mädler's solar-motion, adopted by Klinkerfues. The radiation point of the *divergence* was

R.A. = 272·°5, D. = + 32·°4

while Mädler's direction, as before mentioned, was

R.A. = 261·°6, D. = + 39·°9.

(73) *Maxwell-Hall, 1878.*—Further data being now to hand in regard to the parallaxes and radial velocities of about 23 stars, their motions were investigated with reference to Maxwell-Hall's hypothesis: the results on the whole appeared to confirm the theory of the earlier paper.[4]

(74) *Clerk-Maxwell, 1879.*—In a letter to Mr. Todd of the Washington N.A. Office, dated 19th March, 1879, Clerk-Maxwell remarked that if the sun be moving through the ether, the time

[1] Untersuchungen über die eigene Bewegung des Sonnensystems.—Inaugural-dissertation, Bonn, 1877.

[2] A consideration regarding the proper motion of the sun in space.—Phil. Mag., Vol. vi., Ser. 5, pp. 393-394, 1878.

[3] Ueber Fixstern-Systeme, Parallaxen und Bewegungen.—Veröffentlichen der k. Sternwarte zu Göttingen, pp. 29 – 53, 1878.

[4] Monthly Not. Roy. Astr. Soc., Vol. xxxix., pp. 126 – 133, 1878.

occupied by the light in passing from a planet as Jupiter to the earth, ought to vary as the planet moves through different signs of the zodiac. Hence he thought it might be possible to at least detect the existence of the motion in this way.[1]

(75) *Lagrange, C., 1880.*—Lagrange in 1880 contributed an article to "Ciel et Terre," on the apex of the solar motion through space.[2]

(75A) *Schönfeld, 1882.*—In 1882, Schönfeld introduced into the discussion of the sun's motion in space a term representing a possible rotation in the plane of the Milky-Way.[3] [Not having access to the volume of the quarterly journal of the Astronomische Gesellschaft containing his treatise, I am unable to more fully refer to it.]

(76) *Rancken, 1882.*—Rancken of Brahestad, Finland,[4] in 1882 adopting Gyldèn's hypothesis as to the parallax of the stars,[5] and employing Argelander's proper motions of 250 stars,[6] and Leo de Ball's proper motions of 80 southern stars,[7] computed the direction and quantity of the solar motion from the P.Ms. in right ascension, and in declination, considered independently. Denoting for brevity's sake, the computation from the former by R.A'., and from the latter by R.A. and D.; and putting E for the annual motion in terms of the mean distance of the earth from the sun; he obtained the results hereunder :—

From Argelander's P.Ms.—

R.A'. = 285·°0; R.A. = 284·°6, D. = + 37·°5, E = 10·85

From de Ball's P.Ms.—

R.A'. = 273·°8; R.A. = 244·°1, D. = + 17·°5, E = 4·59

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[1] Proc. Roy. Soc., Lond., Vol. xxx., pp. 108 – 110, 1879.

[2] Le point fixe, I., p. 217, 1880.

[3] Vierteljahrsschrift d. Astr. Ges., Bd. XVII., pp. 256 *et seq.*, 1882.

[4] Ueber die Eigenbewegung der Fixsterne.—Astr. Nach. Bd. CIV., pp. 149 – 156, 1882.

[5] Vierteljahrsschrift der Astron. Gesell., Bd. XII., Heft 4. Gyldèn's hypothesis makes the parallax a function both of magnitude and proper-motion.

[6] Bonner Beobachtungen, Bd. VII.

[7] Inaugural-dissertation, 1877.

According to Gyldén's hypothesis a star with large proper motion has also large parallax. Recalculating with the same material by dividing one side of the fundamental equations, by the parallax, instead of multiplying it into the other side, the normal equations are changed, and the results then became:—

From Argelander's P.Ms.—

R.A′. = 275·°3; R.A. = 288·°5, D. = + 41·°0, E = 10·6

From de Ball's P.Ms.—

R.A′. = 281·°0; R.A. = 240·°4, D. = + 11·°9, E = 7·83

The inconsistency of these results, which seem to indicate that the proper motions cannot be explained on the hypothesis of generally indiscriminate motion, suggested a further analysis, having regard to the fact that several astronomers have suspected a general drift of the stars in a direction parallel to the plane of the Milky Way. A selection was made of 106 stars, whose galactic latitude lay between the limits ± 30°, and whose yearly component of proper motion in galactic latitude did not exceed 0·″25. The suitable investigation of the solar motion from these gave,

R.A′. = 294·°5; R.A. = 275·°8, D. = + 31·°9, E = 9·79

Rancken concluded that a more accurate and thorough investigation of the question of general motion parallel to the plane of the Milky Way was essential in reaching truer views concerning the proper motions of the stars.

(77) *Plummer*, *1883*.—In Galloway's discussion of the direction of the solar motion from southern stars, the assumption of the point to be determined so affects the result that, whatever the data, there can be derived only a relatively small correction. Owing to this fact, and to the circumstance that more exact material had become available through the publication of Stone's catalogue,[1] Plummer in 1883,[2] undertook the investigation from Galloway's stars. The method of calculation was Airy's, the magnitudes

[1] The Cape Catalogue, 1880.

[2] Mem. Roy. Astr. Soc., Vol. XLVII., pp. 327 – 352, 1883.

adopted, Gould's in the Uranometria Argentina; and the stellar parallax that given by Peters.[3] The result according to the two suppositions previously referred to, the latter of which was the probable one, was, when Galloway's stars only were used :—

$$(a)\ \text{R.A.} = 276^{\circ}\!\cdot\!0,\ \ \text{D.} = +2^{\circ}\!\cdot\!7,\ \ \text{R.} = 1''\!\cdot\!470$$
$$(b)\ \ 262\cdot7,\ \ -1\cdot5,\ \ 0\cdot724$$

R denoting as previously the angular value of the motion viewed from a first magnitude star. The differences from the positions computed by Galloway himself were so remarkable, that a further investigation was undertaken in which all the Cape catalogue stars whose proper motions were greater than 0·″1 annually were included. The results from the 274 available stars were

$$(a)\ \text{R.A.} = 281^{\circ}\!\cdot\!3,\ \ \text{D.} = +25^{\circ}\!\cdot\!8,\ \ \text{R.} = 0''\!\cdot\!772$$
$$(b)\ \ 270\cdot1,\ \ 20\cdot3,\ \ 1\cdot690$$

The deviation from other results being still great, and an examination of the influence of certain stars shewing that four greatly affect the result, suggested the adoption of a change in the manner of grouping them. Relying upon the results of Safford's discussion, which apparently shewed that stellar distances should be approximately in the inverse ratio of the proper motions, a reinvestigation was undertaken on the assumption that the distances of the stars were as shewn in the following table :—

Proper Motion	2″ +	2″ – 1″	1″·0 – ·8″	·8″ – ·6″	·6″ – ·4″	·4″ – ·2″	·2″ – ·1″	·1″ –
Distance ...	½	1	1·67	2·14	3	5	10	15
No. of Stars ...	7	16	7	9	16	72	112	35

The computation now gave for the place of the point to which the solar motion was directed, and for the quantity of the motion

$$\text{R.A.} = 276\cdot^{\circ}1,\ \ \text{D.} = +26\cdot^{\circ}5,\ \ \text{R.} = 0\cdot''926$$

A close criticism of the general result convinced Plummer that Safford's doctrine as to the relation of distance and proper motion had some degree of probability. On the other hand there did not appear to be any decisive evidence of change of distance with

[3] Struve's Etudes d'Astronomie stellaire, p. 106.

magnitude; in fact excepting first magnitude stars, the evidence pointed to the other way, since putting R′ to denote the solar motion seen from the mean distance of each magnitude the results were as follows, viz.:—

Magnitude	1	2	3	4	5	6	7
Motion R′	0″·458	0″·108	0″·077	0″·101	0″·089	0″·056	0″·077

(78) *Kövesligethy, 1884.*—Kövesligethy stated, writing from O'Gyalla Observatory in March, 1886,[1] that at the beginning of the year 1883, he endeavoured, from the values of star-velocities in the line of sight (published in the Monthly Notices of the Royal Astronomical Society),[2] to determine the quantity and direction of the sun's motion. The result, from about 70 stars, for 1881·0 was

R.A. = 261·°0, D. = + 35·°1, V. = 8·6 German geog. miles per sec.

Fourteen stars approximately at right-angles to the path gave a residual velocity of 1 geog. mile per second, instead of zero, which supported fairly well the deduction of direction. These results were published in an Hungarian paper. (Haza és Külföld) 1st December, 1884.

(79) *Folie, 1884.*—In August 1884, Folie pointed out the significance of the solar motion in regard to what he denominated "systematic aberration,"[3] an aberration depending upon the relation of the velocity of translation of the solar system to the velocity of light, and he remarked that, although it had been so far neglected in determinations of velocity of translation, it is destined nevertheless to play an important rôle in future astronomy. Folie also pointed out that there is a further aberration which may be called "objective aberration," depending upon the velocity of the body emitting luminous rays to the velocity of their transmission through the ether.[4]

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[1] Bestimmung der Bewegung des Sonnensystems durch Spectral-Messungen.—Astr. Nach., Bd. CXIV., pp. 327-328, 1886.

[2] Monthly Not. R. A. Soc., Nos. 32, 36, 37, 38, 41.

[3] Un chapitre inédit d'astronomie sphérique.—Astr. Nach. 2607, Bd. CIX., pp. 225 – 238,

[4] See Houzeau, Astr. Nachr. No. 496 et 498, 1844; Herschel, *Ibid.*, No. 520. 1845; Villarceau, C. R., t. LXXV., 1872, LXXXI., 1875; C. des Temps, 1878.

(80) *Bischof, 1884.*—In 1884 Bischof also investigated the proper motion of the solar system.[1] From 480 stars, he found for the coördinates of the solar-apex for the epoch 1855

R.A. = 285·°2, D. = + 48·°5

Applying Airy's method, however, the result was

R.A. = 290·°8, D. = + 43·°5

(81) *Homann, 1885.*—Three extensive series of measurements of the radial velocities of the stars, made respectively at Greenwich, by Huggins, and by Seabroke, admitted of a determination of the solar motion from those data alone. This was undertaken by Homann in December 1885.[2] He found for the three series :—

i.	R.A. = 320·°1,	D. = + 41·°2,	V. = 39·3	kilometres
ii.	309·5,	+ 69·7,	48·5	,,
iii.	278·8,	+ 13·6,	24·5	,,

These results though not in perfect accord, yet shew sufficient to indicate that much is to be expected of the application of the method.

(82) *Ubaghs, 1886.*—In February 1886, Ubaghs submitted a paper on the determination of the proper motion of our system, to the Royal Academy of Sciences of Brussels.[3] Comparing the results of Bradley's catalogue with those of the Fundamental Catalogues of the Astronomische Gesellschaft and with the B.A.C. he obtained the following results for the epoch 1810?

Mag.	No. Stars	R.A.	D.	R′	π	E.
2	56	258·°2	+ 30·°1	·057″	″·65	·088
3	145	259·1	25·9	·045	·40	·112
4	263	265·2	26·3	·028	·21	·112
	464[4]	262·4	26·6			

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[1] Untersuchungen über die Eigenbewegung des Sonnensystems—Bonn 1884.

[2] Beiträge zur Untersuchung der Sternbewegungen und der Lichtbewegung durch Spectralmessungen—Inaugural-Dissertation, Berlin 1885. Also :—Bestimmung der Bewegung des Sonnensystems durch Spectral-Messungen.—Astr. Nach., Bd. cxiv., pp. 25-26, 1886. Also The Observatory Vol. ix., p 171.

[3] Détermination de la direction et de la vitesse du transport du système solaire dans l'espace. 1me partie—Bull. l'Acad. roy. Bruxelles 3° Sér., t. xi. pp. 67, 136 – 139, 1886; paper printed also in the Mémoires de l'Acad., t. xlvii., 1886.

[4] Quoted by L. Struve.—Mém. Acad. St. Pétersb., 7me Série, t. xxxv.

R′ denoting the annual motion at the mean distance of stars of the corresponding magnitude, π the parallax agreeing with the magnitude according to Pickering, and E. the absolute annual motion in terms of the mean radius of the earth's orbit about the sun. The values of E are singularly small compared with other estimates.

(83) *Folie, 1886.*—In April 1886, Folie, referring again to his previous communication to the Astronomische Nachrichten, quotes Ubagh's results above given.[1] Beyond quotation and brief comment nothing fresh is indicated.

(84) *Ludwig Struve, 1887.*[2]—Struve, comparing recent Pulkova catalogues with Bradley's observations reduced by Auwers, obtained 2,509 stars from which the constant of precession and the apex of the solar motion could be determined. Putting R.A′. for the result determined from the P.M. in right ascension only, Struve found for the year 1805

$$\text{R.A}'. = 272\cdot^\circ 9;\ \text{R.A.} = 275\cdot^\circ 1;\ \text{D.} = +36\cdot^\circ 3$$

His final deduction was

$$\text{R.A.} = 273\cdot^\circ 3,\ \text{D.} = +27\cdot^\circ 3$$

(85) *Folie, 1888.*—In a theoretical paper,[3] discussing a question raised by Battermann,[4] Folie points out, that if, as is required by rigour, the aberration and systematic parallax are introduced in any expression for the variation of the mean coördinates of a star's positions at intervals of time widely separated, the parallax of the star and the velocity of the solar system may be deduced from the variations.

(86) *Kobold, 1890.*—In 1890 Kobold commenced his elaborate investigations on the motions obtaining among the members of the

[1] Note sur le mouvement du système solaire.—Astr. Nach., Bd. CXIV., pp. 355 – 356.

[2] Bestimmung der Constante der Praecession und der eigenen Bewegung des Sonnensystems.—Mém. de l'Acad. St. Pétersbourg, 7me Série, t. XXXV., 3, 1887.

[3] Sur la détermination de la vitesse systématique et de la parallaxe des toiles, etc.—Astr. Nach. Bd. CXIX., pp. 343 – 346.

[4] See Astr. Nach., Bd. CXVIII., pp. 369 – 372. Folie in reply, *Ibid.*, Bd. CXIX., pp. 185-186; Battermann's rejoinder, *Ibid.*, Bd. CXIX., pp. 297 – 300.

stellar system.[1] He recognised the necessity of guarding against any preponderating influence of stars in particular parts of the heavens forming groups subject to a common drift, such as had been suspected by Michell,[2] and definitely revealed by the investigations of Proctor,[3] Huggins,[4] Safford,[5] and others. This undue influence can be avoided by grouping the stars in different regions, and using the mean proper motion of the region. At the date when the investigation was undertaken the positions and proper motions of 622 stars of the two catalogues of the Astronomische Gesellschaft were available. The general result of previous work was stated to be

$$\text{R.A.} = 266\cdot^\circ 7, \ \text{D.} = +31\cdot^\circ 0.$$

Forming 20 groups arranged in order of their proper motions, it was found that the distance from the adopted pole could be connected with the proper motion itself by the equation

$$-0\cdot^\circ 49 + 2\cdot^\circ 183 \frac{1}{\text{P.M.}} - 0\cdot^\circ 005 \frac{1}{(\text{P.M.})^2}$$

—P.M. denoting the proper motion. Dividing the stars into six classes according to the following scheme, the various results for the place of the parallactic pole shewn in the following table were obtained :—

Class	P.M.	Weight.	R.A.	D.	
I.	> $\cdot 547''$	$\geqq 1$	$259\cdot^\circ 4$	$-0\cdot^\circ 5$	Mean R.A. $266\cdot^\circ 1$, D. $+0\cdot^\circ 35$
II.	$\cdot 292''$ to $\cdot 547''$	$\frac{1}{2}$ to 1	$270\cdot 3$	$+2\cdot 6$	
III.	$\cdot 198$ $\cdot 292$	$\frac{1}{3}$ $\frac{1}{2}$	$266\cdot 9$	$-1\cdot 3$	
IV.	$\cdot 150$ $\cdot 198$	$\frac{1}{4}$ $\frac{1}{3}$	$262\cdot 9$	$+4\cdot 1$	
V.	$\cdot 120$ $\cdot 150$	$\frac{1}{5}$ $\frac{1}{4}$	$267\cdot 7$	$-0\cdot 5$	
VI.	$\cdot 100$ $\cdot 120$	$\frac{1}{6}$ $\frac{1}{5}$	$269\cdot 3$	$+2\cdot 2$	

These results were to be regarded as provisional merely. The epoch for the determination of the proper motions was 1755 –

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[1] Ueber die Bewegungen im Fixsternsysteme.—Astr. Nach., Bd. cxxv., pp. 65 – 72.
[2] See Phil. Trans., 1783. pp. 276 – 277.
[3] Proc. Roy. Soc. Lond.. Vol. xviii., pp. 169 – 171, 1869.
[4] Brit. Assoc. Reports, Sect. 1873, pp. 34-35, and Proc. Roy. Soc. Lond. Vol. xxii., pp. 251 – 254.
[5] Monthly Not. Roy. Astr. Soc., Vol. xxxviii., pp. 295 – 297, 1878.

1865, and the result is for the mean of those dates, viz., for the 1810·0.

(87) *Stumpe, 1890.*—In 1890 Stumpe undertook an investigation of the motion of the solar system having regard to the possibility of some general law in the *motus peculiaris* of fixed stars, existing.[1] All stars used in the investigation were reduced by Struve's Precession-constant to the equinox of 1855·0, the right ascension upon the Fundamental system of Newcomb, the declinations on Boss's system. The material for the determination was fully discussed and carefully corrected. Drawing attention to the fact that in previous determinations it has always been assumed that the *motus peculiaris*[2] of the stars is subject to no regular law —such as was contemplated in J. Herschel's hypothesis of a rotation in the plane of the Galaxy—Stumpe introduced into his equations, for the motion of the solar system, which in other respects were identical with Airy's, terms denoting the galactocentric right ascension, declination, and distance of the sun, and the right ascension of the ascending node of the Milky-way and the inclination of its plane and the equator. The stars were divided into four groups according to the magnitude of the proper motions, with the result shewn in the following table :

Group.	P.M.	No. of Stars.	R.A.	D.	R.
I.	0″·16 to 0″·32	551	287°·4	+42°·0	0″·140
II.	0·32 0·64	340	279·7	40·5	0·295
III.	0·64 1·28	105	287·9	32·1	0·608
IV.	1·28 and upward	58	285·2	30·4	2·057
	Total	1054	Mean 285·0	36·2 or about 39° taking account of number of stars.	

R denoting the ratio of the annual motion to the mean distance of the group. Thus it would appear that the distance of the stars is in general reciprocally proportional to their proper motion.

[1] Untersuchungen über die Bewegung des Sonnensystems.—Astr. Nach. Bd. cxxv., pp. 385 - 426, 1890. See also The Observatory, Vol. xiv., pp. 68-69.

[2] The *motus peculiaris* is the absolute motion of the star itself, while the 'proper motion' is the apparent motion arising from the combined effect of the *motus peculiaris* of the star, and that of the solar system.

There was no definite indication of a general rotation, such as was symbolically represented in the form of the equations of motion.

(88) *Boss, 1890.*—Using stars in the Albany zone, D. = 0·°50′ to 5·°10′, Boss in 1890 deduced the following results by adopting Airy's method :[1]

Series.	No. of Stars.	Mag.	R.A.	D.	R.
1	135	6·6	280°·4	+42°·8	0″·1239
2	144	8·6	285·7	45·1	0·1373
Both	279?	7·6	283·3	44·1[2]	0·1309
„	253	7·7	288·7	51·5	

Quoting Struve's, and Bischof's, and pointing out that the general result was about

R.A. = 287° and D. = + 47°

Boss seemed to think that the most probable position was

R.A. = 280°, D. = + 40°

He pointed out that Struve's result reduced on the system of the American Ephemeris would change its declination from + 27·°3 to + 37·°7.

(89) *Hecker, 1891.*—Hecker in 1891 by developing the observed motion of a star as a function of its position and distance, and by so determining the point that the motion in both coördinates vanishes, obtained the values :[3]

Division I. R.A. = 272·°5, D. = + 13·°8
„ II. 267·8 4·7

or combining the results

R.A. = 270·°0, D. + 9·°9.

(90) *Monck, 1892.*—Pointing out that although there is a considerable amount of agreement, in the determinations of the solar motion in space, the discrepancies are such as to indicate the precarious nature, and indeed even the inadmissibility of some of the

[1] A determination of the Solar Motion.—Astr. Journ., Vol. IX., pp. 161 – 165, 1890. See also, The Observatory, Vol. XIII., pp. 217, 218.
[2] Newcomb corrects this afterwards to 42·°9.
[3] Ueber die Darstellung der Eigenbewegungen der Fixsterne und die Bewegung des Sonnensystems.—München, 1891.

underlying assumptions, a point discussed by him at some length, Monck abandoned entirely all classification in respect of magnitude, and all assumptions with regard to distance.[1] Employing Dunkin's (*i.e.*, Main's) 1,167 stars, he tabulated the numbers in each hour of R.A. shewing *increasing*, and also those shewing *diminishing* N.P.D. The great preponderance of stars with increasing north polar distances, indicated that the apex of solar-motion was in the northern hemisphere, and that the north declination was considerable. The apex seemed to lie between R.A. = 16 hrs. and R.A. = 21 hrs., and the declination to be about +45°. A second table was then formed, giving similarly the numbers of stars with *increasing* and also with *diminishing* right ascensions. This table shewed the R.A. of the apex to lie between 18 hrs. and 19 hrs. Monck concluded further that this method would also serve to shew the rate of our progression, provided we assume that the stars are moving indifferently in every direction. He roughly estimated the velocity to be twenty miles per second, subject to an uncertainty of several miles. His rough values are

$$\text{R.A.} = 280°, \quad \text{D.} = +45°, \quad \text{V.} = 20 \text{ miles per second.}$$

Monck thinks that the proper motions of not less than 10,000 stars are requisite for determining the apex 'within 2 or 3 degrees,' or the sun's velocity 'without a considerable percentage of error.' The paper contains no rigorous mathematical statement of the fundamental assumptions, and the attempt at a quantitative estimate is admittedly 'rough' only.

(91) *Seeliger*, *1892*, (March).—Seeliger in his public address at the Munich Academy of Sciences, on the occasion of the 133rd anniversary of its foundation,[2] makes some important observations as to correct conceptions of the problem of solar motion, pointing out that it is 'very frequently, perhaps most frequently misconceived,'[3] as was established by L. Lange.[4]

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[1] I. The Sun's Motion in Space, I. and II.—Publications of the Astr. Soc. of the Pacific, Vol. xiv., No. 22, pp. 70 – 77, 1892.

[2] Ueber allgemeine Probleme der Mechanik des Himmels, pp. 1 – 29, München, 1892. [3] *Loc. cit.*, p. 29.

[4] Die geschichtliche Entwickelung des Bewegungsbegriffes, etc., Leipzig, 1886.

(92) *Ristenpart, 1892.*—Ristenpart compared the zones of Bessel with Becker's (Berlin) northern zones,[1] the interval being about a half century, in connection with an elaborate investigation of the constant of precession, and of the solar motion. Ristenpart concluded that the Galaxy consists of two intersecting planes, the coördinates of the principal and secondary poles, in 1850 being:[2]

Pole of Primary plane of Galaxy	R.A. = 196·°6,	D. = + 18·°7
,, Secondary ,,	191·1,	55·8
While Houzeau gave as the result	192·2,	27·5

In developing his equations he took account of Schönfeld's hypothesis of a rotation in the plane of the Milky-Way. Dividing the stars into four classes as follows, and abandoning the hypothesis of a rotation he obtained the results :—

Class.	No. of Stars.	P.M.	R.A.	D.
I.	85	over 0″·251	302°·2	+32°·4
II.	221	over 0·158	286·3	29 8
III.	148	under 0·158	294·7	24·8
IV.	4,565	over 0·1	294·3	28·2

A second calculation, including that hypothesis gave—

Class	R.A.	D.
I.	289°·9	+ 33°·3
II.	280·3	33·9
III.	267·3	28·4
IV.	276·5	27·0

While a third, with a modification of the hypothesis, gave—

Class	R.A.	
I.	290°·6	34°·4
II.	281·6	36·9
III.	266·7	33·3
IV.	281·2	41·2

The results shew that when a term (h) depending on the rotation is introduced

$$R.A. = 284°, \quad D. = +30°$$

but if neglected,

$$R.A. = 281°, \quad D. = +39°$$

[1] Untersuchungen über die Constante der Praecession und die Bewegung der Sonne im Fixsternsysteme.—Veröff. d. Grossh. Sternw. zu Karlsruhe, Heft. IV., pp. 197 – 288, 1892. [2] *Ibid.* p. 258.

and when the hypothesis of a place for the centre of inertia is introduced from Class IV., the one determination alone is allowable, viz.

$$\text{R.A.} = 274^\circ{\cdot}2,\quad \text{D} = +19^\circ{\cdot}5$$

Referring to a modification of Bischof's solution, Ristenpart pointed out that the result is changed from

$$\text{R.A.} = 290^\circ{\cdot}8,\quad \text{D.} = +43{\cdot}5$$

to 290·5 42·8

practically the same result. The epoch throughout is 1850.

On the basis of Gyldén's hypothesis the velocity is about

V. = 25·6 kilometres per second,

the simple mean of Homann's results is 28·8 kilometres. Ristenpart considered further the relation of the solar motion to the stellar *motus peculiaris*. He shewed that the P.M. affords a far better criterion of distance than magnitude does. From his analysis it appeared further that the product of the mean P.M. and distance of any class of stars continually increases with increase of distance from the sun: and that the linear *motus peculiaris* is a function of the stars position in space.

The following distance relations are given by Ristenpart:—

Magnitudes	1	2	3	4	5	6	7	8	9
Pickering	·794	1·258	1·994	3·160	5·006	7·929			
Bonner Durchmusterung	1·000	1·531	2·343	3·583	5·473	8·345	12·690	19·231	28·967

(93) *Porter, 1892 (Oct.)*—Employing Schönfeld's method[1] and an adaptation of his formulæ, Porter deduced the solar motion from the 1,340 proper motions given in No. 12 of the publications of the Cincinnati Observatory.[2] He divided these according to their magnitude into four groups, and obtained the results shewn hereunder:—

Group.	P.M.	No. of Stars.	R.A.	D.	Annual Motion R.	
I.	< 0″·3	576	281°·9	+53°·7	0″·16	1900.
II.	0·3 – 0·6	533	280·7	40·1	0·30	
III.	0·6 – 1·2	142	285·2	34·0	0·55	
IV.	1·2 – <	70	277·0	34·9	1·66	

[1] Vierteljahrsschrift Astr. Gesell. Bd. XVII., p. 256.
[2] Astr. Journ., Vol. XII., pp. 91 – 93, 1892. Also The Observatory, Vol. XVI., p. 456, 1892.

R. denotes the motion as seen from the mean distance of the group. It will be noticed that these results appear to confirm the assumption that the P.M. is an index of a star's distance, since the proportionality between it and the annual solar motion is quite remarkable.

(94) *Vogel and Kempf, 1 ·92.*—The motion of a number of stars in the line of sight had been determined by Vogel at the astrophysical observatory at Potsdam, spectrographically.[1] Of these, 45 out of 51 observed had a probable error of not more than ±0·25 Ger. geog. miles. At the suggestion of Vogel, Kempf undertook the investigation of the sun's motion.[2] In the first calculation it was assumed that the influence of the proper motions of the stars would disappear in the mean, and that the motions were independent. This assumption gave the result

R.A. = 206.°1, D. = + 45·9, V. = 2·5 German geog. miles

which it was alleged lay wholly outside the limit of previous determinations.

A second calculation in which different weights were assigned, and the stars were grouped in certain instances gave

R.A. = 159·°7, D. = + 50·°0, V. = 1·75 German geog. miles

Finally accepting the values of earlier observations, viz., R.A. 266·°7, D. + 31·°0[3] a computation was made of the velocity alone, giving V. = 1·66 German geog. miles. The provisional character of the result, since it depends upon a few stars of uncertain distance, is fully admitted.

(95) *Kapteyn, 1893 (Jan.)*—In 1893 Kapteyn commenced the publication of his researches on the distribution of the stars in space, using the Draper catalogue, and taking account of their

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[1] Publicationen des Astrophysik. Observ., Bd. VII., Theil 1, 1892.

[2] Versuch einer Ableitung der Bewegung des Sonnensystems aus den Potsdamer spectrographischen Beobachtungen. H. C. Vogel.—Astr. Nach. Bd. CXXXII., p. 81, 1893.

[3] Best. d. Constant d. Praecess., etc.—Mém. de l'Acad. St. Pétersbourg 7me Sér., t. XXXV.

spectral type.[1] In all there were 2,357 stars, of which 1,189 belonged to the first, 1,106 to the second, and 62 to the third spectral type; these types were considered because any general theory of distance as related to magnitude is obviously imperfect unless the character of the emitted light is regarded. The general result of Kapteyn's researches, in which Ludwig Struve's position of the apex of solar motion was accepted for the purpose of the reductions, is given hereinafter, see Kapteyn 1898. These values were

$$\text{R.A.} = 276°, \ \text{D.} = +34°$$

for the epoch 1865.

(96) *Kobold, 1893.*—Kobold opened his 1893 treatise[2] with a short discussion on the essential nature of the methods previously adopted for determining the sun's path in space. Stating that these may be divided into two species, viz., those that avoid all hypotheses in computing the direction of motion, and those that are deduced on some definite hypothesis, Argelander's and Bessel's methods belonging to the one, and Airy's and Schönfeld's to the other. Argelander so determined the direction that the sum of the squares of the differences of direction between the observed and the computed parallactic motion should be a minimum. Bessel computed the poles of the observed proper motions, and determined the direction of the solar motion as the pole of a great circle so situated, that the pole of the proper motions should approximate as near to its pole as possible. Airy determined the direction and magnitude of the motion together, and was forced to adopt an assumption as to relative distances of the stars, so as to suitably combine his data. Finally Schönfeld introduced by way of explanation of the differences between the deduced parallactic motion and the observed proper motion, the notion of rotation parallel to the plane of the Milky-Way. As already

[1] Over de verdeeling van de sterren in de ruimte. Verslagen der Afd. Natuurk. kon. Akad. v. Wetenschappen, 28 Jan. 1893, pp. 125–140. See also The Observatory, Vol. XVI., p. 275, 1893.

[2] Ueber die Bestimmung der eigenen Bewegung des Sonnensystems—Astr. Nach. Bd. CXXXII., pp. 305–326, 1893.

stated, Bessel had found from 71 stars that the poles of proper motion were so distributed over the spherical surface that the determination of a parallactic equator seemed hopeless. From the proper motions of 3,268 stars of the Auwers-Bradley catalogue 1,374 poles whose uncertainty of position did not exceed 10·°5 were accepted and divided into six classes. The distribution of these on the celestial spherical surface was analysed by dividing it into trapeziums and triangles at every 10° by hour and declinations circles, and observing the distribution thereon. Kobold concluded that by this analysis, it is certainly demonstrated that the Besselian method conducts to an apex, for the solar motion, not sensibly different from

$$\text{R.A.} = 266\cdot^\circ 1, \quad \text{D.} = +0\cdot^\circ 4$$

as deduced in his earlier essay from 622 stars. He discussed the reason why different methods should lead to results so much at variance; for example, Argelander's method leads to the result

$$\text{R.A.} = 260\cdot^\circ 8, \quad \text{D.} = +31\cdot^\circ 3$$

but Bessel's to

$$\text{R.A.} = 261\cdot^\circ 4, \quad \text{D.} = -6\cdot^\circ 0,$$

the cause of difference he concluded is not to be sought in the difference of data but in the treatment thereof. The essential feature of Argelander's method is that it supposes the stellar proper motions to be analogous to errors of observation. An examination shews most obviously, that the "law of error" is not applicable, and therefore its application can lead only to false results. Kobold pointed out that the magnitude of the sun's motion is comparable to that of the stars, and discussed the cases where it is supposed very great, or on the other hand negligible in relation thereto. He stated that Airy made the same assumption as Argelander, modified only by the addition that the distance of the stars is reciprocally proportional to their proper motion. Airy's solution really depended for the element of distance on magnitude.[1] The fuller discussion of the result by Argelander's method and by Bessel's seemed to prove that the latter is altogether preferable.

[1] Monthly Not. Roy. Astr. Soc., Vol. XIX., p. 178.

(97) *Harzer, 1893.*—In 1893 Harzer criticised the mathematical features of Kobold's investigation last mentioned, and defined the analytic conditions which should, in his opinion, determine Kobold's solution.[1]

(98) *Risteen, 1893 (June)*—Risteen, using Vogel's list of 51 stars with the exception of 9 which he thought ought, for various reasons, to be excluded as likely to vitiate the result, deduced from the remaining 42 stars[2]

R.A. = 218°·0, D. = + 45°·0, V. = 10·9 English statute miles per sec.

(99) *Kobold, 1894.*—On 4th June 1894, an investigation by Kobold of the proper motions of the Auwers-Bradley Catalogue, according to the Besselian method, was received by the Imperial Leopold-Caroline German Academy of Scientific Investigators, and published in 1895.[3] This contains the places of the 3,268 stars previously mentioned for the epoch 1810·0, and their proper motions; the latter being determined for the interval 1755 – 1865, the mean of which is the epoch referred to. From the 3,268 stars 1,408 are selected, the poles of whose motion do not shew a greater uncertainty of direction than 10°·5. Remarking that the relation of the weights in different instances will be as follows:—

Uncertainty of direction of P.M. $\epsilon(\phi)$ ±	10°·5	5·9	3·3	1·9	1·05	0·6
Weight	1·0	3 2	10·0	31·6	100·0	316·2

Kobold divided these stars into six classes, the limits of uncertainty being as hereinafter shewn. The 1,408 stars are also divided into six series, following the scale of the magnitudes of the proper motions, viz.,

Series ...	*A*	*B*	*C*	*D*	*E*	*F*
Proper motion	<0″·1	0″·1 – 0″·2	0″·2 – 0″·4	0″·4 – 0″·8	0″·8 – 1″·6	>1″·6
No. of Stars...	618	474	210	81	17	8

[1] Bemerkung zu Herrn Kobold's Aufsatz "Ueber die Bestimmung der eigenen Bewegung des Sonnensystems."—Astr. Nach., Bd. CXXXIII., pp. 79 – 82, 1893.

[2] Astr. Journ. Vol. XIII., pp. 74-75, 1893, also The Observatory, Vol. XVI., p. 274, 1893.

[3] Untersuchung der Eigenbewegungen des Auwers-Bradley-Catalogs nach der Bessel'schen Methode.—Nova Acta d. k. Leop. Carol. Deutsch. Akad. d. Naturforscher, Bd. LXIV., No. 5, pp. 215 – 368, 1895.

A count was then made of the distribution of the poles of proper motion over the celestial sphere, and after shewing that the approximate mean error is sensibly identical for each class, from which it appears that the influence of the chance errors of observation are unrecognisable, Kobold deduced the coördinates of the sun's motion from the stars in each class as follows:—

Class	Stars.	$\epsilon(\phi)$	R.A.	D.	
I.	24	$\leqq 0\cdot^\circ 6$	$264\cdot^\circ 4$	$+12\cdot^\circ 0$	Epoch 1810·0
II.	43	$0\cdot^\circ 7$ to $1\cdot^\circ 0$	264·3	−3·5	
III.	101	1·1 ,, 1 8	264·1	−0·7	
IV.	210	1·9 ,, 3·2	265·0	−4·7	
V.	386	3·3 ,, 5·8	267·4	−1·4	
VI.	636	5·9 ,,10·5	267 3	−4·3	
Total	1,400	Mean result	266·6	−3·0	

Treating the whole of the equations the result was

$$\text{R.A.} = 266\cdot^\circ 5, \quad \text{D.} = -3\cdot^\circ 1$$

practically identical with the mean result as shewn.

Kobold discussed this with respect to the quantity of the solar P.M., from which it appears that it is considerably smaller for the declination -3° than for $+31^\circ$, the former assumption giving

$$V = 0\cdot 61 \text{ German miles per sec.,}$$

while the latter gives 1·23. He moreover deduced the quantity of the sun's motion in relation to the members of two series of stars of which the parallaxes are known, and also the velocity in the line of sight from spectroscopic observations. The first series contains 11 stars, the second 18. The general result is that the evidence points to the apex being very near the celestial equator rather than about 30° away.

(100) *Gyldén, 1894 (Aug.)*—The relations of magnitude and proper motion to parallax are obviously important in connection with the analysis of the sun's motion. An attempt was made by Gyldén in 1894 by discussing stars of known parallax with various proper motions and magnitudes to define those relations quantita-

tively.[1] The results have been subsequently considered in discussions of the solar motion.

(101) *Kobold, 1895 (Jan.)*—In continuation really of his previous investigations, Kobold contributed to the Astronomische Nachrichten in 1895, a paper on the relation between the different methods of investigating the motion of the solar system.[2] His general equations contain terms representing the components of absolute motion, both of the sun and of the stars, that is to say the so-called *motus peculiaris* of both are taken into consideration. He points out that if Airy's method is applied to Vogel's 51 stars the result is

R.A. = 247·°0, D. = + 47·°9, R. = 0·″191

instead of 206·1 45·9

R being the motion at the mean distance of the 51 stars, but points out that the weight of a determination based upon so inconsiderable a number of stars is small. The mathematical theory of the difference between the methods is fully exhibited.

(102) *Kobold, 1895 (Mar.)*—Kobold discussed the relation of the Argelander and Airy to the Besselian method of investigating the solar motion, in March 1895.[3] He states (*a*) that Argelander's and Airy's methods should give the same point for the sun's apex of motion, the fundamental supposition being that the *motus peculiaris* perpendicular to the line of sight will mutually cancel one another. The apex points lie on both sides of R.A. 275° D. + 30° in a narrow zone parallel to the Milky Way: it is not possible that the true apex lies within this region. (*b*) The method dependent upon motion in the line of sight supposes that the *motus peculiaris* in that direction vanishes, and will give a result in agreement neither with the method of Argelander nor

[1] Ueber die mittleren Parallaxen von Sternen verschiedener Grössenclassen und verschiedener scheinbaren Bewegungen—Astr. Nach. Bd. CXXXVI., pp. 289 - 300.

[2] Ueber die Beziehungen verschiedener Methoden zur Untersuchung der Bewegung des Sonnensystems.—Astr. Nach. Bd. CXXXVII., pp. 343 - 348, 1895.

[3] Bemerkungen zur Bessel'schen Methode der Untersuchung der Eigenbewegung.—Astr. Nach. Bd. CXXXVII., pp. 389 - 398, 1895.

that of Bessel. (*c*) The Besselian method proceeds upon the assumption that positive and negative departures from the parallactic motion (due to the sun's motion) are equally probable. This last method gives a point in the Milky Way

$$R.A. = 266{\cdot}^\circ 5, \quad D. = -3{\cdot}^\circ 1$$

and is of course the result previously given in 1894.

(103) *Kapteyn, 1895 (May).*—In 1895 Kapteyn continued the publication of his researches on the distribution of the velocities of the stars in space,[1] taking account of their spectral type; the general result of such researches is given hereinafter, see Kapteyn 1898.

(104) *Anding, 1895.*—In his Habilitationschrift of about 1895 Anding[2] discussed the relations between the methods of Bessel and Argelander for the determination of the apex of the solar motion, having special reference to Kobold's work. For Kobold's reply see August 1895.

(105) *Kobold, 1895 (Aug.)*—Kobold having examined the deductions of Anding, replied that the consequences reached by his mathematical analysis were inconsistent with the actually observed distribution of proper motions, and his hypothesis could not be established.[3] A connection between the distribution of the stars and the position of the apex of motion was certainly most apparent, but it was admittedly difficult to distinguish whether the actual distribution was the consequence or the cause of the position of the apex-point.

(106) *Bompas, 1896 (Jan. and Mar.)*—A brief discussion on a possible explanation of the difference between the positions of the apex of solar motion, when deduced from stars of different distances,

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[1] Over de verdeeling der kosmische snelheden.—Verslagen der Afd. Natuurk. Kon. Akad. v. Wetenschappen, Dl 4, 25 Mei 1895 – Apr. 1896, pp. 4 – 18.

[2] Beziehungen zwischen den Methoden von Bessel und Argelander zur Bestimmung des Sonnenapex.—Habilitationschrift, 1895.

[3] Ueber die Vertheilung der Sterne mit merklicher Eigenbewegung.—Astr. Nach., Bd. cxxxix., pp. 65 – 78.

was contributed by Bompas in January 1896.[1] The results of Herschel, Argelander, Airy, Dunkin, L. Struve, Boss and O. Stumpe are given. Bompas thought it possible that there was a systematic drift of the Milky Way. Later, viz., in February, having noticed Homann's determination from motion in the line of sight,[3] he thought this some confirmation of the view previously expressed.

(107) *Anding, 1896 (Jan.)*—Anding,[4] stating that experience has shewn that the Besselian method of determining the direction of the sun's motion gives a result, different from that of other methods, in which the same data are employed, submitted the question to an analysis, by which he endeavoured to shew that the reason of the disagreement was to be sought in the distribution of the proper motions.[5]

(107A) *Kobold, 1896 (March)*—Kobold replied to Anding's argument three months later, pointing out that although the distribution of proper motions does affect the result, that fact does not explain the systematic difference referred to.

(108) *Stumpe, 1896 (April)*—Pointing out that Airy's method of determining the solar-motion in space is founded on the assumption that the true proper motions of the stars vanish in the mean, and that recent investigations have cast doubt upon that hypothesis, Stumpe returned again to the question of so deducing our path in space that the possibility of stellar proper motions being subject to some general trend—as for example in the plane of the Milky Way—shall be considered.[6] Stumpe consequently, having regard to Schönfeld's assumption that the stars in general

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[1] The Observatory, Vol. XIX., pp. 45 – 49, 1896. [2] *Ibid.*, p. March 1896.

[3] Cited in Miss Clerke's "System of the Stars," p. 328.

[4] Ueber den Einfluss der Sternvertheilung auf die Bestimmung des Sonnenapex nach der Bessel'schen Methode.—Astr. Nach. Bd. CXL., pp. 1 – 18, 1896.

[5] Erwiderung auf Herrn Anding's Aufsatz.—Astr. Nach. Bd. CXL., pp. 141 – 144.

[6] Beiträge zur Bestimmung des Sonnen-Apex.—Astr. Nach., Bd. CXL., pp. 177 – 192, 1896. A very imperfect account may also be found in The Observatory, Vol. XIX., p. 411, November 1896.

move in excentric paths about the centre of the galaxy, introduced into his equations terms representing the galactocentric coördinates of the stars' positions, and investigated the evidence for such motion.

Dividing the proper motions of 996 available stars into three groups according to their quantity, and into three classes according to the magnitudes of the stars—as shewn hereunder—the following results were obtained :—

Group.	P.M.	No. of Stars.	R.A.	D.	Mean P.M.	Mean Mag.
I.	0″·16 – 0″·32	551	284·4	+41·5	0″·229	6·34
II.	0·32 – 0·64	339	275·7	41·9	0·433	6·70
III.	0·64 – 1·28	106	287·7	33·1	0·850	6·38

Class.	Magnitude.	No. of Stars.	R.A.	D.	Mean P.M.	Mean Mag.
1.	7·6 – <	284	286·7	46·9	0·384	8·18
2.	5·6 – 7·5	473	290·7	37·5	0·357	6·63
3.	1· – 5·5	238	263·8	31·1	0·358	4·12

These should give consistent results, if stellar distance be a function of the proper motion in the first series, or a function of the magnitude in the second series.

Rearranging the stars in three divisions (*a*), (*b*), (*c*) by applying Gyldén's hypothesis as to parallax, previously referred to (see 1894), the results then become :—

Division.	Parallax.	No. of Stars.	R.A.	D.	Mean P.M.	Mean Mag.
(*a*)	″·02 – ″·04	404	287·4	+45·0	0″·233	7·12
(*b*)	·04 ·06	348	282·2	43·5	·387	6·82
(*c*)	·06 ·12	243	280·2	33·5	·552	4·89

These all shew a progression of the values for the apex-point, standing out the more clearly when stars of equal P.M. are classed according to brightness, or when stars of equal brightness are classed according to their P.M. Thus for example, the number also being thereby reduced as shewn, the results become—

Class.	Magnitude.	No. of Stars.	R.A.	D.	Mean P.M.	Mean Mag.	Mean π
1.	7·6 – <	139	305·3	56·0	0″·237	8·17	0″·026
2.	5·6 – 7·5	265	281·8	38·3	0·231	6·58	·034
3.	1· – 5·5	146	276·2	30·9	0·219	4·19	·067

that is to say the progression referred to is still more conspicuous.

The following comparison between the parallax and magnitudes according to different estimates, is given, viz.,

Magnitude	1	2	3	4	5	6	7	8	9
Struve	1·00	1·80	2·76	3·91	5·45	7·73	11·55	17·40	—
Ristenpart	1·00	1·53	2·34	3·58	5·47	8·34	12·69	19·23	28·97
Gyldén	1·00	1·31	1·77	2·47	3·51	5·09	7·51	11·21	16·99

Using Gyldén's hypothesis, and accepting Houzeau's values, R.A. 282·°25, I. = 62·°5, for the longitude of the ascending node, and inclination of the plane of the visible galaxy, the following results were obtained—

Parallax.	R.A.	D.
0·″02 – ·04	292·°2	+ 52·°3
·04 – ·06	285·6	47·6
·06 – ·12	280·5	33·7

These still shew the progression referred to, that is to say the hypothesis of motion in the plane of the Milky-Way leads to no better result. Treating again a limited number of stars of classes 1, 2 and 3, it was found that the results were[1]—

Class.	Magnitude.	No. of Stars.	R.A.	D.	Mean P.M.	Mean Mag.
1.	7·6 – <	89	281°·1	+ 22°·9	0″·240	8·13
2.	5·6 – 7·5	199	274·8	13·0	·230	6·54
3.	1· – 5·5	106	272·4	9·4	·219	4·10

Finally, taking all stars of Groups I. and II., according to whether the angle of intersection of the P.M. with the meridians of the solar apex be less or greater 90°, the results become—

Group.	No. of Stars.	R.A.	D.	Mean P.M.	Mean Mag.
I.	394	275°·3	+ 13°·8	0″·230	6·24
II.	243	275·9	14·3	·429	6·70
I.	156	77·3	45·8	·229	6·61
II.	96	88·8	56·2	·443	6·71

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[1] It may be incidentally remarked that the mean result of these 394 stars weighted merely as the number of stars is

R.A. = 275·°6, D. = + 14·°3

which is almost identical with Group II. below, viz.,

R.A. = 275·°9, D. = + 14·3.

The middle value of the first two, viz.,

R.A. = 275·°5, D. = + 14·°0

is exactly the mean between Kobold's value − 3°, and Ludwig Struve's + 31° according to Airy's or Argelander's method, and is moreover the most probable result.

(109) *Kobold, 1896 (July)*—Among the proper motions of 499 southern stars, communicated to Kobold by Auwers, the uncertainty of the directions of 188 were within the previously indicated limits.[1] These gave for the sun's apex at 1880·0—

R.A. = 276·°0, D. = + 2·°9

Treating these in the same way as the previous stars, by dividing the celestial sphere into equal areas, the result was

R.A. = 269·°3, D. = − 0·°1

and combining these with previous results from Bradley's stars this result became

R.A. = 266·°5, D. = − 3·°1.

(110) *Newcomb, 1896 (Dec.)*—In a paper "On the solar motion as a gauge of stellar distance,[2] Newcomb concluded from a discussion on the relation between magnitude and proper motion, that the parallactic-displacement effect of the solar motion diminishes less rapidly with stars of fainter magnitude than has been supposed.[3] His result shews solar motion toward a point R.A. = 297°, the quantity 0·″046 per annum from the mean distance of stars of 9th magnitude. If we accept for the parallax the value 0·″106 $(2^{-\frac{9}{2}}$, see Kapteyn (122) hereinafter, this will make the velocity 28·9 miles per second.

(111) *Kobold, 1897 (April)*—In April 1897 Kobold discussed the proper motions of 523 southern stars,[4] by way of extending his 1894 investigation previously referred to. These proper

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[1] Notiz betreffend die Bestimmung des Poles des parallaktischen Aequators.—Astr. Nach., Bd. CXLI., pp. 421 – 422, 1896.

[2] Astr. Journ., Vol. XVII., (No. 390) pp. 42 – 44, 1896. See also The Observatory, Vol. XX., pp. 214-215, May 1897. [3] *Loc. cit.*, p. 44.

[4] Untersuchung der Eigenbewegung von 523 südlichen Sternen.—Astr. Nach. Bd. CXLIV., pp. 33 – 58, 1897.

motions were determined from observations, differently weighted, at five epochs, the series being,—

I. Lacaille, Bradley: II. Piazzi: III. Johnson St. H., Cape 1840, Taylor, Henderson, Pond: IV. Cape 1880, Cordova 1875, Melbourne (i.) and (ii.), Greenwich: V. Recent observations at the Cape and Cordova. The catalogue gives the places for 1850·0. The celestial surface was divided by 2-hour circles, and by parallels of declination into 122 equal areas, and the general treatment was similar to that in the 1894 treatise. 213 poles whose uncertainty lay within the previously indicated limits gave for the pole of the parallactic equator the coördinates—

(213 stars) R.A. = 274·°4, D. = + 0·°4

Combining this catalogue with the previous one, thus bringing the total number of stars employed up to 1579, the result became

(1579 stars) R.A. = 268·°3, D. = − 2·°9

Again, on dividing the whole sphere in 122 equal trapeziums, (2 calottes at the poles), the result obtained was

R.A. = 269·°7, D. = − 0·°02

the close agreement of both results shewing that the unequal division of the celestial sphere by the stars employed, had not materially influenced the result. Kobold also, employing the list of 11 stars referred to previously, viz., in his 1894 treatise, whose parallaxes and motions in the line of sight have been determined, found that they pointed to the result

R.A. = 240·°1, D. = + 3·°7, V. = 2·53 Ger. miles per sec.

Derived from such limited data, this result could not of course be regarded as having much weight, but the close agreement with the general result is worthy of remark. The epoch for all the values is 1810·0.

(112) *Kobold, 1897 (April).*—In a contribution concerning the value of the precession-constant,[1] Kobold assigned, for the epoch 1810·0, as approximate values of the parallactic pole R.A. 270°,

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[1] Ein Beitrag zur Kenntniss der Praecessionsconstante.—Astr. Nach., Bd. CXLIV., pp. 57–60, 1897.

D. 0°, and obtains from 115 stars of proper motion at least 0·″4

$$\text{R.A.} = 266 \cdot {}^\circ 1, \quad \text{D.} = -0 \cdot 7.$$

The paper is important as bearing on the relation of the determination of the precession-constant to the general discussion of proper motions.

(113) *Kapteyn, 1897 (May)*—Kapteyn continued his discussion of the velocities of stars in space, reviewing the possibility of some general trend in the *motus peculiares* of the stars.[1] His results are more fully referred to hereinafter. See 1898.

(114) *Kobold, 1897 (July)*—In continuation of his previous investigations, Kobold[2] discussed in July 1897, the distribution of the *motus peculiares* of the stars upon the assumption of two apices for the solar motion, viz.

(*a*) R.A. = 268·°25, D. = +31·°0, Argelanderian solution

(*b*) 268·°25, −3·°0, Besselian solution

and further for the apex

(*c*) R.A. = 268·°25, D. = +10·°5

Putting

$$M = \Delta s \cos(\phi - \psi); \quad N = \Delta s \sin(\phi - \psi)$$

in which Δs, ϕ, and ψ are respectively the observed proper motion, its direction, and ψ the direction from the antiapex; and also q to denote the solar motion, and Δp the correction to the precession constant, Kobold found for these points the following results, viz.:

	Argelanderian Point.	Besselian Point.	Point *c*.
Δp	−0″·0289	−0″·0277	
Mean N	± 0·0934	± 0·0847	
No. of + Ns	505	404	456
No. of − Ns	388	499	447

He further calculated, from the equation for M, the values of m/ρ, or one of the angular components of the *motus peculiaris* of each star, drawn perpendicular to the great circle from the antiapex. The distribution of the errors shewed that if, in the determination

[1] Verdeeling der kosmische snelheden.—Verslagen der Afd. Natuurk. Dl. 6, 29 Mei, '97 – 23 Apr. '98, pp. 51 – 60.

[2] Ueber die Vertheilung der *motus peculiares* der Sterne.—Astr. Nach., Bd. CXLIV., pp. 289-300, 1897.

of the direction of the sun's motion, we rigidly adhere to the condition that the sum of the squares of the errors shall be a minimum, we have to take for granted that among the stars, the majority possesses a motion opposed to the solar motion, which, in the observed motions, is combined with the parallactic. There is a considerable number of stars whose motion, while similarly directed to that of the sun, is conspicuously greater in amount. These however, are not arbitrarily distributed. If a plane be drawn through the axis of the point (b) and perpendicular to the plane of the Milky-Way, one of the two hemispheres so formed is rich in stars of this character, while the other is poor. Evidently this is a peculiarity demanding further investigation.

(115) *Kapteyn, 1897 (Oct.)*—In Oct. 1897 Kapteyn discussed the velocity of the solar motion, and that of stellar motions, in space.[1] The results will be found hereinafter: see 1898.

(116) *Newcomb, 1897.*—Newcomb[2] in his American Ephemeris paper on the precessional constant, stated that Struve's result corrected to the recent fundamental positions, becomes instead of

$$\text{R.A.} = 273\cdot^\circ 4, \quad \text{D.} = +27\cdot^\circ 3,$$
$$273\cdot 4 \qquad\qquad 34\cdot 9.$$

Referring to Boss' general result previously quoted, and regarding

$$\text{R.A.} = 279\cdot^\circ 5, \quad \text{D.} = +38\cdot^\circ 7$$

as the most probable value of the apex of the solar motion deduced from Stumpe's data, he concluded that the direction which most probably represented the actual solar motion was

$$\text{R.A.} = 277\cdot^\circ 5, \quad \text{D.} = +38\cdot^\circ 0.$$

In section xx., the elimination of the parallactic motion from the precession of each star is discussed, the distance (?) factors to produce uniformity in the mean result being related to the magnitudes. These are given in the next reference herein to Newcomb's work.

[1] De snelheid, waarmede het zonnestelsel zich verplaatst in de ruimte, en de gemiddele parallax der sterren van verschillende grootte.—Verslagen der Afdeeling Natuurk., Dl. 6, 1897-8, pp. 238 – 244.

[2] Astronomical papers prepared for the use of the American Ephemeris and Nautical Almanac, Vol. VIII., Part i., The Precessional Constant.—Washington, 1897, pp. 1 – 76.

(117) *Newcomb, 1897 (June)*—The question of the relation of distance to magnitude, using the solar motion as a gauge, is further examined by Newcomb in his paper on the precessional constant in No. 405 of the Astronomical Journal.[1] His result, taking unity for the distance of fifth magnitude stars, the factors to make the parallactic motion uniform were found to be[2]

Mag.	1 – 2	3	4	5	6	7
Factor	0·4	0·6	0·8	1·0	1·2	1·4

As stated in the preceding article Newcomb adopted 18½ hrs. as the R.A. of the solar apex.[3]

It is pointed out in a later paper by Boss that the coördinates deduced by Newcomb for the components of the solar motion give[4]

$$\text{R.A.} = 274\cdot{}^\circ 2, \quad \text{D.} = +31\cdot{}^\circ 2$$

Of these coördinates however, Newcomb says:—"it must be remembered that they are derived from stars of small proper motion, which are not the best adapted to the special determination of the solar motion."[5]

(118) *Boss, 1897 (Aug.)*—In discussing Newcomb's value for the precessional constant,[6] Boss pointed out that his, Newcomb's, result for the coördinates of the solar motion determined the direction just given. This position however, he remarks, is at variance with that deduced from more elaborate discussions.[7]

(119) *D'Auria, 1897 (Oct.)*—D'Auria stated that an easy solution of the problem of stellar dynamics can be reached, provided the interstellar aether be assumed to be ponderable.[8] The whole article proposes to demonstrate that the revolution of the stars about the "centre of the universe," conceived to be finite, takes place in the same time, viz., a little over 14 millions years. This period he represents by the equation

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[1] A new determination of the precessional motion.—Astr. Journ. Vol. xvii., (No. 405) pp. 161 – 167, 1897. [2] *Loc. cit.*, p. 163. [3] *Loc. cit.*, p. 164.
[4] See Boss 1897 hereinafter. [5] *Loc. cit.*, p. 163.
[6] Note on Professor Newcomb's determination of the Constant of Precession and on the Paris Conference of 1896.—Astr Journ. Vol. xviii., (No. 410) pp. 9 – 12. [7] *Loc. cit.*, p. 10.
[8] Stellar Dynamics.—Journ. Franklin Inst., Vol. cxliv., pp. 306 – 312, 1897.

$$T = \pi \sqrt{\{(\text{Rad. Earth} \times \text{Density Earth}) / (\text{Accel. Gravity} \times \text{Density Aether})\}}$$

(120) *Bakhuyzen, 1897 (Dec.)*—The question of the distribution of stars in space, is a fundamentally important question in complete methods of determining the solar motion: recognising this, Van de Sande Bakhuyzen[1] in 1898 undertook the investigation of the number of proper motions to be expected within definite limits, assuming any definite elements for the sun's motion, He adopted Ludwig Struve's values for the year 1875, viz.,

R.A. = 276°, D. = + 34°.

His fundamental hypotheses are (*a*) that the *motus peculiares* of the stars vary between very wide limits, and spatially are distributed accidentally, *i.e.*, both in respect of quantity and direction: (*b*) that the proportion of stars with *motus peculiares* lying between any definite limits, and included between the surfaces of concentric spheres, is independent of their radii: and (*c*) that the mean velocity in such a case is also independent of the radii. 2,683 stars were found to be distributed substantially as required by the hypothesis.

(121) *Boss, 1898 (Jan.)*—Boss[2]—in a further discussion on Newcomb's value for the precessional constant, roughly revising Ristenpart's equations, allowing for Becker's personal equation for star magnitude, adjusting to the system of the principal stars of the American Ephemeris, and so combining the equations that the solar-apex coördinates shall depend upon 454 stars having apparent proper motion greater than 0·″1, while the correction to the Struve-Peters ψ shall be derived from the remaining 4,565 stars—found for the apex of solar motion, the value

R.A. = 295·°4, D. = + 39·°0

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[1] Opmerkingen over de verdeeling der sterren in de ruimte.—Verslagen d. Afd. Natuurk. Dl 6, 1897-8, pp. 394 - 404. See also Astr. Nach., Bd. CXLVI., pp. 209 - 220, 1898, in which to the title is added, "nach der Grösse der Eigenbewegungen."

[2] The Paris Conference and the precessional motion.—Astr. Journ., Vol. XVIII., (No. 423) pp. 113 - 118, 1898. [3] *Loc. cit.*, p. 117.

(122) *Kapteyn, 1898 (April)*—In April 1898 Kapteyn republished a number of his smaller papers previously referred to, contributed to the Royal Academy of Sciences in Amsterdam, concerning the velocity of the solar and stellar motions in space, in a more developed form in the Astronomische Nachrichten.[1] This last treatise was divided into four heads :—

(*a*) The mean velocity of the stars compared with the velocity in space of the solar-system.
(*b*) The velocity of the solar-system in space.
(*c*) The mean velocity of stars of different magnitudes.
(*d*) The influence of an error in the assumed constant of precession.

In (*a*) Kapteyn developed the fundamental equations of his investigation, and discussed the definitions and assumptions, involved in their application. He criticised the legitimacy of Ristenpart's deduction as to variation of velocity with increase of distance from the sun. Accepting for the position of the apex of solar motion the values for 1875

$$\text{R.A.} = 276°, \ \text{D.} = +34°$$

and dividing the stars according to their photometric magnitude, and also according to their spectral type, for the determination of which Draper's catalogue was used, he obtained the following results :—

No. of Stars.		Phot. Mag.	Spectr. type.	$[n]/V$	
60	285	0 – 3·5	II.	1·17	1·35
72		0 – 3·5	I. and unknown	0·78	
153		3·6 – 4·5	II.	1·69	
335		4·6 – 5·5	II.	2·04	
488		5·6 – 6·5	II.	1·30	
162		3·6 – 4·5	I. and unknown	1·36	
254		6·6 – 7·5	all	1·95	
356		4·6 – 5·5	I. and unknown	1·41	
705		5·6 – 6·5	I. and unknown	1·48	
Total 2,585			Mean	1·51	

[1] Die mittlere Geschwindigkeit der Sterne, die Quantität der Sonnenbewegung und die mittlere Parallaxe der Sterne von verschiedener Grösse. —Astr. Nach., Bd. CXLVI., pp. 97 – 114, 1898.

$[n]$ denoting the arithmetical mean of the components of the star's absolute velocities, taken at right angles to the line of sight, and V the absolute velocity of the sun's motion in space; so that $[n]/V$ denotes the *ratio* of the former to the latter. Kapteyn concluded that no change of velocity with increase of distance from the sun is indicated by this result. The stars were next divided into two series, all the stars of spectral type II. being put into one, and the remaining ones into the other. These two series were again subdivided into ten groups, containing in each group an equal number, in the following manner, viz:—The stars were divided into sub-groups according to the value of the angle formed between the direction of the stars "total proper motion" and the great circle through the antiapex, these angles being 0° to ± 9°, ± 10° to ± 19° and so on, closing with ± 170° to ± 180°. These greater groups (1) contained the series of stars of the least proper motion throughout the sub-groups, the second group (2) those of the next greater value, and so on to the last, *i.e.*, (10), which contains the stars of greatest proper motion. The result was as follows :—

	Spectral Type II.		Other Stars.	
Group.	No. of Stars.	$[n]/V$	No. of Stars.	$[n]/V$
1	103	1·37	139	1·58
2	103	1·30	140	1·38
3	104	1·59	139	1·42
4	103	1·50	139	1·31
5	103	1·36	139	1·41
6	103	1·44	140	1·52
7	103	1·52	139	1·44
8	103	1·62	140	1·40
9	103	1·69	139	1·43
10	105	1·55	140	1·40
Total	1,033	1·494	1,394	1·429

This shews no distinct evidence of a progression of the ratio, with magnitude of proper motion ; and the inclusion of other stars not embraced in the above result did not vary this result. The finally deduced motions were

$[n] = 1{\cdot}46\ V$ Mean velocity perpendicular to line of sight.

$[s] = 1{\cdot}86\ V$ Mean actual linear velocity.

$[t] = 0{\cdot}93\ V$ Mean velocity (considered as positive) in line of sight.

In (*b*), Kapteyn attempted to determine the value of the unit V: using the 51 stars of Kempf's 1892 determination and the value above mentioned for the direction of the apex, he obtained instead of Kempf's result previously quoted,

$$V = 12{\cdot}3 \pm 3{\cdot}0 \text{ kilometres per second:}$$

varying the weights however, and solving by the method of least squares, this was altered to

$$V = 10{\cdot}7 \pm 3{\cdot}1 \text{ kilometres per second.}$$

After a further discussion, as to the inclusion and treatment of certain star-groups, and also upon the weight of the results, Kapteyn submitted as the most probable values—

Solar velocity	$V = 16{\cdot}7$ kilometres per second	$= 3{\cdot}53$ E	annually
Mean stellar vel.	$[s] = 31{\cdot}1$,, ,,	$= 6{\cdot}57$ E	,,

E denoting the mean distance from the sun from the earth.

With respect to (*c*), Kapteyn's investigation appeared to shew that the average parallax (π) of a star of the photometric magnitude (m) can be expressed by the equation—

$$\pi_m = k^m \pi_0,$$

and if k be taken as equal to $1/\sqrt{2}$, or ·7071, then π_0 will have the following numerical values, viz.,

For spectral type I.	$\pi_0 =$	0·″063
,, ,, II.	,,	0·143
Or for all stars	,,	0·106.

In regard to (*d*) Kapteyn concluded that any error resulting from defect in the precession constant will not prejudice the results obtained more than about two per cent.

(123) *Newcomb, 1899 (March)*—Newcomb further examined the question of the quantity and direction of the solar motion, in the March number of the Astronomical Journal for 1899.[1] In the first part of his paper he considered "the absolute speed of the solar motion derived from the observed parallax of stars." Using for the coördinates of the solar apex the values

[1] Some points relating to the Solar motion and the mean parallax of stars of different orders of magnitude.—Astr. Journ., Vol. xx., (No. 457) pp. 1 - 6, 1899.

R.A. = 277·°5, D. = +38·°0

and employing the proper motions of 72 stars of known parallaxes, he obtained by one method, assigning different weights to the different stars

$$V = 5{\cdot}85 \text{ E.}$$

V denoting the velocity per annum, and E the mean radius of the earth's orbit. Assuming that the result is influenced overmuch by stars of large parallax, he made a second calculation, obtaining the result

$$V = 7{\cdot}2 \text{ E.}$$

A third computation, in which three stars, giving very great values for V, were excluded, reduced this however to

V = 6·4 E, say 30 kilometres per second.

Again taking the mean result of 22 bright stars it was found that

V = 3·5 E = 16·5 kilometres per second;

which agrees with Kapteyn's conclusions from motions in the line of sight.

Sixteen stars whose annual motion exceeded 2·″6, and Arcturus, were used to determine the solar motion, giving

R.A. = 276·°3, D = +41·3, R″ = 3·″15

R″ being the parallactic motion in terms of the mean distance of the group.

The second part of the paper is on "The most likely position of the Solar Apex." Employing the method given in his Astronomical Papers, Vol. VIII., part i., Newcomb deduced the apex of solar motion as follows:—

Stars of small proper motion.

Mag.	No. of Stars.	Weight.	R.A.	D.	R‴
1 – 2·9	64	1	263·°1	31·°7	6·59
3·0 – 3·9	135	2	262·7	26·8	5·61
4·0 – 4·9	327	5	266·5	31·8	3·47
5·0 – 5·9	731	11	268·5	32·0	3·14
6·0 – 6·9	1034	16	277·4	30·6	2·81
7·0 +	236	4	278·2	33·6	2·86
Total	2527	Mean	272·5	31·3	

Stars of large proper motion.

	No. of Stars.	Weight.	R.A.	D.	R‴
All magnitudes	644	10	276·°9	31·°4	?

R‴ here denotes centennial ? parallactic motion, at the mean distance of the group.

In these six results, if we accept Kapteyn's parallax-magnitude theory, see (122) above, adopt the constant 0·″106, and also the mean magnitudes 2, $3\frac{1}{2}$, $4\frac{1}{2}$, $5\frac{1}{2}$, $6\frac{1}{2}$, $7\frac{1}{2}$, which are probably sufficiently near the actual means,—not given by Newcomb—the resulting velocities will be respectively 3·6, 5·2, 4·6, 5·9, 7·7, 10·7, miles per second.

Pointing out that Stumpe's mean positions, weighted according to the number of stars, when classed by proper motions, and by magnitudes were respectively

R.A. = 281·°8, D. = + 40·°7
283·1 38·7

and that Boss' declination would, by correction to the new standard be D. = + 42·°9 instead of 44·°1, Newcomb gives the following table of results :—

Authority.	No. of Stars.	R.A.	D.
Newcomb from Bradley's stars, small P.M.	2,527	272·°5	31·°3
,, ,, large P.M.	644	276·9	31·4
Stumpe, mean two preceding results	995	282·4	39·7
Boss, stars of Albany Zone	279	283·3	42·9

from which he concludes that the most probable position is

R.A. = 277·°5, D. = + 35·°0, V. = 3·5 E.

V denoting the velocity per annum, and E the mean radius of the earth's orbit.

The third and fourth parts of the paper are respectively the "Parallactic motion of the fainter stars"—giving 0·″0039 for stars of magnitude 8·5—and "The mean parallax of the Vogel stars." The paper closes with the fifth part, "Summary of Conclusions." Kapteyn's speed of V = 3·5 E, and parallax formula $\pi_m = k^m \pi_o$ with the constants previously given, are, Newcomb thinks, probably near the truth: the latter at least as far as the ninth magnitude.

(124) *Kobold, 1899 (Sept.)*—In 1899 Kobold returned to the problem of determining the solar motion by the Besselian method,[1] discussing very fully the distribution over the surface of the celestial sphere of the differences between the purely parallactic motion, and the observed motion of the star, $(\phi - \psi)$. Using a still larger number of stars, and as before dividing them into classes according to the magnitude of their proper motions, he obtained the following results:—

Proper Motion.	No. of Stars.	R.A.	D.	dp	
> 1″·6	13	271°·7	+10°·4	0″·9931	Epoch 1810·0
1·6 to 0·8	23	267·5	+3·7	− ·0425	
0·8 „ 0·4	85	267·3	−1·7	+ ·0055	
0·4 „ 0·2	242	269·7	−1·7	− ·0007	
0·2 „ 0·1	542	270·1	+0·1	+ ·0034	
≧ 0·1	Total 905	269·6	−0·4	+ ·0034	

Again, taking all stars with proper motions ranging from 0·″02 to 0·″1, and dividing them into two series, the results were

Proper Motion.	No. of Stars.	R.A.	D.	dp	
0·1 to 0·05	583	267·6	−3·9	+0·0045	Epoch 1810·0
0·05 „ 0·02	774	270·8	−3·0	−0·0048	
0·1 to 0·02 Total	1357	269·6	−3·3	−0·0031	

These gave for the mean result from a total of 2,262 stars

Proper Motion.	No. of Stars.	R.A.	D.	dp	Epoch
≧ 0·02	2,262	269·°6	−2·°3	−0·″002	1810·0

Kobold pointed out that the mean error of the observed directions is not greater for stars of small than for those of large proper motion, a point which, he affirms, demands peculiar attention. The effect of an error in the precession-constant was shewn to be negligible, and also that one must conclude either that the influence of the *motus peculiares* becomes less as the proper motions become

[1] Die Constante der Praecession und die Bewegung des Sonnensystems untersucht auf Grundlage der Methode von Bessel.—Astr. Nach., Bd. CL., pp. 257–296, 1899.

smaller, or that the error found is a systematic and not an accidental error of the proper motions, as later on he demonstrates to be the case. With a view to deciding this question, the 905 stars of greater proper motion were divided into two series; the division and results being as follows :—

	No. of Stars.	R.A.	D.	dp	
Bradley's	747	268·°1	− 0·°8	+ 0·″0013	Epoch
Southern	158	271·0	+ 2·3	− ·0135	1810·0

A further division was made, with the following result :—

	No. of Stars.	R.A.	D.	dp
Bradley's, north of + 23·2 decl.	309	269·°5	+ 1·°2	+ 0·″0058
" + 23·°2 to − 23·°2 decl.	416	265·7	− 1·5	+ ·0122
Southern stars	158	271·0	+ 2·3	− 0·135
				Epoch 1810·0

These deductions for the direction of the solar motion are practically identical, or at least shew no systematic difference.

Continuing the analysis, the surface of the sphere was divided into equal areas by hour-circle quadrants, and as before by parallels of declination (0°, 11·°3, 23·°2, 36·°2, 51·°9 and 79·°6, referred to in the 1897 paper). It was shewn that the solution by the method of least squares led to the values

$$\text{R.A.} = 269{\cdot}^\circ 8, \quad \text{D.} = +16{\cdot}^\circ 5, \quad dp - 0{\cdot}''0381$$

dp denoting a correction to the precession-constant, that is, it led to a result approximating to the position of the apex obtained with the usual assumptions; and, in reference to the precession-constant, one in agreement with the recent investigations of various authors who have followed Airy's method. The strict solution gave however

$$\text{R.A.} = 270{\cdot}^\circ 6, \quad \text{D.} = +0{\cdot}^\circ 1, \quad dp = -0{\cdot}''0028$$

a solution substantially identical with that previously obtained from the 905 stars. Kobold argued that the comparison of these results significantly shews that we have not to do with mere accidental errors, but with systematically occurring differences of motion, thus with the uniformly acting *motus parallacticus.*

A very complete discussion, and a further exhaustive analysis, and solution that apparently leaves nothing to be desired, furnishes as the best value of the apex of solar motion, determined by the Besselian method,

R.A. = 270·°4, D. = − 0·°2, dp = − 0·″0013, Epoch 1810·0

a value which is independent of all assumptions as to stellar distances, and one from which, as far as possible, the systematic character of the *motus peculiares* of the stars has been eliminated. It ought to be said that it is quite impossible in the compass of a necessarily short reference to give anything like an adequate presentation of the comprehensive and masterly way in which the question has been discussed by Kobold.

(125) *Backhouse, 1899 (Nov.)*—Referring to Newcomb's determination of solar motion, Backhouse remarked that the point regarded as fixed, and to which the motion is referred should be defined.[1]

(125A) *Veenstra, 1899 (Nov.)*—Since going to press, two papers on the solar motion are to hand in the translated Proceedings of Science Section of the Royal Academy of Amsterdam, Vol. II., published July 1900. The first is by Veenstra.[2] Using an unpublished catalogue, prepared by Kapteyn, of the Bradley stars, and applying systematic corrections, Veenstra obtains the following results, in which the first results are from proper motions less than 0·″3; and the last one is from 151 stars of proper motion greater than that amount.

Spectral Type.	No. of Stars.	R.A.	D.	
I.	965 ?	268·°3	+ 36·7	
II.	965 ?	272·1	37 6	
III.	710 ?	273·5	33·9	
IV.	710 ?	270·6	34·3	Epoch 1900 ?
I. and II.	1675 ?	269·5	34·3	
I. and II.	1675 ?	274·2	35·1	
P.M. > 0·″3	151	262·4	42·2	

[1] The solar motion.—The Observatory, Vol. XXII., pp. 395-6, 1899.

[2] On the systematic corrections of the proper motions of the stars contained in the Auwers-Bradley catalogue, and the coordinates of the solar motion in space.—Translated Proc. Roy. Acad., Amsterdam, Vol. II., pp. 262 – 267, 1900.

In these, the former of each pair is from proper motion in declination alone, the latter from the proper motions in declination and right ascension. These results have not been plotted on the illustrative figures, viz. 1 and 1 (*a*).

(126) *Newcomb, 1899 (Dec.)*—Newcomb replied that the definition is tedious, but the point referred to by Backhouse and its definition is well understood.[1]

126A) *Kapteyn, 1900 (Jan.)*—The second paper is by Kapteyn, discussing critically the solutions by Airy, Argelander, and Kobold, and shewing the equations of each type of solution or modification thereof.[2] Kapteyn clearly expounds the hypotheses on which these proceed, and shews how far the solutions are in agreement therewith. His conclusion is that what must perhaps more than anything else, hinder us from accepting the methods so far used for the derivation of the solar motion is, that quantities treated as small are in reality *not* so.

(127) *Yowell, 1900 (March)*—Yowell[3] taking 86 fundamental stars from the Berliner Jahrbuch, whose proper motions were greater than $0''.2$ and less than $0''.5$ per annum, found that

$$\text{R.A.} = 284^\circ.1, \quad \text{D.} = +34^\circ.1$$

He stated that if, employing Kobold's method, he had adopted as a first approximation, the values 270° and 0°, he would have obtained a very small correction, less than $0^\circ.1$ each way, and similarly if he had adopted 284° and 34°. He concluded that Kobold's method gives simply small corrections to *any* assumed position for the apex, and leaves its real position indeterminate.

(128) *Kobold, 1900 (April)*—Replying to Yowell's assertion that Kobold's method of indirect solution will furnish only small corrections whatever the assumed place of the solar motion, he,

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[1] *Ibid.*, p. 443.

[2] The determination of the apex of the solar motion.—Translated Proc. Roy. Acad. Amsterdam, Vol. II., pp. 353–374.

[3] Note on a new method of determining the solar-apex.—Astr. Journ., Vol. XX., No. 479, p. 187.

Kobold, furnishes an example with 43 stars of class II.[1] These gave by direct solution the result

$$R.A. = 264°{\cdot}3, \quad D. = -3°{\cdot}5$$

Starting with R.A. = 270° D. = +30° as assumed values, the first approximation led to

$$R.A. = 267{\cdot}°1, \quad D. + 11{\cdot}°2$$

Again proceeding with R.A. = 270° and D. = +11·°2 as the assumed values, the result for second approximation was

$$R.A. = 267{\cdot}°1, \quad D. = +2{\cdot}°7$$

from which Kobold concluded that doubtless the differential formula leads finally to the same point as is obtained by the direct solution. Whatever the explanation of the peculiar result obtained by Yowell, the one which he offers is certainly not correct.

Additional Memoirs, etc.

The following memoirs and results were overlooked when compiling, in proper historical sequence, the work of the various investigators. They have advisedly been numbered so as to fall in their proper place according to the general plan. It has not, however, been possible to interpolate them. In the tabulated results hereinafter given, each appears in its proper place.

(4A) *Jacques Cassini, 1738.*—On the 12th November, 1738, J. Cassini submitted a memoir to the French Academy of Sciences, on the variations observed in the situation and motion of several fixed stars,[2] including those mentioned by Halley.

(10A) *Bailly, J. S., 1775.*—In his history of modern astronomy Bailly, like Michell, also considered the question of the possibility of solar motion.[3]

(64A) *Gyldén, 1871.*—In Oct. 1871, Gyldén determined the right ascension of the direction of solar motion from four groups

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[1] Bemerkungen zu dem Artikel: Note on a new method of determining the solar apex, by E. I. Yowell, in Astr. Journ. Nr. 479. Astr. Nach., Bd. CLII., pp. 279 – 280.

[2] Histoire de l'Acad. roy. des Sciences, Paris 1738, p. 331.

[3] Histoire de l'Astronomie moderne, Paris 1775 – 1783, t. II., p. 662 *et seq.*

of stars,[1] the results being as follows :—

Group	(*a*)	(*b*)	(*c*)	(*d*)	Mean
R.A. =	268·°4	270·°9	270·°9	286·°2	274·°1

Epoch 1800?

(70A) *Gyldén, 1877.*—In his 'Elements of Astronomy,' Gyldén gives for the R.A. of the direction of the sun's motion.[2]

R.A. = 260·°5. Epoch 1800.

(84A) *Ubaghs, 1887.*—In February 1887 Ubaghs discussed more fully the velocity of the solar motion. From a group of 34 near stars the result was practically zero, while from a larger group of 163 it amounted only to 0·05 of the radius of the terrestrial orbit, *i.e.*, say 0·15 miles per second.[3]

(85A) *Eastman, 1889.*—The general trend of the investigation of the solar motion was the subject of a presidential address by Eastman to the Philosophical Society of Washington in December 1889.[4] He discusses somewhat fully the intrinsic difficulties of the problem, gives a sketch of the history of the inquiry, and a list of some of the results of previous investigators. Using the known parallaxes of 46 stars, arranging them in groups of nine according to the magnitudes of their proper motions, he obtained the following results :—

No. of Stars.	Mean Mag.	Mean P.M.	Parallax.
9	5·57	4·93	0·″32
9	5·59	2·33	0·20
9	3·37	1·04	0·20
9	2·36	·38	0·16
10	2·84	·06	0·13

from which, so far as the evidence goes, it appears that the fainter, rather than the brighter stars are nearest our system! This

[1] Antydningar om lagbundenhet i stjernornas rörelser.—Oefversigt kon. Vetens. Akad. Förhandl., 1871. Årg. xxviii., pp. 947–960.

[2] Grundlehren der Astronomie, Leipzig, 1877, p. 388. Quoted by Eastman, see (85A).

[3] Détermination de la direction et de la vitesse du translation du système solaire dans l'espace.—Bull. l'Acad. Roy. Belg. 3me sér. t. xiii., pp. 66–68, 1887.

[4] Solar and stellar proper motions.—Bull. Phil. Soc., Washington, Vol. xi., pp. 143–171, 1888–1891.

sufficiently shews how precarious are the deductions of distance from magnitude.

(94A) *Bakhuyzen, 1892.*—In December 1892 Bakhuyzen deduced the direction of the solar motion from all stars in the Auwers-Bradley catalogue within 50° of the pole of the Milky Way, for the plane of which Houzeau's value was accepted.[1] The results for the epoch 1810 ? were

R.A'. = 264·°6; R.A. = 260·°2; D. = + 39·°5

From the whole of the proper motions

R.A. = 263°, D. = + 32°.

Quoting L. Struve's results, Bakhuyzen gives finally

R.A. = 266·°7; D. = + 31°0.

103A) *Pannekoek, 1895.*—In the June number of Nature, 1895, a discussion of the motion of the solar system by Pannekoek is referred to.[2] The deduction is made from stars of declination between 0° and 20°, divided into two groups according to their spectral type, and into sub-groups according to the magnitude of their proper motions. The results are as follows:—

Sub-group.	No. of Stars.	P.M.	R.A.	D.
		Spectral Type I.		
I.	203	·02	322°·8	+ 14°·7
II.	93	·06	304·7	12·1
III.	58	·10	275·8	18·3
IV.	48	·34	251·6	33·0
		Spectral Type II.		
I.	77	·02	274·6	− 2·6
II.	52	·06	280·1	+ 35·8
III.	65	·21	268·6	31·4

The spectra were from the Potsdam observations.

(105A) *Tisserand, 1895 (Sept.)*—In the Bulletin Astronomique of September 1895, Tisserand discusses the determination of the

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[1] De vraag of de bewegung van het zonnestelsel ten opzichte van de sterren binnen den melkweg dezelfde is als die voor de sterren daarbuiten. —Versl. d. Afd. Natuurk., 1892-3, pp. 92-93.

[2] Nature, Vol. LII., 1895, p. 135.

proper motion of the sun from that of the stars, and shews that the evidence of its reality is very cogent.[1]

(129) *Defects in Bibliography of subject.*—Although no known accessible source of information has been neglected, it has not been possible to make the bibliographical record here attempted —extensive as it is—complete. It is very likely that some discussions of the precessional constant, containing investigations of the solar motion, may have been overlooked, despite the care taken in regard thereto. As an exhaustive determination of this constant, demands the eliminination of the *motus parallacticus* from the proper motion of each star, so that the *motus peculiares*, affecting as they do the value of the constant, may be determined in accordance with the law of probability, particular attention has been paid to all memoirs treating of precession. In some instances I have been unable, however, to obtain copies of the memoir, *e.g.* Dreyer's, "New determination of the constant of precession."[2] Radau's[3] and Bakhuyzen's[4] articles in the Bulletin Astronomique which also touch on the solar motion, I have likewise failed to obtain. In cases where there was great doubt as to how and when a writer treated of the subject under consideration, I have omitted all reference to him. For example, Villarceau states that Brünnow treats of the theory of aberration, taking account of motion of the solar system. Whether this however was in the earliest edition of his spherical astronomy[5] or not, I cannot ascertain.

Works treating of the solar motion, of the same type as August Tischner's "Die Richtung der Sonnebewegung," Giralomo Marzocchi's "Il sole e l'universo," and William Sandeman's "The Path of the Sun . . . with an exposure of the fallacy of the precession of the equinoxes," I have not troubled to note, for reasons which hardly need explanation.

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[1] See also, Nature, Vol. LII., p. 487, 1895.

[2] Proc. Roy. Irish Acad., 3, 1883, pp. 617 - 623 and Copernicus, 2, 1882, pp. 135 – 155.

[3] *Op. cit.*, t. X., p. 407. [4] *Ibid.*, t. XII., p. 97.

[5] Lehrbuch der sphärischen Astronomie, Berlin, 1851, 8vo.

(130) *References in Popular Science Journals.*—In general no trouble has been taken in regard to references to the subject of solar motion in popular science journals: the following brief lists however contain such references as I have noted in "Nature" and "The English Mechanic."

"Nature."

Year	Name.	Vol.	Page.	Year.	Name,	Vol.	Page.
1884	Plummer	29	246	1890	Boss	41	548
1885	Groth	31	215-6	1890	Stumpe	43	90
1886	Homann	33	450-1	1891	„ Clerke	44	572-4
1886	Kövesligethy	34	131	1892	Porter	47	41
1886	Ubaghs	34	158	1893	Risteen	48	208-9
1887	Ubaghs	36	45	1893	Bakhuyzen	48	401-2
1890	Eastman	41	351	1895	Pannekoek	52	135

"English Mechanic."

Year.	Vol.	Page.	Year.	Vol.	Page.	Year.	Vol.	Page.
1866	2	371	1871	12	444	1885	41	562
„	„	389	1871	14	25	1891	54	175
1867	5	43	1871	14	49	1897	65	528
1871	12	417	1880	31	5			

(131) *Tabulated Results.*—In order that the whole biliography of the subject, and the results obtained by the various investigators may be readily examined, a synopsis has been given in Tables I. and II., the former containing the literature preceding the first numerical estimate of the direction of the motion, the latter the literature from that first estimate onwards. In order that these results may be immediately comparable, it was necessary that they should be reduced to a common epoch. For this purpose the date 1900·0 was selected, and each value has been corrected to that date. It has not always been possible to ascertain with certainty the date for which the values are assigned in the different estimates: the difficulty has occurred to every one who has considered the matter, and is a fact is to be regretted. The uncertainty is indicated by a query mark. In order to facilitate the reduction, Table III. was prepared, which gives the precessional

differences in declination and right ascension for the period 1800 – 1900 approximately. In the computations no especial care was taken to ensure accuracy to the nearest tenth of a degreee, since the real uncertainty runs into degrees. The basis of Table III. is, α denoting right ascension, δ declination, in which N = +, S = –, and t is the period in years,

$$\Delta\alpha/\Delta t = 0\cdot{}^\circ 0128 + 0\cdot{}^\circ 00557 \sin\alpha \tan\delta$$
$$\Delta\delta/\Delta t = 0\cdot{}^\circ 00557 \cos\alpha.$$

In each case the nearest star to any determination of the solar-apex has been given: in most cases its coördinates have been taken from the Auwers-Bradley catalogue, and reduced from the epoch of that catalogue 1810 to 1900 for precession merely, the small correction for proper motion being neglected.

These resulting positions for the epoch 1900, for the solar-apex and for the nearest stars, have in each case been plotted in the illustrative figures. In the projection employed the celestial equator and the 240° circle of right ascension have been uniformly divided. The radii of the circles of declination are determined on the polyconic system. The arcs of right ascension are circular, the centres lying on the equator and so determined that the intercepted arcs on the parallel of 60° declination shall be one half of those at the equator. For mere diagrammatic purposes the distortion is not serious.

Conclusion.

(132) In the Ephemeris of the Observatory of Rio de Janeiro for 1900 it is stated that the approximate coördinates for the solar motion are[1]

$$\text{R.A.} = 280^\circ, \ \text{D.} = +40^\circ$$

the point being in the constellation Hercules. It will be manifest however, from the results tabulated in II. and shewn in the illus-

[1] O Sol, centro de attracção dos planetas, não é fixo no espaço. As observações estellares provão que elle se desloca, arrastandando comsigo o systema planetar e dirigendo-se para um ponto denominado *Apex,* situado na constellaçao de Hercules, e cujas coordendas approximadas são:— R.A. = 280°, D. = 40°.—Annuario de 1900, p. 104.

trative figure, that this statement is ill-founded. Neither the direction nor the quantity of the solar motion has yet been ascertained to a high order of precision, nor has the best method of determination been established beyond dispute. The general mean of the whole of the results, would indicate a point approximately having the coördinates, and velocity,

R.A. = 270·5, D. = + 23·9, V. = 15·3, miles = 24 6 kilometres.

The question as to the value of this result, turns however upon the decision as to whether the Besselian, or Argelanderian or Airy method should be followed, and to some extent upon the definition of what is meant by the solar motion in space. This it is not proposed here to inquire into. It will suffice to say that, *per se*, a mere mean has no strong claim to acceptance. In the absence however of decisive evidence that a particular solution should be adopted, such a mean can be taken as affording on the whole a very probable value.

In conclusion, I desire to express my appreciation of the very kind way in which the astronomical literature of the Sydney Observatory has been placed at my disposal by the Government Astronomer, Mr. H. C. Russell, B.A., C.M.G., F.R.S., etc., and my thanks to that gentleman for his kindness and courtesy; also to Mr. J. Tebbutt, F.R.A.S., etc., proprietor of the Observatory at Windsor, for similar kindness and courtesy.

Figures 1 and 1 (*a*), and Tables I., II. and III., will be found in the subsequent pages.

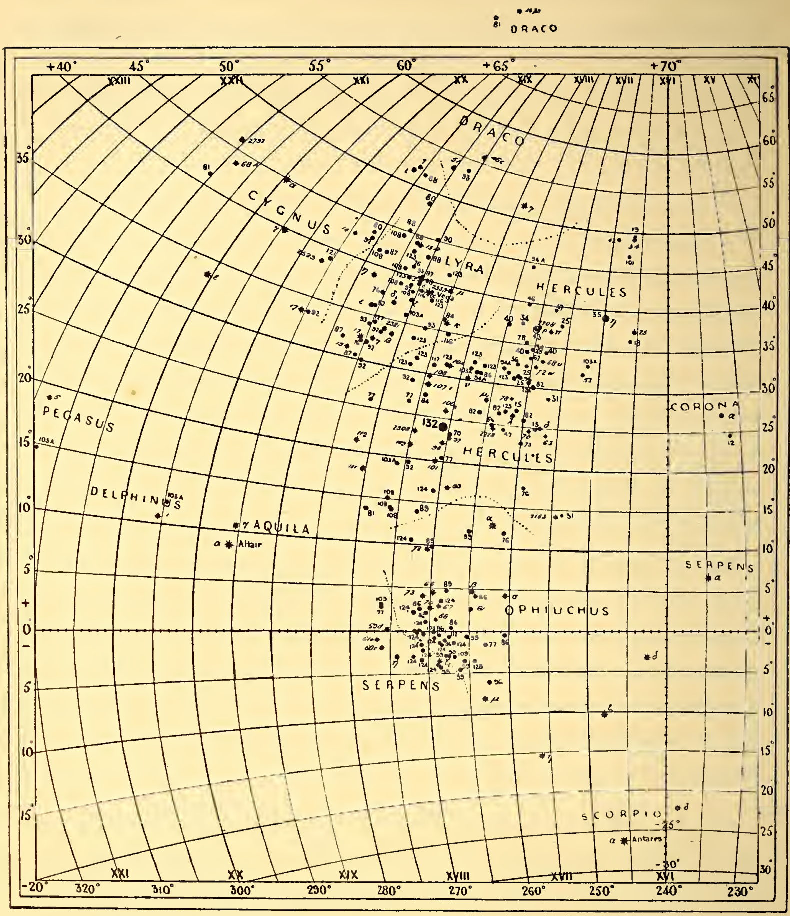

Fig. 1.

Round dots shew the position of the solar apex, reduced to the instant 1900·0.

The reference number corresponding to the paragraph number in the Bibliography and History, is denoted by vertical figures thus:—86.

Mean Result, excluding results (125A), not shewn,

R.A. = 270·°5; D. = + 23·°9; V. = 15·3 miles per second.

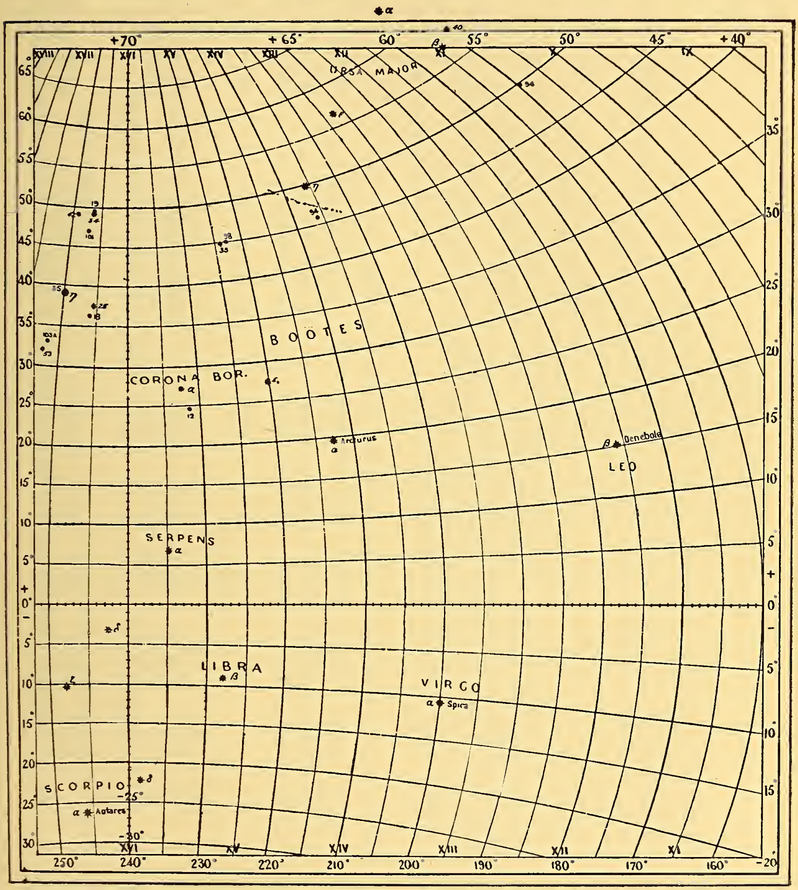

Fig. 1 (*a*).

Stars are denoted by dots with radial lines.

The Greek letters are the star's characteristic letters in the constellation.

The star's number, shewn by sloping figures, corresponds to the number in the Auwers-Bradley Catalogue for 1810·0: thus *2208*.

Mean Result, including results (125A), not shewn,

R.A. = 270·°5; D. = +24·°4; V. = 24·6 kilometres per second.

I.—*Genesis of Idea of Sun's Motion in Space.*

Ref. No.	Date.	Name.	Nature of Contribution to idea of Solar Motion in Space.
1	1584	Bruno	Universe indefinitely extended. Suns and worlds in motion.
2	1645	Schyrleus	Stars probably have proper motion: imperceptible through distance.
3	1686	Fontenelle	Exposition of Copernicus' and DesCartes' theories. Stars may have some proper motion.
4	1717	Halley	Stars have altered their relative positions since Ptolemy's time.
4A	1738	J. Cassini	Variation in situation and motion of several of the stars.
5	1747	Bradley	Discusses how solar and stellar motion can be investigated.
6	1750	Wright	Speculates on general stellar motion. Speculations read by Kant.
7	1755	Kant	Publishes anonymously "General Natural History and Theory of the Heavens."
8	1760	Mayer	Reality of proper motion. Shewn by recent observations of star places.
9	1761	Lambert	Speculates on revolutions of stellar systems about centres.
10	1767	Michell	Sun one of system of stars. Apparent change due to solar or stellar motion or to both [combined.
10A	1775	Bailly	Possibility of solar motion, see his History of Modern Astronomy.
11	1776	Lalande	Theory as to cause of solar motion in space.

II.—*Determination and Discussion of Solar Motion in Space.*

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. ° (1900)	Decl. ° (1900)	Velocity *	Remarks.	R.A. °	Decl. °
12	1781	Prévost	26	1781?	230·	+25·	231·3	+24·6	...	5 *a* Coronae	232·6;	+27·1
13	1783	Herschel ..	54	1783?	257·	25·	258·2	24·8	...	70 Herculis	259·2;	+24·6
14	1786	Du Séjour ...	...	...	?	?	...					
15	1789	Klügel	?	?	260·	27·	261·1	26·9	...	76 λ Herculis	261·7;	+26·2
16	1795	Wurm	...	...	?	?						
17	1805	Prévost & Maurice	39	..	?	?						
18	1805	Biot	8	1805?	245·0	36·4	245·9	36·2	...	25 Herculis	245·5;	+37·6
19	1805	Herschel ...	6	1805?	245·9	49·6	246·6	49·4	..	34 Herculis	246·7;	+49·2
20	1806	Herschel—Estimate of velocity of motion.					...	...	8·4	Parallax Sirius = 0·″39.		
21	1809	Prévost	...	...	?	?						
22	1809	Burkhardt—Formulæ for computing solar motion.								Conn. d. Temps 1809.		
22A	1810?	Gauss	?	1810?	259·2	30·8	260·1	30·7	...	72 w Herculis	259·2;	+32·6
23	1818	Bessel	71	No definite result from this limited number of stars.								

[* English Statute miles per second.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. 1900 °	Decl. 1900 °	Velocity.	Remarks.	R.A. °	Decl. °
24	1821	Olbers	82	...	?	?						
25	1837	Argelander ...	21	1792·5	260·8	+31·3	261·8	+31·2	...	72 w Herculis see 22A.		
,,	,,	,, ...	50	,,	255·2	37·6	256·1	37·5	...	67 π Herculis	257·9;	+36·1
,,	,,	,, ...	319	,,	261·2	31·0	262·2	30·9	...	72 w Herculis see 22A.		
,,	,,	,, ...	390	1800	259 9	32·5	260·8	32·4	...	ditto		
26	1837	F. Struve—Report on Argelander's determination.										
27	1837	Wartmann ...			?	?						
28	1838	Taylor			?	?						
29	1839	Cauchy—Supposed optical effects due to sun's motion in space.										
30	1840	Gruithuisen—Solar motion deducible from apparitions of meteors.										
31	1840	Lundahl ...	147	1792·5	252·4	14·4	253·6	14·2	...	2163 (A.B) Herculis	254·6;	+14·2
,,	,,	,, ...	537	1800	257·9	28·8	256·9	28·7	...	{ 63 Herculis	256·7;	+24·3
32	1841	Wolfers			?	?				{ 65 δ Herculis	257·7;	+25·0
33	1842	Richter			?	?			?			
34	1842	O. Struve ...	392	1792·5	261·4	37·6	262·3	37·5	...	2208 (A.B.) Herculis	260·2;	+37·0
,,	,,	...	669?	,,	259·2	34·6	260·2	34·5	...	ditto		
35	1843	Bravais	62	1843	249·4	39·2	249·9	39·1	5·5[1]	44 η Herculis	249·9;	+39·1
36	1843	Bolzano—Discussion as to existence of a Doppler effect from motion.										
37	1844?	O. Struve & Peters	?	1859	259·7	34·5	260·1	34·5	...	Probably same as 34.		
38	1846	Mädler	η Tauri passive centre of a sidereal system						30·0	η Tauri =	55·4;	+23·8
39	1847	Mitchell... ...			?	?						
40	1847	Galloway ...	81	1790	263·8	37·3	264·7	37·2	...	2208 (A.B.) Herculis see 34.		
,,	,,	,, ...	79	,,	257·1	34·3	258·1	34·2	...	68 u Herculis	258·3;	+33·2
,,	,,	,, ...	78	,,	260·0	34·4	261·0	34·3	...	72 w Herculis see 22.		
41	1847	Encke	...	1837	259·3	34·7	Quotation of Struve's result, evidently: see 34.					
42	1852	Fleury—Suggested experimental method of determining solar motion.										
43	1852	Plana	81	1852	260·2	36·9	260·6	36·9	...	2208 (A.B.) Herculis, see 34.		
44	1853	F. Struve—Results relating to proper motion of the solar system.										
45	1855	Arago—Gives some historical references in Astronomie populaire, t. II.										

[1] Assuming parallax for mean distance of first magnitude star to be 0·″15.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. °	1900 Decl. °	Velocity.	Remarks.	R.A. °	Decl. °
46	1856	Mädler	2163	1800	261·6	+39·9	262·4	+39·8	...	2208 (A.B.) Herculis, see 34.		
47	1859	Airy	113	1800?	256·9	39·5	257·7	39·4	24·9[1]	ditto		
,,	,,	,, ...	,,	(1840?)	261·5	24·7	262·5	24·6	37·6[1]	76 λ Herculis, see 15.		
48	1859	Carrick—The Sun's orbit-plane.										
49	1859	Faye	?	1859	259·7	34·5	260·1	34·5	4·9	O. Struve's result for direction.		
50	1859	Liagre—Some historical references to various determinations, etc.										
51	1859	Gautier—On the latest researches of Mädler respecting the solar motion.										
52	1860	Peters—Discussion of proper motions with respect to Mädler's hypothesis.										
53	1862	Babinet	...	1862	260·	34·5	260·3	34·5	4·6	O. Struve's result for direction.		
54	1863	Carrington—As to evidence of solar motion from non-periodic comets.										
55	1863	A°ngstrom—Optical experiments gave no definite evidence of solar motion.										
56	1863	Dunkin	1167	1800	261·2	32·9	262·1	32·8	6·6[1]	78 Herculis	262·0;	+28·5
,,	,,	,, ...	,,	,,	263·7	25·0	264·7	24·9	8·0[1]	2228 (A.B.) Herculis	264·3;	+24·6
57	1863	Stone—Discusses velocity accepting O. Struve's direction.							?			
58	1864	Reddie—Popular discussion merely.										
59	1864	Babinet—As to whether sun is one component of a double star.										
60	1867	Stone—Evidence of actuality of solar motion.										
61	1868	Hoek—Cometary evidence of solar motion							0·9?	Velocity admittedly doubtful.		
62	1869	Hurst—Quoted	...	1869	257·6	37·2	257·9	36·9	1·1	π Herculis, see 25.		
63	1869	Proctor—Criticism of Hurst merely.										
64	1869	Proctor—As to quantity of motion and distance of each class of stars.										
64A	1871	Gyldén	...	1800?	274·1	...	275·1	...	...	Declination not given.		
65	1872	Flammarion—Études et lectures, t. III.										
66	1872	Villarceau—Solar motion and the constant of aberration.										
67	1873	Doppler, Fizeau, Huggins, Zöllner, etc. Velocity in line of sight.										
68	1875	Villarceau—Solar motion and the constant of aberration.										
69	1876	Maxwell-Hall ...	?	1850	259·8	33·6	260·3	33·6	29·3	72 w Herculis, see 22A.		
70	1877	Leo de Ball ...	67	1860	269·0	23·2	269·4	23·2	...			
70A	1877	Gyldén	...	1800	260·5	...	261·5	...	...	Declination not given.		

[1] Assuming parallax for mean distance of first magnitude star to be 0″·15.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. °	1900 Decl. °	Velocity.	Remarks.	R.A. °	Decl. °
71	1878	Preston—As to cause of sun's motion in space.										
72	1878	Klinkerfues ...	4	?	272·5	+32·4	Divergence point for Vega, Capella, Sirius, Fomalhaut.					
73	1878	Maxwell-Hall—Further consideration of sun as member of a sidereal system.										
74	1879	Clerk-Maxwell—As to determining solar motion from evidence in solar system.										
75	1880	Lagrange—Article in 'Ciel et Terre.'										
75A	1882	Schönfeld—Introduces term representing rotation in plane of Galaxy.										
76	1882	Rancken ...	250	1855?	285·0 284·6	37·5	285·2	37·6	31·9	19 Lyræ	287·0;	+31·1
„	„	„ ...	80	„	273·8 244·1	17·5	259·0	17·5	13·5	73 Herculis	260·0;	+23·1
„	„	„ ...	250	„	275·3 288·5	41·0	282·3	41·1	31·2	13 R Lyræ	283·1;	+43·8
„	„	„ ...	80	„	281·0 240·4	11·9	261·2	11·9	23·1	55 *a* Ophiuchi	262·3;	+12·6
„	„	„ ...	106	„	294·5 275·8	31·9	285·6	32·0	28·8	17 Lyræ	285·9;	+32·3
77	1883	Plummer ...	81	1880	276·0	2·7	276·3	2·7	28·9[1]	59 d Serpentis	275·5;	+0·1
„	„	„ ...	„	„	262·7	−1·5	263·0	−1·5	14·2[1]	61 Ophiuchi	264·9;	+2·6
„	„	„ ...	274	„	281·3	+25·8	281·5	+25·8	15·2[1]	112 Herculis	282·0;	+21·3
„	„	„ ...	„	„	270·1	20·3	270·3	20·3	33·2[1]	101 Herculis	271·1;	+20·0
„	„	„ ...	355?	„	276·1	26·5	276·3	26·5	18·2[1]	2308 (A.B.) Herculis	274·5,	+23·2
78	1884	Kövesligethy ...	70	1881	261·0	35·1	261·2	35·1	39·7	2208 (A.B.) Herculis	260·2;	+37·0
79	1884	Folie—Systematic and objective aberration through solar and stellar velocity in space.										
80	1884	Bischof	480	1855	285·2	48·5	285·5	48·6	...	51 Draconis	285·6;	+53·2
„	„	„	„	„	290·8	43·5	291·2	43·6	...	10 *ι* Cygni	291·8;	+51·5
										14 Cygni	294·0;	+42·6
81	1885	Homann ...	?	1885?	320·1	41·2	320·2	41·3	24·4	2792 (A.B.) Cygni	320·4;	+46·3
										68 A Cygni	318·7;	+43·5
„	„	„ ...	„	„	309·5	69·7	309·5	69·8	30·1	2673 (A.B) Draconis	307·9;	+72·2

[1] Assuming parallax for mean distance of first magnitude star to be 0·″15.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. °	1900 Decl. °	Velocity.	Remarks.	R.A. °	Decl. °
81	1885	Homann ...	?	,,	278·8	+13·6	279·0	+13·6	15·2	111 Herculis	280·5;	+18·2
82	1886	Ubaghs ...	56	1810?	258·2	30·1	259·1	30·0	0·26	72 w Herculis	259·2;	+32·6
,,	,,	,, ...	145	,,	259·1	25·9	260·0	25·8	0·33	70 Herculis	259·2;	+24·6
,,	,,	,, ...	263	,,	265·2	26·3	266·1	26·3	0·33	86 μ Herculis	265·7;	+27·8
,,	,,	,, ...	464	,,	262·4	26·6	263·3	26·5	...	2228 (A.B.) Herculis	264·3;	+24·6
83	1886	Folie—Reference to Ubagh's investigation.										
84	1887	L Struve ...	2509	1805	{272·9 275·1	36·3	274·8	36·3	...	1 κ Lyræ	274·1;	+36·0
,,	,,	,, ...	,,	,,	273·3	27·3	274·3	27·3	...	107 t Herculis	274·3;	+28·8
84A	1887	Ubaghs	163	Estimate of velocity only.					0·15			
85	1888	Folie—Theoretical paper: deduction of stellar parallax and solar motion.										
85A	1889	Eastman—Critical review of whole question of stellar and solar motion.										
86	1890	Kobold (General result of previous work.)	?	1810	266·7	31·0	267·5	31·0	...	94 ν Herculis	268·7;	+30·2
,,	,,	,,	?	,,	259·4	−0·5	260·5	−0·6	...	49 σ Ophiuchi	260·4;	+4·2
,,	,,	,, ...	?	,,	270·3	+2·6	271·4	+2·6	...	73 Ophiuchi	271·1;	+4·0
,,	,,	,, ...	?	,,	266·9	−1·3	268·1	−1·3	...	57 ζ Serpentis	268·7;	−3·7
,,	,,	,, ...	?	,,	262·9	+4·1	264·0	+4·0	...	60 β Orphiuchi	264·6;	+4·6
,,	,,	,, ...	?	,,	267·7	−0·5	268·9	−0·5	...	67 Ophiuchi	268·9;	+2·9
,,	,,	,, ...	?	,,	269·3	+2·2	270·4	+2·2	...	70 Ophiuchi	270·0;	+2·5
,,	,,	,, ...	622	,,	266·1	+0·35	267·3	+0·3	...	57 ζ Serpentis, see above		
87	1890	Stumpe	551	1855	287·4	+42·0	287·8	+41·9	20·0[2]	20 η Lyræ	287·6;	+39·0
,,	,,	,, ...	340	,,	279·7	40·5	280·1	40·4	21·0[3]	3 α Lyræ	278·4;	+38·7
										4 ε Lyræ	280·2;	+39·6
,,	,,	,, ...	105	,,	287·9	32·1	288·3	32·0	21·8	19 Lyræ	287·0;	+31·1
,,	,,	,, ...	58	,,	285·2	30·4	285·6	30·3	?	17 Lyræ	285·9;	+32·3
,,	,,	,, ...	1054	,,	285·0	36·2	285·4	36·1	?	18 ι Lyræ	285·9;	+35·9
88	1890	Boss	135	1890?	280·4	42·8	280·5	42·8	?	5 Lyræ	280·3;	+39·5

[2] 20·0 arbitrarily taken in order to shew agreement of results. [3] Arbitrarily assuming 20 miles as velocity, and that the distances vary inversely for proper motions for other groups.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. °	1900 Decl. °	Velocity,	Remarks.	R.A. °	Decl. °
88	1890	Boss	144	1890?	285·7	+45·1	285·8	+45·1	?	13 R Lyræ	283·1;	+43·8
,,	,,	,, ...	279?	,,	283·3	44·1	283·4	44·1	?	ditto		
,,	,,	,, ...	253	,,	288·7	51·5	288·8	51·5	?	7 Cygni	291·0;	+52·1
,,	,,	,, ...	...	,,	280·	40·	280·1	40·0	?	5 Lyræ	280·3;	+39·5
89	1891	Hecker	I.	1891?	272·5	13·8	272·6	13·8	...	72 Ophiuchi	270·7;	+9·5
,,	,,	,, ...	II.	,,	267·8	4·7	267·9	4·7	...	66 Ophiuchi	269·8;	+4·4
,,	,,	,, ...	...	,,	270·0	9·9	270·1	9·9	...	72 Ophiuchi, see above.		
90	1892	Monck	1167	1800?	280·	45·	280·7	45·1	20·	13 R Lyræ, see above		
91	1892	Seeliger—As to correct conception of problem of solar motion.										
92	1892	Ristenpart ...	85	1850	302·2 289·9 290·6	32·4 33·4 34·4	294·7	33·5	...	17 Cygni	295·7;	+33·5
,,	,,	,, ...	221	,,	286·3 280·3 281·6	29·8 33·9 36·9	283·2	33·6	...	2381 (A.B.) Lyræ	282·8;	+33·8
,,	,,	,, ...	148	,,	294·7 267·3 266·7	24·2 28·4 33·3	276·7	28·9	...	107 t Herculis	274·3;	+28·8
,,	,,	,, ...	4564	,,	294·3 276·5 281·2	28·2 27·0 41·2	284·5	32·2	15·9	17 Lyræ	285·9;	+32·3
,,	,,	,, ...	...	...	284·	30·	284·5	30·1	...	ditto		
,,	,,	,, ...	...	...	281·	39·	281·4	39·1	...	5 Lyræ, see above		
,,	,,	,, ...	...	...	274·2	19·5	274·7	19·5	...	109 Herculis	274·8;	+21·6
,,	,,	,, ...	Bischof corrd.		290·5	42·8	291·0	42.9	...	14 Cygni	294·0;	+42·6
93	1892	Porter	576	1900	...		281·9	53·7	20·0[3]	46 c Draconis	280·2;	+55·4
,,	,,	,, ...	533	...	See other columns		280·7	40·1	18·7[3]	4 ϵ Lyræ	280·2;	+39·6
,,	,,	,, ...	142	...	...		285·2	34·0	18·1[3]	18 ι Lyræ	285·9;	+35·9
,,	,,	,, ...	70	...	...		277·0	34·9	?	1 κ Lyræ	274·1;	+36·0

[3] Arbitrarily assuming 20 miles as velocity, and that the distances vary inversely as the proper motions for other groups.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. 1900 °	Decl. 1900 °	Velocity.	Remarks.	R.A.	Decl.
94	1892	Vogel and Kempf	45	1892?	206·1	+45·9	206·2	+45·8	11·5	19 λ Boötis	213·2°;	+46·5°
,,	,,	,,	,,	,,	159·7	50·0	159·8	49·9	8·1	40 Ursæ Maj.	159·9;	+57·5
,,	,,	,,	accepting		266·7	31·0 for veloc. determ.			7·7			
94A	1892	Bakhuyzen ...	?	1810?	{264·6 260·2	39·5	263·1	39·4	...	75 ρ Herculis	260·1;	+37·2
,,	,,	,, ...	?	,,	263·	32·	263·9	31·9	...	78 Herculis	262·0;	+28·5
,,	,,	,, ...	?	,,	268·7	31·0	267·6	31·0	...	94 ν Herculis	258·7;	+30·2
95	1893	Kapteyn ...	accepts		276·0	34·	for discussion of distribution of stars in space.					
96	1893	Kobold	1374	1810(A)	260·8	31·3	261·6	31·2	...	78 Herculis, see 94A.		
,,	,,	,, ...	,,	1810(B)	261·4	−6·0	262·6	−6·1	...	57 μ Ophiuchi	263·1;	−8·1
97	1893	Harzer—Theoretical discussion of Kobold's memoir.										
98	1893	Risteen	42	1892	218·0	+45·0	218·1	+45·0	10·9	33 Boötis	218·8;	+44·8
99	1894	Kobold	24	1810	264·4	12·0	265·4	11·9	...	55 α Ophiuchi	262·6;	+12·6
,,	,,	,, ...	43	,,	264·3	−3·5	265·5	−3·5	...	57 ζ Serpentis	268·7;	−3·7
,,	,,	,, ...	101	,,	264·1	−0·7	265·3	−0·7	...	ditto		
,,	,,	,, ...	210	,,	265·0	−4·7	266·2	−4·7	2·81	ditto		
,,	,,	,, ...	386	,,	267·4	−1·4	268·6	−1·4	...	68 Ophiuchi	269·2;	+1·3
,,	,,	,, ...	636	,,	267·3	−4·3	268·5	−4·3	...	57 ζ Serpentis, see above.		
,,	,,	,, ...	1400	,,	266·6	−3·0	267·8	−3·0	...	ditto		
,,	,,	,, ...	1400	,,	266·5	−3·1	267·7	−3·1	...	ditto		
100	1894	Gyldén—Relations of magnitude, proper motions, and parallax.										
101	1895	Kobold	51	1892?	247·0	47·9	247·1	47·7	?	42 Herculis	249·0;	+49·1
102	1895	Kobold—Essential difference between Bessel's, Argelander's and Airy's methods.										
103	1895	Kapteyn—On the spatial distribution of stellar velocities.										
103A	1895	Pannakoek ...	203	1895?	322·8	+14·7	322·9	+14·7	...	5 Pegasi	323·2;	+18·9
,,	,,	,, ...	93	,,	304·7	12·1	304·8	12·1	...	1 Delphini	305·4;	+10·6
,,	,,	,, ...	58	,,	275·8	18·3	275·9	18·3	...	109 Herculis	274·8;	+21·6
,,	,,	,, ...	48	,,	251·6	33·0	251·7	33·0	...	53 Herculis	252·3;	+31·9
,,	,,	,, ...	77	,,	274·6	−2·6	274·7	−2·6	...	60 c Serpentis	276·1;	−2·0
,,	,,	,, ...	52	,,	280·1	+35·8	280·2	+35·8	...	6 ζ Lyræ	280·3;	+37·5

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. 1900 °	Decl. 1900 °	Velocity.	Remarks.	R.A. °	Decl. °
103A	1895	Pannakoek ...	65	„	268·6	31·4	268·6	31·4	...	94 ν Herculis	268·7;	+30·2
104	1895	Anding—Criticism of the Besselian and Argelanderian methods.										
105	1895	Kobold—Reply to Anding's criticism.										
105A	1895	Tisserand—Evidence of actuality of solar motion.										
106	1895	Bompas—Discussion as to possibility of drift in plane of Galaxy.										
107	1896	Anding—Position of apex dependent on spatial distribution of P.M.										
107A	1896	Kobold—Reply to preceding paper.										
			551		284·4	41·5						
108	1896	Stumpe	339	1855?	275 7	41·9	283·0	38·9[1]	...	12 δ² Lyræ	282·8;	+36·8
			106		287·7	33·1						
			284		286·7	46·9						
„	„	„ ...	473	„	290·7	37·5	280·8	38·6	...	6 ζ Lyræ	280·3;	+37·5
			238		263·8	31·1						
			404		287·4	45·0						
	„	„ ...	348	„	282·2	43·5	283·6	40·7	...	13 R Lyræ	283·1;	+43·8
			243		280·2	33·5						
			139		305·3	56·0						
		„ ...	265	„	281·8	38·3	288·1	41·8	...	20 η Lyræ	287·6;	+39·0
			146		276·2	30·9						
					292·2	52·3						
	„	„ ...	...	„	285.6	47 6	286·4	44·6	...	13 R Lyræ, see above.		
					280·5	33·7						
			89		281·1	22·9						
	„	„ ...	199	„	274·8	13·0	276·6	15·1	...	111 Herculis	280·5;	+18·2
			106		272·4	9·4						
			394		275·3	13·8						
		„ ...	243	„	275·9	14·3	276·1	14·1	...	ditto		
„	„	„ ...	637	„	275 5	14·0	276·0	14 0	...	ditto		
109	1896	Kobold	188	1880	276 0	2·9	276·3	2·9	...	61 e Serpentis	276·7;	−1·1

[1] Simply mean values reduced to 1900.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. 1900 °	Decl. 1900 °	Velocity.	Remarks.	R.A. °	Decl. °
109	1896	Kobold	188	1880	269·3	−0·1	269·6	−0·1	...	68 Ophiuchi	269·2;	+1·3
„	„	„	810	„	266·5	−3·1	266·8	−3·1	...	57 ζ Serpentis	268·7;	−3·7
110	1896	Newcomb ...	?	1900?	...	...	297·0	not given	28·9			
111	1897	Kobold	213	1810	274·4	+0·4	275·6	+0·4	...	61 e Serpentis	276·7;	−1·1
„	„	„	1579	„	268·3	−2·9	269·5	−2·9	...	57 ζ Serpentis, see above.		
„	„	„	„	„	269·7	−0·0	270·9	−0·0	...	73 Ophiuchi	271·1;	+4·0
„	„	„	62	„	240·1	+3·7	241·2	−3·5	...	9 Herculis	242·1;	+5·3
112	1897	Kobold	115	1810	266·1	−0·7	267·3	−0·7	...	67 Ophiuchi	268·9;	+2·9
113	1897	Kapteyn—Stellar velocities. Possibly of uniformities among *motus peculiares*.										
114	1897	Kobold—Examination of *motus peculiares* under three different assumptions.										
115	1897	Kapteyn—Solar and stellar velocities in space.										
116	1897	Newcomb ...	?	1897	273·4	+34·9	273·4	+34·9[3]	...	1 κ Lyræ	274·1;	+36·0
„	„	„ ...	?	„	279·5	38·7	279·5	38·7[4]	...	3 α Lyræ	278·4;	+38·7
„	„	„ ...	?	„	277·5	38·0	277·5	38·0	...	ditto		
117	1897	Newcomb ...	?	1897	274·2	31·2	274·2	31·2	...	108 Herculis	274·3;	+29·8
118	1897	Boss—Discussion as to this last value by Newcomb.										
119	1897	D'Auria—Period of rotation of stellar universe.										
120	1897	Bakhuyzen ...	2683	Spatial distribution of stars. Solar motion assumed							276·;	+34·
121	1898	Boss	4565	1900?	...	...	295·4	39·0	...	2529 (A.B.) Cygni	296·5;	+38·5
122	1898	Kapteyn ...	2585	1875	276·	34·	adopted		10·4	Velocity of Sun.		
„	„	„ ...	„	...	„	„	„		19·3	Mean velocity of stars.		
123	1899	Newcomb ...	72	1900	...	...	277·5	38·0	17·2	2339 (A.B.) Lyræ	278·0;	+38·8
„	„	Newcomb—Second computation, rejecting some stars ...							21·2			
„	„	„ —Third computation, rejecting further stars ...							18·3			
„	„	„ ...	22	Bright stars only...			...		10·3			
„	„	„ ...	16	1900	...	...	276·3	41·3	...	2 μ Lyræ	275·2;	+39·5
„	„	„ ...	64	„	...	...	263·1	31·7	3·6	86 μ Herculis	265·7,	+27·8
„	„	„ ...	135	„	...	...	262·7	26·8	5·2	76 λ Herculis	261·7;	+26·2

[3] Struve's result corrected. [4] Deduced from Boss' result.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R.A. °	1900 Decl. °	Velocity	Remarks.	R.A. °	Decl. °
123	1899	Newcomb ...	327	,,	...	...	266·5	+31·8	4·6	86 μ Herculis	265·7 ;	+27·8
,,	,,	,, ...	731	,,	...	...	268·5	32·0	5·9	ditto		
,,	,,	,, ...	1034	,,	...	...	277·4	30·6	7·7	108 Herculis	274·3 ;	+29·8
,,	,,	,, ...	236	,,	...	...	278·2	33·6	10·7	10 β Lyræ	281·6 ;	+33·3
,,	,,	,, ...	2527	,,	...	...	272·5	31·3	...	104 A Herculis	272·0 ;	+31·4
,,	,,	,, ...	644	,,	...	...	276·9	31·4	...	108 Herculis, see above.		
,,	,,	,, ...	995	(Stumpe)	...	...	282·4	39·7	...	5 Lyræ	280·3 ;	+39·5
,,	,,	,, ...	279	(Boss)	...	...	283 3	42·9	...	13 R Lyræ	283·1 ;	+43·8
,,	,,	,, —General result			...	...	277·5	35·0	...	2339 (A.B) Lyræ	278 0 ;	+28·8
124	1899	Kobold	13	1810	271·7	10·4	272 8	10·4	...	72 Ophiuchi	270·7 ;	+9·5
,,	,,	,, ...	23	,,	267·5	3·7	268·6	3·7	...	66 Ophiuchi	269·8 ;	+4·4
,,	,,	,, ...	85	,,	267·3	−1·7	268·5	−1·7	...	68 Ophiuchi	269 2 ;	+1·3
,,	,,	,, ...	242	,,	269·7	−1·7	270·9	−1·7	...	58 η Serpentis	274·0 ;	−2 9
,,	,,	,, ...	542	,,	270·1	+0·1	271·3	+0·1	...	ditto		
,,	,,	,, (Total)	905	,,	269·6	−0·4	270·8	−0·4	...	68 Ophiuchi, see above.		
,,	,,	,, ...	583	,,	267·6	−3 9	268·8	−3·9	...	57 ζ Serpentis	268·7 ;	−3·7
,,	,,	,, ...	774	,,	270·8	−3·0	272·0	−3·0	...	58 η Serpentis, see above.		
,,	,,	,, (Total)	1357	,,	269 6	−3·3	270·8	−3·3	...	ditto		
,,	,,	,, (Total)	2262	,,	269·6	−2·3	270 8	−2 3	...	ditto		
,,	,,	,, ...	747	,,	268·1	−0·8	269·3	−0·8	...	68 Ophiuchi, see above.		
124	1899	Kobold	158	,,	271·0	+2·3	272·1	+2·3	...	73 Ophiuchi	271·1 ;	+4·0
,,	,,	,, ...	309	,,	269·5	+1·2	270·6	+1·2	...	68 Ophiuchi, see above.		
,,	,,	,, ...	416	,,	265·7	−1·5	266·9	−1·5	...	57 ζ Serpentis, see above.		
,,	,,	,, ...	158	,,	271·0	+2·3	272·1	+2·3	...	74 Ophiuchi	273·7 ;	+3·3
,,	,,	,, ...	...	,,	269·8	+16·5[1]	270·8	+16 5	...	93 Herculis	268·9 ;	+16·8
,,	,,	,, ...	...	,,	270·6	+0·1[2]	271·8	0·1	...	68 Ophiuchi, see above.		
,,	,,	,, —General result		,,	270·4	−0·2	271·6	−0·2	...	ditto		
125	1899	Backhouse—Relative character of solar motion.										
125A	1899	Veenstra ...	965?	1900?	...	...	268·3	+36·7	...	91 θ Herculis	269·0 ;	+37·3
	,,	,, ...	,,	,,	...	...	272·1	37·6	...	1 κ Lyræ	274·1 ;	+36·0
	,,	,, ...	710?	,,	...	...	273·5	33·9	...	ditto		

[1] Least squares method. [2] Kobold's method.

II.—*Determination and Discussion of Solar Motion in Space.*—continued.

Ref. No.	Date.	Name.	No. of Stars.	Epoch.	R.A. °	Decl. °	R A. 1900 °	Decl. 1900 °	Velocity.	Remarks.	R.A.	Decl.
125A	1899	Veenstra ...	710?	,,	...	...	270·6	34·3	...	99 b Herculis	271·1 ;	+30·5
,,	,,	,, ...	1675?	,,	...	...	269·5	34·3	...	ditto		
,,	,,	,, ...	,,	,,	...	...	274·2	35·1	...	1 κ Lyræ	274·1 ;	+36·0
,,	,,	,, ...	151	,,	...	...	262·4	42·2	...	85 ι Herculis	265·2 ;	+46·1
126	1899	Newcomb—Reply to Backhouse's criticism.										
126A	1900	Kapteyn—Theoretical criticism of Airy's, Argelander's and Kobold's solutions										
127	1900	Yowell	86	1900	...	...	284·1	+34·1	...	14 γ Lyræ	283·8 ;	+32·5
128	1900	Kobold	43	1900	...	...	264·3	−3·5	...	57 μ Ophiuchi	263·1 ;	−8·1
										97 Herculis	269·6 ;	+22·9
132	1900	Knibbs—General mean of all previous results, approximate only					270·5	+23·9	15·3	98 Herculis	270·5 ;	+22·2
										100_2 Herculis	271·0 ;	+26·1

III.—*Table shewing precession differences in right ascension and declination, 1800 – 1900.*

R.A.	Difference in R.A. for 100 years. Dec. −20°	−10°	0°	+10°	+20°	+30°	+40°	+50°	+60°	Difference in D.
150°	+1°·18	+1°·23	+1°·28	+1°·33	+1°·38	+1°·44	+1°·51	+1°·61	+1°·76	−0°·48
160	1·21	1·25	1·28	1·31	1·35	1·39	1·44	1·51	1·61	0·52
170	1·25	1·26	1·28	1·30	1·31	1·34	1·36	1·40	1·45	0·55
180	1·28	1·28	1·28	1·28	1·28	1·28	1·28	1·28	1·28	0 56
190	1·31	1·30	1·28	1·26	1·25	1·22	1·20	1·16	1·11	0·55
200	1·35	1·31	1·28	1·25	1·21	1·17	1·12	1·05	0·95	0·52
210	1·38	1·33	1·28	1 23	1·18	1 12	1·05	0·95	0 80	0·48
220	1·41	1·34	1·28	1·22	1·15	1·07	0·98	0·85	0·66	0·43
230	1·43	1·35	1·28	1·21	1·13	1·03	0·92	0·77	0 54	0·36
240	1·45	1·36	1·28	1·20	1·11	1·00	0·88	0·71	0·44	0·28
250	1·47	1·37	1·28	1·19	1·09	0 98	0·84	0·66	0·37	0·19
260	1·48	1·38	1·28	1·18	1·08	0·96	0·82	0·63	0·33	−0·10
270	1·48	1·38	1·28	1·18	1·08	0·96	0·81	0·62	0·32	∓0·00
280	1·48	1·38	1·28	1·18	1·08	0·96	0 82	0·63	0·33	+0·10
290	1·47	1·37	1·28	1·19	1·09	0·98	0·84	0·66	0·37	0 19
300	1·45	1·36	1·28	1·20	1·11	1·00	0·88	0·71	0·44	0·28
310	1·43	1·35	1·28	1·21	1·13	1·03	0 92	0·77	0·54	0·36
320	1·41	1·34	1·28	1·22	1·15	1·07	0·98	0·85	0·66	0·43

INTERCOLONIAL WATER RIGHTS AS AFFECTED BY FEDERATION.

By H. G. McKinney, M. Inst. C.E.

[With Plate V.]

[*Read before the Royal Society of N. S. Wales, December 5, 1900.*]

In the Australasian Federation Enabling Act, the only section which directly relates to the question of State Water Rights is as follows:—"The Commonwealth shall not, by any law or regulation of trade or commerce, abridge the right of a State or of the residents therein to the reasonable use of the waters of rivers for conservation or irrigation."

There will doubtless be many important questions to settle in connection with the regulation of intercolonial trade and commerce but none of them will be more difficult, or will require more care in its treatment, than those relating to "the reasonable use of the waters of rivers." The section succeeding that quoted indicates the means by which all such questions are to be settled. It reads as follows:—"There shall be an Inter-State Commission, with such powers of adjudication and administration as the Parliament deems necessary for the execution and maintenance within the Commonwealth, of the provisions of this Constitution relating to trade and commerce, and of all laws made thereunder."

Three other colonies—Queensland, Victoria, and South Australia—are interested to a very important extent in our western river system, or in other words in the Murray River and its tributaries. New South Wales and Victoria have also a joint interest in the Snowy and Genoa Rivers, Queensland and South Australia have a joint interest in Cooper's Creek and other important though intermittent creeks and rivers, and it may prove that South Australia and Western Australia have similar joint interests of more value than is at present believed. It would appear, however, that the powers of the Federal Government do not extend to rivers which are neither navigable themselves nor affect others which are navigable, but notwithstanding this limitation the field for inquiry which is opened by the use of the word "reasonable" in the first section quoted, is much wider than might at first sight be imagined. Consideration of the existing conditions and of the potentialities of the river Murray and its tributaries makes this point sufficiently clear. In fact, the extent and importance of the question of intercolonial water rights are little understood and generally greatly under-estimated.

In 1891, Sir Henry Parkes, who had a clear conception of the importance of the subject, instructed the present writer to prepare a map of the drainage area of the river Murray, and the accompanying map was the result. In view of the fact that comparatively little information was available regarding the positions of the natural features of large portions of the country, and that a map shewing merely the great extent of such a catchment area as that of the river Murray, was likely to give a very incorrect impression regarding the quantity of water which might be expected to flow off, as good an approximate division as practicable was made between the effective and non-effective portions of the catchment. There is, of course, no actual boundary between these, but it may fairly be assumed that the parts of the various tributary catchments which are shown on the map by horizontal shading, constitute the effective drainage area, while the great central area (unshaded) contributes practically nothing to the supply of water in the rivers.

This great drainage area of 414,255 square miles includes portions of four colonies as follows :—

Colony.	Catchment in Square Miles.		
	Effective.	Non-effective.	Total.
New South Wales	75,500	158,860	234,360
Queensland ...	67,690	36,835	104,525
Victoria	16,700	34,280	50,980
South Australia ...	... ...	24,390	24,390
Totals	159,890	254,365	414,255

With regard to this division, it is necessary to mention that the area described as effective is so only in a limited degree, and that the non-effective area is the scene of the loss of an important proportion of the waters which flow off the areas classed as effective. Reflection on these points will afford some indication of the greatness and complexity of the question of water rights throughout this immense catchment, whose only apparent outlet to the sea is the mouth of the river Murray in South Australia. The intermittent character of many of the tributary rivers, the low rate of discharge to which even the most valuable among them are liable to fall, and the small rainfall throughout by far the greater part of the entire catchment, are factors which increase both the importance and the difficulty of the question of intercolonial water rights.

Before proceeding to particulars regarding the extent to which the different colonies are interested in this question, is it necessary to have a clear conception of the manner in which rights to water are used, or are likely to be used, in the country drained by the river Murray and it tributaries. Taking in their natural order, according to the stages of settlement and development of the country, the means by which the waters of the rivers and of their tributary creeks have been or can be utilised, we have first the use of the water under natural conditions, that is as it flows or as it is found stored in the channels; second, the construction of dams to store water in these channels; third the erection and use of pumps on the rivers and creeks; fourth, the improvement of the flow in natural outflow channels; and fifth, the construction of cuttings, or canals, for conducting water through the delta land between the rivers. Some of these means are frequently used in combination with others, but the order of progress as stated is of sufficiently general application for present purposes. As regards the drainage area of the river Murray, the colony of Victoria is well advanced in the last stage. New South Wales cannot be considered to be beyond the fourth stage. In South Australia, owing chiefly to want of natural facilities, only the third stage has been reached; while Queensland, which has not yet had time for developing its resources, is still in the second stage.

Before proceeding to deal *seriatim* with the rivers of New South Wales, it is necessary to mention that as the result of lengthened investigation of the question, the present writer reported, about fourteen years ago, that the only rivers of this State which afford a sufficiently regular supply of water to warrant the construction of canals on a large scale for irrigation and other purposes are the Murray and the Murrumbidgee, and that in the case of the latter, the subject of adding to the regularity of the supply of water by means of storage reservoirs, should receive attention. When Colonel Home visited this State to report on water conservation and irrigation, he was supplied with particulars regarding all the western rivers, and two extensive schemes for canals were placed before him. One of these schemes was for a canal from the river Murray at Bungowannah, six miles down stream from Albury, the main canal extending to near Moulamein with branches taking off to Daysdale, Jerildirie, Deniliquin, and Tocumwal. The other project was for a canal from the Murrumbidgee taking off below Narandera, the main channel extending to a point south-westerly from Hay, with branches heading to near Darlington Point and Hay on its north side and to the neighbourhood of Jerilderie, Conargo, and Wangonilla on the south side.

Colonel Home concurred in the conclusion that the Murray and the Murrumbidgee are the only rivers of New South Wales from which extensive canal works could be constructed with advantage; but he considered that even in these cases storage reservoirs should at the outset be constructed as part of any such large schemes as had been proposed. In view of the established practicability of these works, of the extent to which the natural conditions are favourable, and of the immense benefits which the works would confer, it is safe to assume that their construction is only a question of time. One of the schemes would, in fact, have been constructed years ago by private enterprise, if the necessary powers had been obtainable. Under these circumstances it is an important question to consider whether any difficulty would be likely to arise with the Federal Government if these works were undertaken.

Taking first the case of the river Murray, the diversion of a large quantity of water as proposed, would have a perceptible effect in lowering the river, and any injury thus caused to the interests of navigation would be augmented if the storage of water in the reservoir were permitted to interfere materially with the flow of summer freshets. On the other hand, the Murray is by far the most regular of our rivers in its flow, and a good discharge can always be depended on during the latter half of the year. In Colonel Home's report it was pointed out that during a period of seventeen years there were nine years throughout which a supply of 1,300 cubic feet per second was available for diversion, or that as a rule, a large storage reservoir such as Colonel Home recommended, would be utilised to only a limited extent. During the spring and early summer months, the discharge is so great that the reservoir could be filled and the full supply maintained in the proposed canal without any interference with navigation. The only periods—and they are periods of very short duration—during which the navigation would be interfered with in any degree, are when the river is falling below or rising above navigation level. At such times the storage reservoir could be used in such manner as to minimise, if not entirely prevent any temporary injury which might be done to the interests of navigation. Taking all points into consideration, it appears safe to assume that although the river Murray forms part of a boundary for three different States, the questions arising in connection with the use of its waters and with interference with navigation will not be so difficult to settle as in the cases of other rivers which are less uniform in their flow.

The Murrumbidgee may fairly be regarded as a river in the early stages of decrepitude. Its average discharge is not sufficient nor its floods of sufficient duration to carry on the silt which is brought down from the higher parts of its catchment. In evidence of this, we have the fact that passing down from Wagga Wagga to the junction with the Murray there is a perceptible diminution of the cross section of the channel. This can only mean that the channel is slowly silting up, and that as a consequence, the tendency to flooding of the low lands will increase. In regard to this it may be mentioned that during the flood of last winter, residents along the River expected that owing to the clearing of the channel of Yanko Creek, the height of the floods below that place would be less than formerly for a corresponding height at Wagga Wagga. As a matter of fact some of them came to the conclusion that the flood level was really higher than formerly under corresponding conditions. In this conclusion they were probably correct. From 1894 till the present year there were no floods, so that it is natural to suppose that much of the silt which in years of flood would be carried beyond Hay, was deposited a long distance above that place. The snagging operations which have been carried out below Hay have doubtless had a material effect for the time in improving the conditions for navigation, but what it is desired to make clear is that the Murrumbidgee is a changing river, and that the changes are in a direction adverse to navigation.

Again, the Murrumbidgee is more uncertain in its flow than the Murray, this being chiefly due to the much smaller quantity of snow-water which it receives. The effect of the winter and early spring rains together with the melting snow is sufficient in the case of the Murray to maintain a high supply in it till the middle of December in average seasons, while in the Murrumbidgee the fall of the river may be expected to set in about the middle of October. In addition to this, the supply of water in the Murrumbidgee at Wagga Wagga falls considerably lower than that in the Murray at Albury, although the catchment area in the former case is nearly double that in the latter.

The necessity for storage reservoirs on the Murrumbidgee is much greater than it is on the Murray, and it fortunately happens that the basin of the Murrumbidgee possesses three magnificent sites for such reservoirs besides several others which on any of our more northern rivers would be most valuable. The plains adjoining the Murrumbidgee are remarkably favourable for the distribution of water from it for irrigation and other purposes, so that the conditions for the conservation of water and the construction of canals are all that could be desired. With regard to the value of such work, one of the most extensive landowners in Riverina stated not many months ago in evidence before a Board of Inquiry on the diversion of water from the Murrumbidgee, that if the proposed Murrumbidgee Canal System had been completed at the beginning of 1895, it would, during the five year's drought which then set in, have saved its entire cost, several times over to the country. In the face of evidence of this description, it is impossible to imagine that works for properly utilizing a fair portion of the waters of the Murrumbidgee can be much longer delayed.

The question now arises as to how the interests of this State in the Murrumbidgee will be affected by the powers conferred on the Federal Government. It has been pointed out that the Murrumbidgee is less regular in its flow than the Murray, that the discharge falls lower, that the channel is less satisfactory as regards navigation, and that the necessity for storing water on the upper part of its catchment is much greater. All these conditions tend to increase the number of cases in which the interpretation of the word "reasonable" in the Federation Enabling Act will become an important question. It always appeared to the writer that in a country so badly supplied with large rivers and other large natural supplies of permanent water as Australia is, the best course would have been to settle definitely, that in all cases where navigation comes in conflict with water conservation and supply, the latter should have the preference. However, we have to take conditions as we find them, and it is evident that the definition of the "reasonable use" of water is a question of the first importance, and one which will require careful treatment.

In discussing the question of the bearing of Federation on rights in the Murrumbidgee, only proposed works have been referred to, the reason for considering these first being that the proposed works are of far greater magnitude and importance than any yet undertaken. But there is another aspect of the case of immediate and direct interest to a large number of landholders. In the first place Yanko Creek has been greatly improved so that water commences to flow in it when the surface level in the Murrumbidgee is about eighteen inches, above what is termed "Summer Level" at Wagga Wagga. The further improvement of this creek has been authorised. In addition, there are other outflow creeks which landholders are beginning to value more than they did formerly, and are therefore disposed to utilise to greater advantage. But besides these there are about thirty pumping establishments on the river, the great majority of which include large centrifugal pumps of considerable lifting capacity. It is at once obvious that the interpretation which the Inter-State Commission will place on the term "reasonable use" will be one of great interest to the owners of these pumps, and of the land along the outflow creeks.

As the waters of the river Lachlan do not reach the Murrumbidgee, except during high flood, it may be assumed that they will be outside the jurisdiction of the Inter-State Commission. A similar remark applies to the waters of the Bogan, which is an intermittent tributary of the river Darling.

The case of the Macquarie River is somewhat different. Although this river has a more or less effective catchment of over 10,000 square miles, the flow in it is very irregular and often for long periods does not reach the river Darling. The quantity of water gradually diminishes, especially after passing Narromine, and the landholders on the lower parts of the river can generally tell, within a fair degree of approximation, how far a freshet will reach before it is exhausted. On the other hand, during seasons when the rainfall on the Upper Macquarie is abundant, a considerable flow passes into the river Darling, and if the supply already in the latter river is scanty, that received from the Macquarie may prove to be of considerable benefit to navigation.

On the Lower Macquarie there are immense areas of low-lying plains and swamps which benefit greatly from inundation during floods in the river. In ordinary seasons the whole of the water can be advantageously utilised in this way. Works have been constructed for distributing surplus water for stock purposes, and other works of a similar character are now in progress. These works while providing water for several hundred miles of creek will furnish the means of materially mitigating the damage which sometimes arises from excessive flooding of the lower holdings, but they may at the same time diminish the quantity of water which would otherwise reach the river Darling.

The storage of water on an extensive scale on the upper part of the catchment of the Macquarie would be a most useful work. The Engineer-in-Chief for Public Works, Mr. Darley, has this matter under investigation, and it is to be hoped that a satisfactory site for a reservoir will be obtained. In dry seasons the flow in the Macquarie frequently fails to reach Warren, but a suitable storage reservoir would afford the means of keeping up a permanent supply beyond that place, and as far as the Macquarie Marshes. The water would be stored in the reservoir in times of abundant supply and allowed to flow off by degrees in periods of low river. The management of such a reservoir would require much care and judgment, as the interception of a large quantity of water during moderate floods would affect the flow which would reach the river Darling. Landholders along the Macquarie may be expected to hold the opinion that it is perfectly "reasonable" from their point of view to make the utmost use of its waters by storage and distribution works; but it is equally natural that persons interested in the navigation of the river Darling will be disposed to raise the question whether such interference with natural conditions should be considered "reasonable."

So far as the navigation of the river Darling is concerned, the Namoi is a much more important river than the Macquarie. It is only occasionally that the Macquarie has any perceptible effect on the Darling, but the Namoi frequently affords a valuable contribution towards the maintenance of navigation. This river, like the Macquarie, receives practically no snow-water, and though it has a more or less effective catchment of nearly 9,500 square miles, the flow in its channel sometimes stops altogether for considerable periods. There is a site for a reservoir at which an enormous quantity of water could be stored—ample, in fact, to make the flow in the river permanent. By careful and judicious management it would be possible to use this reservoir in such manner as to benefit navigation, but if it happens that the supply of water in the river Darling is low whilst the reservoir is being filled, it will be difficult to persuade persons interested that no damage to navigation is being done. Thence will arise the question as to the "reasonable use" of the waters of the river Namoi.

Proposals have been made for the diversion of an increased supply of water from the river Namoi into outflow creeks, and two or three large pumping plants have been erected on the river and are used by private landholders. These are comparatively small matters, but as will presently be explained, knowledge in regard to water rights has spread in recent years and the sensitiveness of persons interested in such matters has increased in a corresponding degree. It might not, therefore, be difficult to show that even the small works referred to, would, under certain conditions, have a perceptible effect on the quantity of water which without them would have reached the river Darling.

The conditions of the Gwydir River correspond closely with those of the Macquarie, and the question of the storage of water in the upper part of the catchment is in practically the same stage. Extensive drainage works on the lower part of the Gwydir were proposed some years ago, and if these be constructed, the effect will be beneficial to the river Darling. In other respects there will be the same possibilities of disagreement as to the "reasonable use" of the water.

As regards the storage of water on the higher part of the catchment of the McIntyre, this question is in practically the same stage as in the case of the Macquarie and the Gwydir. If a satisfactory site for a reservoir be obtained, the management of the storage water while requiring care and discrimination should be less likely to give rise to objections than in the case of the Namoi. There are, however, natural facilities for the diversion of water from the McIntyre River, particularly through the Whalan Creek—and when these facilities are availed of, questions of some difficulty may be expected to arise.

It may be mentioned here that, as was pointed out many years ago by Mr. Oliver, President of the Land Court, when a question involving water-rights was under inquiry, the McIntyre River is not a boundary in the same sense as the river Murray. In the case of the latter it was specially laid down in the Constitution Act, that the boundary of New South Wales is on the south bank of that river. As regards the length through which the McIntyre is a boundary of this colony, no exact definition of the boundary was given, and on this account it must be taken as following the middle of the river.

Extending through the Western Division of New South Wales from Queensland on the north, to Victoria on the south, and providing in high floods a navigable channel about 1,300 miles in length, the river Darling presents several difficult problems in connection with its management and utilisation. Of the total catchment area of 256,400 square miles, not more than 105,500 square miles can be classed as in any degree effective, or in other words, more than seven-twelfths of the whole area contributes nothing to the discharge. Not only so, but the streams from the more or less effective portions of the catchment flow in many channels and for long distances through the dry plains of the non-contributing area. It naturally follows that under ordinary circumstances, only a very small proportion of the rainfall ever reaches the main river.

A factor of much importance in connection with the flow in the river Darling, and one which has a great tendency to complicate the question of water-rights, is the intermittent character of the flow in a number of its tributaries. When the channel of a river becomes quite dry, the loss of water from the first freshet is enormous. Cases have come under the notice of the writer in which the water in a creek after a period of drought has flowed only from two to three miles per day, while the same discharge after the channel was saturated covered twenty-five to thirty miles per day. Thus a small flow which would merely keep the bed of a channel saturated, might be the means of accelerating by weeks the flow of a succeeding freshet. On the other hand a work of comparatively trifling importance which interfered with a small flow might be the cause of extensive loss. Numerous cases of this kind are conceivable on tributaries of the River Darling. For instance, it is not difficult to imagine circumstances under which injudicious interference with the waters of the Namoi or of the McIntyre would have a perceptible effect on the River Darling hundreds of miles distant. But, as already indicated, the storage of water on the higher parts of the catchments of tributaries of the Darling may be made distinctly beneficial. The question of benefit or injury in such cases, so far as navigation is concerned, would have to be judged by the Federal Government, or the Inter-State Commission.

Throughout the lower parts of the River Darling few difficulties are likely to arise. The Upper and Lower Tallywalkas on the east side of the river, and the Great Ana Branch on the west are the only outflow channels of any considerable importance, and though they are capable of great improvement they are so much above the bed of the river that no alterations likely to be attempted will affect navigation.

Licenses under the Water Rights Act have been granted for a number of pumping plants along the course of the Darling, but considering the uncertainty of the rainfall and the dryness of the district, the number of these pumps is surprisingly small, being only a fourth or a fifth of the number licensed on the Murrumbidgee. In view of the fact that the flow in the Darling has on several occasions ceased from the neighbourhood of Bourke downwards, it seems not improbable that the Federal Government will claim the right to have a voice in the granting of such licenses in future.

The Government of New South Wales has expended large sums on snagging the River Darling, a work which has undoubtedly been beneficial to the settlers along its banks and in its neighbourhood, but has also been of much benefit to Victoria and South Australia. Whether such outlay should in future be incurred by New South Wales alone, seems doubtful. On this point it is significant that on two different occasions the Public Works Committee of New South Wales in reporting on the question of locking the River Darling, has given the opinion that the improvement of the navigation of the River Darling is a work which should be dealt with by the Federal Government.

Having sketched briefly in outline the nature of the principal difficulties which are likely to present themselves to the Inter-State Commission in connection with the rivers of New South Wales, it is necessary to state the present condition of affairs in regard to water rights in this State.

The question of the division of the waters of the river Murray was the subject of much discussion about fourteen years ago. Conferences between the Royal Commission on the Conservation of Water in New South Wales and the similar Royal Commission appointed by the Victorian Government were held in Melbourne and Sydney, and certain recommendations were made, but the Government of South Australia protested against a settlement in which it had no part, and the whole matter was allowed to drop. No further attempt was made to arrive at an agreement on this subject, so that the Inter-State Commission will have a free hand in dealing with it.

During the past fifteen years it has frequently been stated by some of the public men of New South Wales, that this State is much too young for the construction of large works for water conservation and irrigation. It is probable that a large number of people in Victoria and South Australia will not be displeased if this opinion is adhered to and acted on during the next fifteen years. Some very useful works have, however, been constructed in New South Wales for the distribution of water for stock and domestic purposes in the Central and Western Divisions of the State. The Willandra and Middle Billabong Weirs for instance, diverted surplus water from the river Lachlan during the past season, through a length of fully a thousand miles of creek. The improvements to Yanko Creek have also produced most useful results, and several other successful works of a similar character have been constructed. The outlay on these works has been comparatively small, and the works whilst properly managed will not affect any public or private rights prejudicially.

As regards water rights in New South Wales, the great feature of the last four years has been the successful start made with the administration of the Water Rights Act. Before that Act came into operation, every dam and pumping engine on every river or creek throughout the State, existed or was used on sufferance only; surely a strange state of affairs in a country depending so much on the conservation of water. Since that Act came into operation the number of applications for licenses has been over 700. The great majority of the works thus sought to be licensed were dams, but about an eighth of the number were pumps, which as a rule were centrifugal pumps of large lifting capacity for irrigation purposes. When the Act came into operation the popular opinion was that dams necessarily caused more or less injury to landholders below them, and opposition to the granting of licenses was frequent. But in the course of time more enlightened views began to be held, and it was gradually recognised that the conditions approved by the Public Works Department were equitable, and the result was that latterly applications have rarely been opposed.

The security afforded by the Water Rights Act has led to the construction of works of a better class than formerly. In one case the licensee of a large pumping plant has over forty miles of channels for the distribution of the water, while another has between thirty and forty miles.

As the licensing of dams and other works was not made compulsory, licenses have been applied for, as a rule only in cases where the owners of such works had reason to apprehend interference. In view of the merely nominal fees prescribed, this is short-sighted economy, as the development of the country increases the value of the water supply, creates additional requirements, and raises the question of the acquisition of new rights or the subdivision of old rights. The great financial companies which own station properties, have generally been more far-seeing on this subject than private landholders, and the Railway Commissioners have been more thorough still in taking advantage of the security afforded by the Act. The actual outlay on works which the licensing sections of the Water Rights Act were intended to protect was considerably over two millions sterling, and possibly over three millions. This outlay represents only a small fraction of the value of these works to their owners and to the country, for on these works depends, in a large measure, the successful occupation of a great part of the Central and Western Divisions of the State. Hence, it appears, that irrespective of anything that the Government has done or may do, the protection and the further development of water rights in the basin of the western river system are matters of the first importance.

With regard to the prospects of large irrigation works in this State, two points of special interest were brought to notice in the course of the recent inquiry on the proposal to construct a weir for the diversion of an increased supply of water into Yanko Creek. The first of these related to the extent and value of the irrigation by natural overflow from the Murrumbidgee, and the second to the value of the proposed Murrumbidgee southern canal.

It will probably surprise many persons to hear that in an average season, hundreds of thousands of acres of land along the Lower Murrumbidgee are flooded, and that without this flooding the land is practically worthless. The evidence[1] given before the Board of Inquiry, all tended to show that the rainfall alone on the Lower Murrumbidgee is quite insufficient to produce good grass and herbage on the dark soil flats, and that the inundation of these flats from the overflow of the river is highly beneficial. As an instance of the extent and importance of this natural irrigation, it was stated that on Yanga Station alone during a year of high flood, as much as 200,000 acres is inundated, while the corresponding area in average season is 75,000 acres. During the latter part of summer the stock depend almost entirely on the results of this flooding.

It appeared that the flooding involved practically no outlay, the only works referred to in any instance in connection with it being trifling improvements to outflow creeks. The floods in the Murrumbidgee are only moderately regular in their period of occurrence, and are very irregular in their height, yet it is evident that even under these circumstances the irrigation so done is a great boon to the landholders. In other words, irregular and uncertain irrigation of the native grasses is profitable when the water costs nothing. The question naturally suggests itself—"Would it not be remunerative to flood the native grasses if a regular and certain supply of water could be delivered at a small cost"? If the question be answered in the affirmative, the remark might well be added—"Much more would it be remunerative if such regular and certain supply of water were used for the production of such fodder crops as lucerne and sorghum." For instance, if in the case of Yanga, where an area of 75,000 acres is flooded in an average year, and about 40,000 acres in a bad year, an average of 100,000 acres could be flooded regularly, would that

[1] This refers specially to the evidence of Mr. Humphry Davy of Glendean, Mr. S. Lindsay of Yanga, Mr. G. D. Ringrose of Balranald, Mr. John Dill of Toogimbie, and Mr. W. McKechnie of Nap Nap.

not warrant considerable outlay? In connection with these questions, it is a significant fact that the witnesses directly concerned were practically unanimous in their support of the proposed Murrumbidgee Southern Canal Scheme.

The second important item of information elicited was a statement by an extensive landowner,[1] who is also a first class practical authority on the value of water in the back country. This statement was furnished in writing, and the main points in it relating to the value of the proposed Murrumbidgee Southern Canal and Storage Reservoir were as follows :—

"The estimated storage capacity of the proposed reservoir at Yass is eighteen thousand millions of cubic feet. This quantity of water would irrigate 275,482 acres to a depth of 18 inches, which would be sufficient to grow two crops of sorghum or four of lucerne. The former would carry fifty sheep to the acre for four months, and the latter fifteen sheep to the acre for six months, or a total of 13,774,100 sheep if fed on sorghum and of 4,132,230 sheep if grazed on lucerne.

"To show the value that this would be at all times, and especially in seasons of drought, I estimate it costs the owners of stock six pence per head per month for renting grass, including other expenses, to save their sheep. This would be equal to two shillings per head on sheep fed on sorghum for four months, or £1,377,410, which is more than double the estimated cost of the proposed Murrumbidgee Canal and Yass Storage Reservoir, and if the same acreage (275,482 acres) were in lucerne, estimated to carry fifteen sheep to the acre for six months at three shillings per head, it would amount to the sum of £619,834—about the estimated cost of the proposed Murrumbidgee Weir, Canal, and Yass Reservoir. These figures do not represent one half the benefit annually that would be derived from saving the stock in such disastrous droughts as those experienced of late years ; as under present conditions it will take several years to breed up to the full carrying capability

[1] The Honorable Samuel McCaughey, M.L.C.

of the country, whereas with the water supply mentioned, sufficient stock could be always available to take advantage of good seasons when they come. There is always a deterioration in stock during seasons of drought that could be avoided if the higher method of stock farming were adopted by growing food as proposed. . . . The estimate of fifty sheep to the acre fed on sorghum for the summer four months is only about half the stock carried per acre on a small paddock on North Yanko last year.

"The average cost of growing sorghum would be about £1 per acre per annum, and of growing lucerne considerably less, as the sowing of the latter would only be required once in five years, while sorghum would require to be sown annually.

"The amount of labour required to cultivate and water the areas referred to would bring unprecedented prosperity to the towns in the districts benefited by this scheme, as well as to the whole community. I know of no soil better suited for the growth of sorghum than the immense polygonum areas below Hay. If supplied by gravitation, with say 18 inches of water annually, it would increase its value tenfold. . . . . The interest on the cost of the Southern Murrumbidgee Canal at say £600,000 at 4% would amount to £24,000 annually, and I would undertake to pay £2,000 a year for a right to one-fifteenth part of the flow."

The foregoing statement coming from such an authority speaks for itself, and requires no comment.

The information given in connection with the proposed Murrumbidgee Southern Canal Scheme is intended to illustrate the value and importance of some of our water rights, and the necessity for keeping them in view. This scheme is one of several the practicability of which was long ago established, and which remain to be dealt with. The importance of guarding our rights in such manner that no obstacle will arise to prevent the carrying out of these schemes will not be disputed even by those who still consider that the time for them has not yet come.

The principal tributaries of the river Darling in New South Wales have been referred to in their order, and the remarks made in regard to the question of water rights in connection with them apply in almost every particular to the tributaries which flow from Queensland. The Warrego, the Balonne and its subsidiary rivers, the Moonie, and the Weir have characteristics so much in common with the Macquarie, the Gwydir, and the Namoi, that it is unnecessary to refer to them separately.

As already mentioned, the utilisation of the rivers of the Darling Basin in Queensland is still in the initial stage, and the only question of an Inter-State character which has yet arisen in connection with them, related to the interception of water by dams. Some of the landholders in New South Wales considered that their rights were being infringed in this manner by landholders in Queensland. The matter dropped for the time, but it is safe to anticipate that such questions will arise in increasing number as settlement progresses. The very important part played by the Queensland tributaries in supplying flood water to the river Darling and maintaining the facilities for navigation will render it necessary for the Inter-State Commission to watch the steps which may be taken to utilise these rivers to the greatest advantage.

It is interesting to contemplate what has been done by the people of Victoria in preserving and using their rights, and to contrast the views held and the action taken in that State with the views held and the absence of action, so far as large works are concerned, in New South Wales.

The principal tributaries of the river Murray in Victoria are the Mitta Mitta, the Kiewa, the Ovens, the Broken River, the Goulburn, the Campaspe, and the Loddon. The courses of the first two extend almost entirely through mountainous country and no arrangements appear to have been made by the Government of Victoria for diverting their waters for irrigation. Of the other tributaries of the river Murray on its south side, the Goulburn, which is by far the most important, is intercepted at Murchison by a weir forty feet in height, which willl divert the whole of the summer supply into two canals for irrigation. The western canal, which is partly constructed, is designed to carry 103,000 cubic feet per minute, and the eastern channel, the head works of which have been completed, will carry 21,000 cubic feet per minute. That is, the total quantity which will be diverted when both channels are in full operation, will be 124,000 cubic feet per minute.

In the case of the Campaspe River, works have been carried out at a cost of £53,000, the effect of which is to intercept and divert the whole of the ordinary discharge. This discharge would not be sufficient for the irrigation of the area proposed to be dealt with, so that it may fairly be assumed that except in extraordinary floods no water will be allowed to reach the Murray.

The case of the Loddon is similar to that of the Campaspe. Works for intercepting the whole of the ordinary supply have been constructed at a cost of £174,000, and, as in the case of the Campaspe, the whole flow of the Loddon would be quite insufficient for the irrigation intended to be carried out.

Of the Victorian tributaries of the Murray, there remain only the Ovens and the Broken Rivers, and proposals have been made for the diversion of the waters of both of these.

Particulars of Government works which draw their water supply direct from the south side of the river Murray are not available, but the areas which the works were designed to irrigate have been published. From the returns of these, it appears that works have been constructed for the irrigation of 97,000 acres in the Cohuna Trust, 6,500 acres in the Koondrook Trust, 4,000 acres in the Myall Trust, 13,500 acres in the Swan Hill Trust, 10,800 acres in the East Boort Trust, 10,000 acres in the Benjeroop and Murrabit Trust, 9,000 acres in the Twelve Mile Trust, and 16,000 acres in the Kerang East Trust. Works for the diversion of water from the river Murray have thus been constructed by Government aid, which will irrigate 166,800 acres. Taking as a basis an estimate in an official report of the Victorian Government, this area would require a flow of about 80,000 cubic feet per minute. To this has to be added the concession to Mildura by that Government, the effect of which was to authorise the taking of water up to 60,000 cubic feet per minute from the river Murray.

It appears from the figures given that arrangements have actually been made for the diversion of water from the river Murray and its tributaries under the sanction of the Victorian Government as follows :—

From the	Goulburn River ...	124,000	cubic feet	per minute.
,,	Campaspe River ...	10,000	,,	,,
,,	Loddon River ...	20,000	,,	,,
,,	Murray (for Trusts)...	80,000	,,	,,
,,	Murray (for Mildura)	60,000	,,	,,
	Total ...	294,000	,,	,,

The Government of Victoria has thus actually constructed works or concluded arrangements for the interception and utilisation of 294,000 cubic feet of water per minute from the river Murray and its tributaries. This is nearly 5,000 cubic feet per second, and is in excess of the entire quantity proposed to be diverted from the Murray, Murrumbidgee and Darling, by all the projects yet placed before the Government of New South Wales. In addition to the works enumerated, several projects which will require further supplies of water from the river Murray and its tributaries have been suggested to the Government of Victoria.

From the facts now set forth, it is clear that as regards the question of Inter-State water rights, the position of Victoria differs widely from that of Queensland and New South Wales. In dealing with the latter two States the Inter-State Commission will find its duties practically unaffected by any works which have yet been constructed, whereas in regard to Victoria it will have to consider the position of large and important works which are already in partial operation, and of extensive water rights which have been granted and are partly being utilised.

While South Australia contributes practically nothing to the supply of water in the river Murray, it occupies an important position in regard to navigation. For a distance of about 470 miles the remnant of the waters of the Murray and Darling Rivers and their tributaries flows through South Australian territory to the ocean near Goolwa. The magnitude of the question of navigation may to some extent be inferred from the following statement of approximate lengths of river which are navigable in good seasons :—

	Miles.
Goolwa to Wentworth	617
Wentworth to Mungindi	1,356
Wentworth to the junction of the Murray and Murrumbidgee	255
Murray-Murrumbidgee junction to Narandera	500
Murray-Murrumbidgee junction to Corowa...	485
Total	3,213

Although this navigation is liable to long interruptions on the river Darling, and is intermittent even on the Murray, still in view of the cheapness of water carriage, it seems safe to infer that the question of inland navigation on the river Murray and its tributaries will remain a subject of great importance and one in which the interests of South Australia must receive consideration.

Throughout its course in South Australia, the surface of the river Murray is, as a rule, so much below the level of the adjacent land, that diversion of water by gravitation is impracticable. Hence the use of the waters of the river Murray in that colony can only be provided for by pumping, and in regard to enterprise in this direction, South Australia is little behind Victoria. Rights to take water from the river Murray for the purposes of the Renmark Settlement have been granted to the extent of 31,250 cubic feet per minute, but if the whole of the land reserved for the settlement be utilised, the quantity of water required will be 55,000 cubic feet per minute. Hence in South Australia as in Victoria, the Inter-State Commission will find itself confronted with extensive rights to water which are in the course of being utilised.

The object of this paper is to afford some idea of the magnitude and importance of Inter-State water rights, and to point out the nature of some of the difficulties which have to be overcome by the Inter-State Commission. It is scarcely necessary to mention that it is impossible in a paper such as this, to give more than a bare outline of the question. It therefore seemed, on all grounds, the best course to furnish a concise statement of facts and to abstain from comment regarding them, and this has been the course adopted.

On the CRYSTALLINE STRUCTURE of some SILVER and COPPER NUGGETS.

By A. Liversidge, M.A., LL.D., F.R.S.

[With Plates VII. - IX.]

[*Read before the Royal Society of N. S. Wales, August 3, 1898.*]

In previous papers I have described the structure presented by nuggets of gold, and in this, an attempt is made to do the same for natural masses of two other metals; unfortunately it is very difficult to obtain nuggets of silver; after trying for some years to obtain them through most of the principal mineral dealers, I have only succeeded in securing one, from Lake Superior, through the late Mr. J. R. Gregory, F.G.S., of South Kensington. I mention the difficulty of obtaining silver nuggets, because I have to trust to the one specimen.

It was irregular in outline and but slightly waterworn, with a deep cleft on one side. (*Plate* 7, fig. 1.) A little calcite, quartz, and a few particles of native copper were found in the cavities by treatment with hydrochloric acid. The section was etched by means of dilute nitric acid, and presents a well marked crystalline structure, the crystals are large, and most of them present a satiny sheen, apparently from the reflection of light from the edges of their plates. The half-tone reproduction of the photograph, (*Plate* 7, fig. 1) has not come out well and gives but a very imperfect representation of the true appearance. Sp. gr. 9·73 at 24° C.

An analysis was made, under my direction, of a portion of the nugget by Mr. G. A. Waterhouse, B.Sc., a student in the University Laboratory, who obtained the following results :—

Gangue insoluble in HNO_3	1·210
Silver	97·390
Gold	traces
Copper	·071
Iron and aluminium oxides	·270
Undetermined and loss	1·059
	100,000

By cupellation 97·27 and 97·60 per cent. of silver were obtained from other portions of the nugget.

The next section (*Plate* 7, fig. 2) is a section of a silver-copper nugget also from Lake Superior; the light parts are silver and the dark are copper, the two metals are seen to mutually interpenetrate. The crystalline structure is not sufficiently well developed in either of the metals to show it with the low power of two diameters. The metals have both undoubtedly been deposited from solution, but not necessarily simultaneously; in the next specimen, the associated silver has been deposited only upon the surface of the copper.

Plate 8, fig. 3) is from a photograph of the exterior of a copper nugget from Lake Superior; it is an imperfect rhombic dodecahedron of about one inch diameter, and seated upon it are small imperfect rhombic dodecahedra of metallic silver of about one-eighth inch across; the white appearance of the upper part of fig. 3 is largely due to the silver, scattered crystals of silver are also seen as white patches on other parts of the copper crystal, unfortunately they are not well formed, and they are still more imperfect in the reproduction of the photographs. None of the silver crystals penetrate the crystal of metallic copper; as seen in *Plate* 8, fig. 4, the copper has a confused crystalline structure, with a tendency to radiation in parts. The silver has in this case been deposited only upon the surface of copper, in the other instance (*Plate* 7, fig. 2) it has apparently filled cavities in the copper, which appear to have previously contained other mineral matter, since removed by solution.

In one specimen which I saw several years ago, and not now accessible to me, (I think that there are similar ones in the collection at the Geological Museum, London) the silver was so scattered through the copper in isolated patches as to present a porphyrytic appearance. This structure used to be explained by assuming that the metals had cooled so slowly in the matrix (melaphyre) that the silver and copper had completely separated and solidified apart from each other. One difficulty felt in this explanation was that no artificial instances of such complete separation of two metals which readily alloy were known.[1]

I think that it is highly probable that such porphyrytic specimens, if sliced at right angles instead of in one plane only, would show that the apparently isolated masses of silver have connections with external surfaces of the copper and that it was possible for the silver to have found its way in from solution, as is seen to be the case in *Plate* 7, fig. 2; in this specimen the porphyrytic structure is not so characteristic as those I am referring to, because in the illustration accompanying this paper all the silver masses are seen to reach the exterior either directly or indirectly, hence there is no difficulty in accounting for the relative positions of the two metals.

Pumpelly[2] in speaking of the deposits of copper as a whole states that the silver appears to have been directly precipitated by the copper, but he does not give any details of the structure, beyond stating that on rolling, the two metals became more or less separated and may be detached from each other.

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[1] ? See Am. Journ. Sci. and Art, Vol. III., (1821) p. 201.

[2] Geology of Michigan 1873.

Copper Nugget from Bolivia, (*Plate* 9, fig. 5)—This specimen is water-worn and massive although it contains a few cavities and fissures. The crystalline structure is well developed in parts, many of the crystals show an elongated or prism-like section, although copper crystallises in the cubical system—this prismatic or platy form is often seen in gold nuggets. Sp. gr. 8·64 at 24° C.

Copper Nugget, Burra Burra, South Australia, (*Plate* 9, fig. 6)—This specimen is but little, if at all waterworn, internally it contains fissures and cavities, and some of the crystals are seen to radiate from various points; mainly to the circumference. The fissures etc., look as if the nugget had been formed in much the same way as an agate, *i.e.*, that the copper has in this case been deposited within a cavity which it has more or less completely filled. The exterior of the mass is granular with, perhaps, traces of crystals. Sp. gr. 8·22 at 24° C.

As in the case of the gold and platinum nuggets, there is every indication of the silver and copper nuggets having been deposited from solution, and nothing to indicate that they have undergone fusion, either igneous or hydrothermal.

ON THE CRYSTALLINE STRUCTURE OF SOME GOLD NUGGETS FROM VICTORIA, NEW ZEALAND, AND KLONDYKE.

By A. LIVERSIDGE, M.A., LL.D., F.R.S.,

Professor of Chemistry in the University of Sydney.

[With Plates X.-XIII.]

[*Read before the Royal Society of N. S. Wales, November 1, 1899.*]

IN a previous paper on the crystalline structure of gold and platinum nuggets,[1] an account was given of some nuggets from New South Wales and West Australia: since then some nuggets from other widely separated localities have been obtained and sections cut from them, and reproductions of photographs of some of the typical sections accompany this paper, so that they may be compared with the preceding series.

Victorian Nuggets.—Several nuggets from Victorian alluvial gold fields were kindly obtained for me by Mr E. Barton, Deputy Master of the Royal Mint, Melbourne. Of the sections prepared two are illustrated herewith as being typical.

The nugget, (*Plate* 10, fig. 1) from Gippsland, was dark in colour from the presence of ferruginous matter filling up the pores and cavities. The nugget was flattened in form, with approximately parallel sides as if it had been formed in a narrow fissure, and was about one-third of an inch in thickness. As will be seen from the section the surface fissures and pits do not pass into the substance of the nugget in any well defined way, although the interior also shows numerous pits and patches of ferruginous matter; the dark appearance of the section (fig. 2) is largely due to the numerous granules and patches of ferruginous matter; although this foreign material looks as if it were present in great quantity, the amount is really not great, and the quality or assay value of the Gippsland

[1] Journal Royal Society of N. S. Wales, 1897.

gold is high. Some particles of quartz are also present; the large white spot which occurs near the upper left hand side of the section is the largest of them, there are also others visible in the photograph, but most of the white portions are, of course, metallic gold. I need hardly say that the true appearance of this section is very different from that of the illustration—the section itself is of a rich but dull gold colour, with a matt surface; the matt surface is due to the removal of the closely intermingled ferruginous matter by the nitric acid, used for etching the surface.

On account of the granular or rather spongelike condition of the nugget and the small area of the interlacing gold surfaces exposed in the section, the crystalline structure of the gold is not visible in the illustration, (2 dias.) although it is apparent with higher powers. The polished sections of this and other similar ferruginous nuggets give but little indication of the true structure, for until they are etched they look as if they were of solid burnished gold, with hardly an indication of the spongy structure and of the enclosed foreign matter. The sp. gr. of this nugget section at 23° C. is only 15·21.

Plate 11, fig. 3, shews the internal structure of a nugget from Queenstown, twenty-eight miles from Melbourne; like the Gippsland nugget it shows much iron oxide, the very dark parts of the photograph are cavities from which it had been removed by treatment with acid, the surfaces of these cavities in some places show minute imperfect crystals, but usually they are merely pitted. Externally this nugget was water-worn and rounded, the Gippsland nugget, (*Plate* 10, fig. 1) shows but slight traces of attrition. The patches of gold free from iron oxides are somewhat larger than in the preceding, (see fig. 2) and the crystalline structure is not so minute. Sp. gr. at 23° C. is only 15·02.

New Zealand Nuggets.—Two nuggets from the Molyneux River were sliced and etched, and the section of one is shown in *Plate* 11, fig. 4, enlarged 3 diameters. Both of them appeared massive and free from any appreciable amount of iron oxide, quartz, etc., but on slicing them they were both found to contain much scattered oxide and quartz, the gold itself presenting no large areas free from extraneous matter—the crystalline structure of the gold is on a small scale, and not well defined. The photograph shows the surface of the section covered with pits and irregular cavities, these have been left after dissolving out the iron oxide, quartz, etc., by means of hydrochloric and hydrofluoric acids. The gold itself is of a deep colour, and thus resembles the Gippsland gold, in fact there is a considerable amount of resemblance between the foregoing Victorian and the Molyneux River nuggets; these nuggets were obtained from the Bank of New Zealand through the kindness of Mr. Michie, the manager at Dunedin, who allowed me to select such as suited my purpose, from large parcels of gold which had just been received and which were opened in my presence, hence the locality of the nuggets cannot be questioned. Sp. gr. at 24° C. is 17·15. Assay 92·128 per cent.

Klondyke Nuggets.—Several specimens from Klondyke were examined, some were kindly obtained for me with certificates as to their authenticity by Capt. M. W. Campbell Hepworth, then of the R.M.S. *Aorangi*, 1899, from the Bank of Vancouver, Victoria, and others by Mr. H. E. Ward of Rochester, New York. *Plate* 12, fig. 5, shows the external appearance of one of them, it is well rolled, as if it had travelled far, and is free externally from gangue and pits, although it has the usual depressions and hollows seen in most nuggets. The sections, (*Plate* 12, fig. 6 and *Plate* 13 fig. 7) however, show that it is much fissured and that there are irregular cavities containing ferruginous matter and quartz: the fissures give it a granular appearance as if made up of agglutinated or welded particles of gold. The crystalline structure is small, and it is visible in the illustrations (figs. 6 and 7); it is however not well defined. The Klondyke nuggets are all, as far as I have seen, very pale in colour, due to the very large amount of silver present. Their structure and appearance are quite distinct from that of gold from any other locality. The assays of two gave only 64·550 and 64·622 per cent. of gold, with a specific gravity 24·5° C. of only 16·23.

The percentage of gold is, of course, reduced by the presence of mineral matter, but assays made of Klondyke gold after the melting of the metal gave in one case, only ·749 gold and ·246 silver and in another ·820 of gold and ·174 of silver.—(Mineral Industries 1898.)

THE ORGANISATION, LANGUAGE AND INITIATION CEREMONIES OF THE ABORIGINES OF THE SOUTH-EAST COAST OF N. S. WALES.

By R. H. MATHEWS, L.S., and Miss M. M. EVERITT.

[*Read before the Royal Society of N. S. Wales, December 5, 1900.*]

THE aboriginal tribes whose customs form the subject of this treatise, formerly inhabited the south-eastern coastal district of New South Wales, from the Hawkesbury River to Cape Howe, extending inland to the Blue Mountains, and thence southerly by a line passing approximately through the following places, viz., Hartley, Crookwell, Yass, and Kiandra. In the following pages we propose to give a cursory outline of the social organisation, language, initiation ceremonies, and some other customs gathered by ourselves among the remnants of the tribes within the region referred to.

It may tend to increase the value of our work if we state the sources of our information. The organisation we obtained by personal inquiry from a large number of different natives, among whom the following old men may be mentioned :—"Jerry Murphy," a native of Bega, and also a resident for many years at Cooma; "Steve," of Braidwood; "Budthong," of Shoalhaven; "Timbery," of Wollongong; "Ned Carroll," of Goulburn; and from many others, including some old women. We have given considerable attention to the study of the Gundungurra language, having visited and camped with the natives of Burragorang, on the Wollondilly River, the most isolated and hence the best preserved and primitive remnant of the Gundungurra speaking people—two of our principal informants being "Billy Russell," and "Bessie Sims," who were able to satisfy us in every particular. The details of the initiation ceremonies were gathered from substantially the same men as the organisation—our inquiries respecting these two branches of the subject having extended over some years.

Social Organisation.

Marriages are regulated by a system of betrothals, the main principles of which we will endeavour to describe. The old men assemble in council for the purpose of assigning certain young married women to be what is termed *Nanarree* to certain boys, and the boys selected also become Nanarree to these women. In ascertaining what woman is qualified to be Nanarree to a given boy A, for example, the old men, who are well acquainted with all the people around them, know, or have ready means of discovering, who is the father of A, who may be distinguished as B. They next discuss who are the cousins of B, A's father. These cousins, whom we shall denominate C, may be the offspring either of B's father's sisters, or of his mother's brothers. There will probably be several of such cousins, some in each of the lines of descent just mentioned, from among whom the old men will select one or more to exercise the important function of becoming the parent of A's future wife. Let C^1, who is one of the cousins of A's father, be a woman chosen in this manner, then she is Nanarree to A, and he will by and bye marry one of her daughters. The old men may also appoint the mother of A to be Nanarree to one of the sons of C^1. An unmarried girl on attaining puberty, may be assigned to the position of Nanarree in the same manner as a married woman. On her obtaining a husband and bearing a family, her daughters eventually become the wives of the men entitled to them. Moreover, a woman may be appointed Nanarree to the prospective son of a given woman.

A youth and a woman who are Nanarree to each other theoretically occupy the position of son-in-law and mother-in-law. He is forbidden to speak to or even look at the woman, and she is subject to the same ban in regard to him. This Nanarree relationship has the good effect of preventing a man from having any improper intimacy with a woman who might ultimately become his mother-in-law; or, in other words, it precludes the possibility of his being the father of his own wife.

A woman who is Nanarree to a certain man may die before she bears a daughter—or although a daughter be born she may die before the intended husband gets her—therefore, to neutralize the chances of a man not securing a wife, more than one woman is usually appointed Nanarree to the same man. This also enables a man to have more than one wife, polygamy being sanctioned. In like manner the same woman may be Nanarree to several young men, so that if the youth to whom her daughter has been betrothed dies or is killed before he is old enough to claim her, she then becomes the wife of one of the other men. As far as practicable, it is arranged that when a girl is taken as the wife of a particular man, this man's sister shall be given to his wife's brother in exchange. This has the effect of binding the two families together by ties of kinship, and strengthening their claims to consideration in the tribal councils.

Every child, whether male or female, inherits the name of some animal, plant, or inanimate object, to which anthropologists have given the name of *totem*—a word in use among the North American Indians for the same purpose. The totem is inherited from the male parent, thus, if the father be a native bear the sons and daughters will be native bears, irrespectively of the totem of the mother. Marriage between individuals of the same totem is strictly forbidden, *e.g.*, a man who is an iguana cannot marry a woman who is an iguana. These totemic divisions of the members of a community is of great help to the old men when making the Nanarree appointments—the affinity of any given individuals being by this means traced with greater facility.

The Gundungurra Grammar.

The Gun′-dung-ur′-ra is one of the principle dialects used in the area defined in the opening paragraph. It was spoken in all the country intervening between Burragorang and Picton, as far as Goulburn, Crookwell and Yass. The Dhar′-rook dialect, very closely resembling the Gundungurra, was spoken at Campbelltown, Liverpool, Camden, Penrith, and possibly as far east as Sydney, where it merged into the Thurrawal. A very old Dharrook blackfellow, named "Jimmy Lownds," only recently deceased, informed us that the Gundungurra and Dharrook natives could converse together with but little difficulty. Adjoining the Gundungurra on the west, is the great nation of the Wiradjuri-speaking people.

I. *Value of letters, etc.*—The spelling is on an English basis. All the vowels have the same sound as in English unless marked as follows:—

ā as in fate.	*ô* as in mote.
â as in far.	*ū* as in mute.
ī as in mine.	

G is always hard. *Dh* is pronounced nearly as *th* in *that*, but with a slight sound of *d* before it. *Ng* at the commencement of a syllable has a peculiar sound, which can be got by assuming *oo* to precede it, thus *ngan* is pronounced *oong-an*, articulating it as one syllable. *N* before *y*, as in nyin, is pronounced like *inyin′* the two syllables being pronounced as one. The same applies to *d* before *y*, as dyer, pronounced *de-yer′* in one syllable. *Ch* is sounded as *ch* in church. A final *h* is guttural, resembling the German *ch* in *noch*, *nach*, *ich*, etc., but not quite so strong. *Ng* at the end of a syllable has the sound very nearly of *ng* in sing, but more nasal. The accented syllable is marked thus ′.

II. *Nouns.*—The plural is shown by an attached pronoun, jil′-long, they; or darh′-gang, the whole lot of them. Singular—Bow′-wil, man. Plural—Bow′-wil-jil′-long, man-they, or men; Bow′-wil darh′-gang jil′-long, man-all of them-they.

There are two genders, the masculine denoting the male sex; and the feminine, denoting the female sex; generally expressed by the use of different words. Bow'-wil, man; Bul'-lân, woman.

The sex of animals may also be distinguished by the prefixes gō'-wul,[1] male; and ngō-wāl, female. Gō'-wul mir'-ree-gung, he-dog.

Nouns have eight cases:—nominative, nominative-agent, genitive, dative, accusative, locative, ablative, and vocative, all except the nominative and vocative, being formed by the addition of post-positions or particles, to the nominative singular.

The nominative, if a noun, usually begins the sentence:—

(*a*) Nom. Bul'-lân, woman; as, Bul'-lân mun'-na-mīn, woman runs.

(*b*) Nominative-agent, or subject of a transitive verb. Bul'-lân-gâ woman; as, Bul'-lân-gâ thī-mīn ngul'-lee, woman eats fish.

N.B.—Gâ interchangeable with bâ and wâ in certain cases for the sake of euphony.

(*c*) Genitive Bul'-lân-ngoo, woman's; as, Bul'lân-ngoo gow'-will-lee'-goong, woman's yamstick.

(*d*) Dative, Bul'-lân-ngoo, to or for the woman; as, Yoong'-ee bul'-lân-ngoo dhung'-ung, give to woman food. For the use or benefit of the woman, is expressed in the same way.

(*e*) Accusative, Bul'-lân, woman. Is generally like the nominative, but sometimes indicated by the genitive sign, as, Bul'-lân-*ngoo* ngoó-bee-ngâ'-jil'-long, they are beating the woman. Here there is the sense of possession, the woman being the possessor of the beating. Where there is no such sense, the word is invariable.

(*f*) Locative, Bul'-lân-wâ'-ro, in, on, or at, the woman. Wâ'-ro, pronounced also wâ'-roo, and bar'-roo, accompanies adverbs of place and prepositions, where no preposition would be used in English; as, Dhoó-lân ngoo-nân'-bil bâ-bâ-roong'-

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[1] *Cow-ul,* evidently equivalent to *gō-wul,* meaning the male of animals, is given in Collin's "Account of the English Colony in New South Wales," (London, 1798), Vol. I., p. 612.

bar'-roo, River this-side hill-at; or, on this side of the river is a hill.

(*g*) Ablative, Bul'-lân ngoó-rij-jee, from the woman. Bow'-wil goó-rij-jee, from the man. Boó-reen bar'-ra-jee, from the stringybark tree. This slight fluctuation in the sound of the particle, due no doubt to the governed word, is frequent.

(*h*) Vocative, Mâ bul'-lân! Oh, woman!

III. *Prepositions.*—(*a*) Of place, in or at, wâ-ro, or war'-rea.

Ngul'-lâ-mīn'-yâ goon'-jee wâ-ro,
Sit down I hut in.
Gur-rīn'-yen-noong' min'-jee-gar'-ree,
Father ours heaven in.

On, wâ'-ro, or war'-un-goon. Dhum'-bang mung-â'-lee-mīn goó-ree wâ'-run-goon, hat rests ear on; or, the hat rests on the man's ear.

Around, or round, meaning behind, or the other side of, ngun'nâ. When it means *surrounding*, as, the men are sitting round the gum-tree, it is translated simply by wâ-ro. Bow'-wil darh'-gang ngul'-la-mīn-gil'-long dhur'-rum-bī wâ'-ro, the whole lot of the men are sitting round the gum-tree.

Between, thur'-ree, with wâ-ro. Ngul'-lân-in-jee dhur-ree wâ-ro bul-lân bul'lar-ngoo-ra, wilt sit down thou middle-at woman-two. Joó-loo-gung-âng thoó-ree-wâ-ro ngar'-ree war'-rea, lizard between-at leg-at, *i.e.*, a lizard is between my legs. Joó-loo-gung-âng mun'-noo-mīn thoo-ree-wâ-ro ngar'-ree-war'-rea, lizard is running between-at legs-at; *i.e.*, a lizard is running between my legs. Thoó-lân nân-boó-roó-mīn' thur'-ree-wâ-ro bâ-bâ-roong ngâ-lee-mīn-burr, river lies between-at hills two.

On, meaning on top of, gun'-nâ goon'-jee-wâ-rō, opossum sits top hut-at. Bâ'-bath-ool nam'-boo-râ-mīn jil'-long ngun'-neen wur'-rân-gīn-bar'-roo, geebung lie-they beneath boomerang-at; *i.e.*, the geebungs beneath the boomerang.

On this side of, ngoo-nīn'-bil. Nul'lâ-mīn gil'long ngoon-nin'-bil thoó-lân-bâ-rō, sit-down they this side-of river-at. *Bil* intensifies, is equal to "here-self."

In front of; meaning also, the whole of, ngoó-mir-râ. Wul′-lee ther′-ree-mīn′ ngoó-mir-râ wâ′-roon-ngoo, opossum stands in front of tree-trunk.

The other side of, ngun′-a-ow. Mun′-nee wur′-rin-jung ngun-a-ow bâ-bâ-roong gin-nee, run, run to the other side of the hill.

Behind, ben′-gul wá-rea. Ngul-lee ben′-gul wá-rea, sit behind; *i.e.*, sit down behind me.

(*b*) For, meaning for the benefit of, ngoo, the affix that denotes possession. Bow′-wil-gâ jung′-ga-jâ-mar′-ra mīn bul-lân-ngoo thung-âng, man begs food for woman. Mun′-na-gâl-an-in′-ngâ mir′-ree-gâng, will bring I dog-for grass.

For, meaning for a purpose, gin′-nee. Yoong-ee ag′-gee-jâ bow′-wun gum′-mee gin-nee, give thou me grease spear-for; *i.e.*, give me some grease to rub my spear with. Gud′-bâ-mīn moo-rool goó-roo-gung gin′-nee, cuts (she) grass bag-for.

With, by means of, gâ; which is also the affix of agency. Boo-bâl′-gâ mung′-â-rin ngul′-lee gum′-me-gâ, boy (agent) catches fish spear (agent). Bul-lân′-gâ ngoô-bun-ning mul′-lung-a-ngoo gnul′-la-gâ, woman (agent) will hit girl stick (agent).

IV. *Adjectives.*—1. Of quality.—These may also be used as nouns and verbs. Mij′-jurh, sharp, means also a point; and, as far as abstract notions can be grasped by Australian aborigines, Mij′-jurh is equivalent to sharpness. Comparison is denoted by a kind of balance, which places the compared groups side by side, without conjunction. However, the Gundungurra use mâ′-dee, more; as a prefix or affix to adjectives. To express abundance or intensity, they prefix bug′-ga-ra-bâng, large or great to a noun; and they use reduplication of the adjective, as dâm′-boo dâm′-boo, everywhere.

(*a*) Comparative—Bul′-lân thee-al′-le-mīn; boó-bal moó-goo, woman hungary; boy not. Bul′-lân mâ′-dee thee-al′-la-mīn; boó-bal moó-goo, woman more hungry; boy not. Both mean, the woman is more hungry than the boy.

Yad′-dung ngâ, good I ; goo-lân′-jee gud′-ba, thou bad, or I am better than thou. Boó-bâl nin gud′-bâ ; mul′-lung-ul yad′-dung, that boy bad ; girl good ; or the boy is worse than the girl. Yad′-dung-bil is used for better ; *bil* means self, and serves to intensify.

(*b*) Superlative.—Ngee′-ran bâ′-rij-jee nin boó-bâl gud′-bâ, among whole lot that boy bad ; or, that boy is the worst of the crowd. Wâ′-goo-lin nin boó-ra-boó-ra ngeé-rân bar-rij-jee, that crow black whole lot among.

Adjectives denoting want are expressed by affixing the negative moo-goo ; as, yad′-dung moo-goo, worthless, no good.

Denoting resemblance, 'like,' go-bâ′-bâ. Gun′-bee go-bâ′bâ, fire-like, like fire. Wur-rân′-ga-bâ, that's something like a light over there. Mur′-rin bul'-lân-ngoon good′-thar-â-bâ′-bâ, that woman is just like a child. (Mur′-rin means any black person).

Colour adjectives. Very few of these.—Boó-râ-boo-râ, black ; day′-ga-roo-ga-rack, white ; thir′-rim-thir′-rim, red ; goó-burh, yellow.

2. Demonstrative.—An equivalent for *the* is *nin*, that, which is much used. Bul′-lân nin ; that woman. Which, ngun′-ning-gâ bul′-lân thīn-bâ′-lee-mīn ? which woman is eating ?

3. Numerals are indeclinable.—Med′-dung, one ; bul-lâ-la, two; bul-lâ-med′-dung, three ; jum′-ma-gun′-dâ, a large number ; darh'-gâng, the whole crowd. There are no ordinals.

V. *Pronouns.* 1. Personal pronouns, in answer to a question, are: Mit′-ta-bâl′-jâ, I, or I myself. Is very strong, meaning, "I alone." Goo-lân′-jee, thou. Jum′-ma-gung, he, or she. Goo-lang′-a-lâ, we. Goo-lân′-oo, you. Jum′-ma-gun′-da, they.

Verbal pronouns are nearly always placed after their predicate. If the predicates be adjectives, there is no copula in the present tense. Yad′-dung ngâ, good I (at present), I am good. Yad′-dung-jee, thou art good. Yad′-dung ab′-oo-la, he is good. Yad′-dung oó-lung, we both are good. Yad′-dung ngil′-lâ, we all are good. Yad′-dung boo, you both are good. Yad′-dung ngoo, you all are good. Yad′-dung bul′-lar, they both are good. Yad′-dung jil′-long, they all are good.

2. Reflexive pronouns will be given in the conjugations of the verb.

3. Possessive pronouns.—Ngul′-leenin *goo-lâng′-ee-a*, that fish is mine. *Gool′-lan-yee* nin ngul′-lee, thine that fish. Jum′-ma-gâng-oo nin ngul′-lee, his, her, its, fish. Ngul′-lee nin goo-lâng′-nga-ngal′-loo, that fish belongs to us two. Ngul′-lee nin goo-lâng′-ba-loong, that fish belongs to you two. Ngul'-lee-oo-lâng-oo nin, that fish belongs to them two. Ngul′-lee nyun′-noong-oong nin, that fish belongs to all of us. Ngul′-lee nyin′-ner-roong nin, that fish belongs to all of you. Ngul′-lee jil′-long nin, that fish belongs to all of them. Gooj′-ja-roó ee-ya, my club. Gooj′-ja-roó in′-yee, thy club. Gooj′-ja-roo jum-ma-gâng-oo, his club. Gooj′-ja-roo ngun′-noong-oon, our club. Gooj-ja-roo in-yer, your club. Gooj′-ja-roo-a-jin-nung, their club.

The use of these possessives in the oblique cases does not appear to alter them materially.

Forms of the objective are:—Ngoó-boo-mīn *gij-jee*, thou hittest me. Ngoó-boo *jin-jâ*, he beats me. Ngoó-ber-in gan′-*yee*, I hit you. Ngoó-boon-yâ-nyool-loong-*yee*, we two are beating you.

4. Relative pronoun.—In the Gundungurra, the interrogative ngun′-nun-gow′-a, who? is actually used as a relative, but so rarely that it may have been adopted from analogy. Good′-thar ngun′-nung-ow′-a-wá thīn-bâ-lee-mīnnūn, wur′-ree-na, the child who is eating (is) there.

But though this form is said to be correct, it is far more common to use no relative. Bul′-lân′-gâ nin nīn-mur′-ra-mīn good′-thâ-oong yad′-dung gin-nee, the woman takes care of child, good indeed.

5. Demonstrative pronouns.—That, nin, nīn′-gâ, gâ′-nin. Mâ′-on-yee gâ′-nin? husband thine that? Nin′-gâ yad′-dung? that good? *i.e.*, is that good? This, ngoo-noo.

6. Interrogatives.—(*a*) Who? ngun′-nungâ? or ngun′-nun-gow′-a. Ngun′-nun-ngâ yer′-ro-bin′-yâ war′-ree? who goes far? *i.e.*, who is going away? Ngun′-nin-gâ thīn-bâ′-lee-mīn? who is eating?

(*b*) Possessive.—Ngun′-na-gân′-ngoo-bâ, whose? Ngun′-na-gângoo-bâ goon′-jee-oong nin? whom-belonging-to house that?

(*c*) Ablative.—Ngun′-nin-gâ ngoo′-rij-jee-bâ mung′-â-rin′-jee-bâ nin gan-bee? whom-from gottest-thou that wood?

(*d*) What, min′-yā-bā. Min′-yâ-bâ yoon′-ga-bâ′-lee-mīn? what singing? Min′-yâ-bâ mun-na-gâ-lee-mīn jee? what bringest thou? Min′yâbâ seems to be indeclinable.

VI. *Adverbs.*—These do not differ from the corresponding adjectives. 1. Quantity and size. Much, many, goó-roong. Not much, few, goó-roong moó-goo. Goó-roong′-a mull′-ee-mīn′-jee? much hast got thou?

Sometimes gud′-ba means much, or very, and has then nothing of its original meaning, bad. Bug′-ga-ra-bâng gud′-ba, very big.

2. Time. Day-time, dur′-ra-wung. Night-time, bur-rī′-oo-loo. Sun-rise, win′-yoo-a boong′-bâ-mīn; lit., sun rises. Mid-day, win′-yoo boong′-bâ-rin; lit., sun has risen. Sunset, beet gon′-yâ win-yoo; lit., goes down sun. Mun′-na-gâ-nin′-gâ will′-in win′-yoo boong-ba-nig, will run I back sun will sink, or, I shall return at sunset. When, wun′-da, wun′-dīn. Now, to-day, yang′-oo. To-morrow, boo′-rân′-doo. Every day, always, boó-loó; bow′-wil nin weem′-bâ-lee-jin boo-loo, man-that drinks always, or that fellow is always drinking. By-and-bye, later on, gow-gow. Before, in the passage, "I'll eat before I drink," the construction must be, "I'll eat first; I'll drink after." "Thīn′-bul-lin-in-gâ; weem′-bâ-lee-jân-nee-ngâ."

3. Place. Here, ngoo-nīn. Mun′-na-gī ngoo-nīn ben′-gul war′-eea, come up here to the back of me. Yonder, wur′-ra-nân-deé; yer′-ra-bee wur′-ra-nân-dee, go over there (yonder). Where, where to, wun′-dee-nee; wun′-dung ngoó-roo bâ? whereabouts is it? A long way off, war′-ree. In the neighbourhood of, close to, ngoon-ee-nâ muthurh (muth′urh, close).

VII. *Conjunctions.*—Too, also, boonn. Yet, yang'-oo (also *now*, an adverb). Only, oo-loo. Then, yán-bee (also an adverb). And, oo.

VIII. *Interjections and phrases.*—Hark! hah! Woe, alas! ngī! (if in pain). Indeed, it is true! thoó-ree gin'-nee, (my word! it *is* true!) I am sorry, nar'-rál-a-mīn-ya. Oh! mâ (sign of vocative). Thank you, yad'-dung jee (good thou). Yes, ngee, No, gur'-rang-ung.

Gur'-ang-ung is sufficiently like Gundungurra to rouse enquiries as to whether *Gundungurra* means the place of *gurrangung*, *i.e.*, *no*, but our enquiries elicited nothing as to that point.

IX. *Verbs.*—To beat (Transitive). The sign of the infinitive mood is clear; it is pronounced indifferently eé-ree, or ā-ree.

To beat, ngoo-beé-ree.—Indicative mood, present tense.

I beat, ngoó-boo-rin-gâ
Thou beatest, ngoó-boo-rin-jee
He beats, ngoó-boo-jin
We two beat, ngoó-boo-ring-oo-loong
We all beat, ngoó-boo-ring-ya-lâ
You two beat, ngoó-boo-ring-boó
You all beat, ngoó-boo-rin-goo-lâ-na
They two beat, ngoó-boo-rin-bul-lâ
They all beat, ngoó-boo rin jum'-ma-gân'-da.

Negative: contains moó-ga, equal moó-goo, not, after the root of the verb.

I beat not, ngoó-boo-moó-ga-jin-gâ
We two beat not, ngoó-boo-moó-ga-jin ngoó-lung
We all beat not, ngoó-boo-moó-ga-jin ngul-lâ.

Perfect tense.—I have beaten a man this morning, ngoó-boo-ring-ngâ' bow'-wil-ngoon thur'-ra-wâng'-gâ. We two have beaten a man this morning, ngoó-boo-ring'-a-oó-loong thur'-ra-wân'-gâ bow'-wil-ngoon.

The negative perfect is formed like the perfect except that moó-ga follows the root ngoo-boo.

Future.—I shall beat the man to-day, ngoó-boo-ning′-gâ bow′-wil-ngoon yang′oo. We two shall beat the man to-day, ngoó-boo-ning′-ngoo-loong bow-wil-ngoong yang′-oo. We all shall beat the man to-day, ngoó-boo-nying′-ga-loong bow′-wil-ngoó-ee yáng-oo.

Negative.—I shall not beat the man to-day, ngoó-boo-moó-ga goó-ning-gâ bow-wil-ngoon yâng-oo. We two shall not beat the man to-day, ngoó-boo-moó-ga-goó-ning-oo-loong bow′-wil-ngoon yang′-oo.

Nging or ning, seems to be the great sign of the future time, as yur′-ra-bun′-ning, he will go; thīm′-bâ-loo-ning, he will eat.

Conditional mood, present tense.—I should beat the man to-day (This bears the sense of 'ought to,' for which the sign is '*moó-ee.*') ngoó-boo-moó-ee ow′-ee-wâ bow′-wil-ngoon-ee yang′-oo. We two should beat the man to-day, ngoó-boo-moó-ee-oon′-oo-loong bow′-wil-ngoo-ee yang-oo. We all should beat the man to-day, ngoó-boo-moó-ee-ang′-yea-la bow′-wil-ngoo-ee yang-oo.

Negative.—I should not beat the man to-day, ngoó-boo-moó-gun′-ning-gâ un′-doo bow′-wil-ngoo yang′-oo. We two should not beat the man to-day, ngoó-boo-moo-gun-in-oo-loong boon′-doo bow′-wil-ngoó-ee yang′-oo. We all should not beat the man to-day, ngoó-boo-mo-goon-ngil-lâ un′-doo bow′-wil-ngoo-ee yang′-oo.

A particle, pronounced either in′-doo, un′-doo, or oon′-doo, as it best assimilates with its fellow syllables, may be noticed in the last tense. It means doubt, and may be used in the future simple as, "Goo-râ′-ing-ngâ in-doo boó-rân-doo, we shall stay (or be) to-morrow."

Boó-roo yar′-râ-mìn, gool-ân′-doo yar′-râ-moó-goo-moon, kangaroo swims, at sometime swims not; *i.e.*, a kangaroo seems to swim, but it is doubtful.

Future tense of conditional.—I shall perhaps beat the man to-day, ngoó-boo-ung-gâ ung-doo bow′-wil-ngoo. I shall perhaps not beat the man to-day, ngoó-boo moó-goon-ning-ngâ oon-doo bow-wil-ngoo.

Imperative mood.—Beat (thou), ngoó-bee (it understood). Beat (you two), ngoó-boo-yow. Beat (you all), ngoó-boo yân′-oo. Beat not, ngoo-boo moó-gee. (You two) beat not, ngoo-goo moó-gee-yow. (You all) beat not, ngoo-goo moo-ga-yan-now.

The last syllablle in the singular present of the imperative is always *ee*; as, yoong-ee, give. The verbal pronoun itself (second singular) is *jee*.

I must beat, ngoo-bun′-nin-ngâ We two must beat, ngoo-bun′-ing-a-loong. *Bun* is always inserted after the root-sound to imply necessity; as, yer′-ra-bun′-nin-ngâ gâ′-ding-bill-in-ngâ, I must go hunting. Yer′-ra-bun-ngâ war′-ree, I *must* go away.

Participles.—I am beating, ngoó-goo-mīn′ yâ. We two are beating, ngoó-goo-min′-yil′-loong. We all are beating, ngoó-goo-mīn′-yil-lâ. I am not beating, ngoó-goo-moó-goo-mīn′ yâ. I was beating, ngoo-goo-mīn′-yâ, with time specified.

Reflexive.—The reflexive is known by having *l* in one form or another after the root. I am beating myself, ngoó-bil′-lee-mīn′ yâ. We two beat ourselves, ngoó-bil′-lee yang′-ee-loong. They beat each other, ngoó-bool-leé-ngâ′-lâ. I beat myself not, ngoó-boo-lee-moó-goo-mīn-yâ (yâ equal ngâ, I.) They have beaten each other, ngoô-bul-lee-nging′-bil-lâ. I shall beat myself to-morrow, ngoó-bul-lee-ng-ee-ngâ boo-rân′-doo. Beat each other, ngoó-bul-ee-yow. Do not beat thyself, ngoó-bool-ee-moó-gee.

Bun, sign of necessity, and *l* or *ll*, sign of the reflexive, are blended in the supine, as, I must beat myself, ngoó-bul-lin′-in-ngâ. We two must beat ourselves, ngoó-bul-lin-in-ngoo-loong.

Participle.—Beating myself, ngoó-bul-lee-mīn-yâ.

Other forms of verbs:—I shall beat again, ngoó-bun-nin-ngâ ngoó-ring; (ngoó-ring, again). He beats always, ngoó-ba-jin boó-loo. You (then) must always hear, ngur′-rum-ba-lee-bun′-nin-jee. You (then) must always go, yur′-ra-bun-nin-jee. Don't beat often, ngoó-goo-moó-goo mum′-nin-jee. I have finished beating, ngoó-ngâ ngoo-boo-rin-ngâ. I beat continually, ngoó-boo-jin gow′-ul-loo. I beat (him) running away, ngur′-rit mun′-ningâ. I beat coming home, ngur′-rit mun′-ning-gowâ. I beat thee from here, *i.e.*, from place where speaker is standing, ngur′-rit mun′-ning-gân-yee ngoó-noo-jee. Beat quickly, ngoó-bee bur′-rī. I'll beat you for certain, ngoó-boon-ning-gân-yee gin-nee.

There is no passive. "I am beaten," translated by "ngoó-boo-jin′-ja," which, literally is "beats me."

There is a verb meaning 'to be,' or 'to become,' of which the present of the indicative has already been given with the verbal pronouns.

The future is:—I shall be good to-morrow, yad′-dung gur′-rung-ing-ngâ boo-rân′-doo. Thou shalt be good to-morrow, yad′-dung gur′-rân-jee boo-rân′-doo. He or she shall be good to-morrow, yad′-dung gur′-run-ding boo-rân′-doo. We both shall be good to-morrow, yad′-dung gur′-ruh-ning ngoó-loong boo-rân′-doo. We all shall be good to-morrow, yad′-dung gur′-ruh-ning ngul′-dar boo-rân′-doo. You both shall be good to-morrow, yad′-dung gur′-ruh-ning-boo boo-rân-doo. You all will be good to-morrow, yad′-dung gur′-ruh-ning ngoo boo-rán′-doo. They two will be good to-morrow, yad′-dung gur′-ruh-ning bullar boo-rân′-doo. They all will be good to-morrow, yad′-dung gur′-ruh-ning jil′-long boo-rân′-doo.

A verb meaning "have," with the sense of possession, is used; as, mul′-lee-mīn′-ngâ wur′-ran-gīn, I have a boomerang. This may also be expressed, wur′-ran-gīn mul′-lee-mīn-ngâ. "My boomerang" is translated, wur′-ran-gīn-ngâ.

"The man, while running, cut his leg," is translated, "Bow′-wil-gâ nin mun′-na-mīn, ngar′-ree-ong gud′-bā-rin"; lit., man-that running, leg cut."

After the man ran, he cut his leg, mun′-na-run′-ba mer′-rung, nin bow-wil gud′-ba-jâ-ring ngur′-ree-oong; *i.e.*, ran after, that man cut leg.

After that man cut his leg, he ran away, gud′-ba-ba-rin′-ba nin bow′-wil ngur′-ree-oong, mun′-nun-bil′-lee-jâ-ring; *i.e.*, cut that man leg, ran away.

To express an inclination, or the sense of "would like to," the Gundungurra use "bil′-lâ" after the verbal pronoun. I would like to go away, yer′-ra-bo-ī′-yâ-bil′-lâ war′-ree. I would like to go hunting, yer′-ra-bo-ī′-yâ-bil′-lâ gâ′-din-bill-eé-ree. I would like to drink, weem′-bâ-lee-wī′-ee-yâ-bil′-lâ.

Nouns are formed from verbs and other parts of speech by the addition of war′-ree. To beat, ngoó-bee-ree. A beater, ngoó-boo-war′ ree. To give, yoon′-gee-ree. A giver, yoon′-go-war′-ree. To hunt, gâ′-ding-ba-lá-ree. A hunter, gâ′-doo-war′-ree. Sandy country, jarr′-jarr′. A man belonging to the sandy country, jarr-jarr-war′-ree-jee.

[Note.—The reader will readily understand the difficulties encountered in obtaining the outlines of the grammar of any language which is entirely colloquial. We are aware that in the preceding pages there are some errors in the orthography and syntax, as well as other defects, these will receive attention in a future article.]

Initiation Ceremonies.

The *Kud′sha*, or *Nar′ramang*, is an abridged form of initiation ceremony practised among the tribes dealt with in this article. If a tribe have one or more novices old enough to be initiated, and it will be a considerable time before a Bunan will be held, it is sometimes thought desirable or politic to inaugurate them into the privileges of manhood by means of the Kudsha. Although it is not necessary to muster the whole community, as is imperative in the fuller ceremonial referred to, yet it is generally considered safest to consult with the chief men of some of the neighbouring tribes, who may also have a few youths ready to pass through the ordeal. Messengers *(jerra)*, who must be men who have been initiated, are despatched to arrange the preliminaries, and when the time arrives the people proceed to the appointed meeting place. There are no circles formed on the ground, nor are there any marked trees or figures cut in the turf, as at the Bunan ceremony, all these embellishments being omitted in the Narramang or Kudsha. There is, however, a level cleared space on the margin of the main camp, where all the chief men meet for private consultations—this is called the *bâhmbilly.*

The people being thus assembled, festive and ceremonial dances are indulged in for a few evenings, which terminate in an apparent quarrel among the men of the different families present. At dawn on the following day all the initiated men meet at the bahmbilly, with a small leafy bough in each hand, and start in a sinuous course, in single file, and march through the entire camp, mustering up all the boys they intend to initiate. When the old women, and mothers of the lads, see all the men coming through the camp in this way, they know what is about to take place, and commence singing certain prescribed songs, called *yah'anga*, and beat time on their folded skin rugs. As soon as the novices are assembled, a guardian is appointed to each, and they are placed standing in a clear space, with their heads bent down, surrounded by a cordon of men who hide them from view.

The mothers of the novices, and all the other women in the camp, together with the little boys and girls, are also gathered up in a convenient place where they are made to lie down, and are covered over with bushes, grass, or rugs, a sufficient number of men being appointed to keep guard over them, so that they may see nothing of the subsequent proceedings. The *mooroonga*, or bullroarer, is then sounded by a man assigned to that duty, and the novices are marched away by their sponsors. When this cortege gets out of sight of the women's camp, a stoppage is made for the purpose of painting the boys with red ochre and grease, and fastening a belt round the body of each. Strips of the skin of the ring-tail opossum are tied round the upper arms of the novices, and under this bandage, which is called *nooroongal*, is inserted the small bone of a rock wallaby's leg, sharpened at one end. If a boy wants to scratch any part of his body, he draws out this bone and uses it for the purpose, because he is not allowed to scratch himself with his finger nails. A rug is now adjusted over each novice's head in such manner that he sees only the ground at his feet. The *Kooringal*, or band of strong active men who are responsible for the due administration of the several portions of the ceremonies, also avail themselves of this stoppage to paint their bodies with powdered charcoal, or burnt grass, mixed with emu fat.

On the completion of the painting of the boys and men, all hands proceed to a camp, called *bun'numbéal*, in a secluded part of their hunting grounds. On the way thither the novices are told to hold their hands on their stomachs, which after a time becomes very tiring to the muscles of the arms. When the party come to a deep rut or dry watercourse, the novices must walk down into the bottom and up the other side, even although it be so narrow that they could easily jump over it. If, however, there is any water in the bottom of the channel, the guardian carries his boy over it on his shoulders, the novices not being allowed to go into the water until after they have been initiated. If a log, or fallen tree, obstructs their path, the boys cannot step over it, but must make a detour round either end. If a novice's belt works loose and drops on the ground, his guardian takes off his own belt, and gives it to the boy—it being considered inauspicious to hand him the belt which has fallen off, this being appropriated by the guardian in lieu of his own.

The bunnumbeal is a level, cleared piece of ground, say fifteen to twenty yards in diameter, around which the men make their camps, the novices being placed lying upon green leaves strewn on the ground, in the custody of their sponsors. During the evening, by the light of the camp fires, the kooringal imitate different animals, some of which are the totems of those present, whilst others are connected with the myths and superstitions current among the people. The songs, dances, pantomimic displays, and the whole of the procedure, is interspersed with a good deal of obscenity which need not be described here. In former times, before the white man's authority became supreme, it was the custom to kill a man, and some of his flesh and blood was consumed by the men and novices. The posterior portion of his body was skinned, the pelt being then cut into strips and given to the principal men present at the gathering.

Early next day the boys are taken a little way from the bun-numbeal, and are shown a colossal horizontal image of Dharamoolan formed by heaping up the loose earth into human shape—his wife, on a smaller scale, lying near him. After that, one of the front upper incisors is punched out of each novice in succession. As the tooth is held up to public view, the men shout the names of remarkable places in the novice's country, and the totems of his family. The tooth is then handed to one of the boy's relatives who attaches it to his girdle. That evening at the camp, some of the old men, the bards of the tribe, chant Dharamoolan's songs, the words of which are as follows :—

1. Dhurram'ooloon gálay wir'rabroo gangá
   Bágoon-bána goo-ranána mamarána.
2. Dhurram'oolunba nganboan'ya gówine mirreng'ga.
3. Ngalal'bo wallool'ma jil'ly jil'leen may gangá.

The following morning the bullroarers are shown to the novices, who are at the same time cautioned against revealing what they have seen and been taught, during their sojourn in the bush.

We must now go back to the morning the boys were mustered, and marched away. Immediately after their departure, the men who had charge of the women set them at liberty, and the camp was shifted to another locality, perhaps some miles distant. The mothers of the novices, and the principal old women of the tribe, are collectively known as *yan'niwa*, and have a place to themselves called yanniwa-dhoogan, alongside the main camp. Since the morning on which their sons were taken from them, these women have carried pieces of burning bark, *dhung'gawa*., in their hands. Every morning at daylight, and every evening at dusk, the bull-roarer, mooroonga, is sounded by a man in close proximity, which is the signal for the yanniwa to sing the customary songs, called *mir'rilga.* While so employed they wave the burning dhungga, towards the east in the morning and towards the west in the evening. The following are specimens of these songs, taken down by us from the lips of some of the old women :—

One of the songs sung in the morning runs thus:—

A-jil-ba-râ′-ra mur′-ra-gâ-dyarh
Jil-ba-râ′-ra mur′-ra-gâ-dyarh
A-jil-ba-râ′-ra mur′-ra-gâ-dyarh
Yun′-nang-ngâ jin-ya ing-â
Jil-ba-râ′-râ !

The last syllable is long and high. The following is one of the songs for the evening:—

Wam-bâ′-oon neé-ngâ-lâ′ jir-ran′
Wam-bâ′-oon neé-ngâ-lâ′ jir-ran′ dīn-ngeé
Mīl-war-roó wīn-gow′-ra
Wam-bâ′-oon nee-nga-lâ,

the last syllable being very prolonged. Our informants could not give us any meaning of the words of these songs, except that "jirran dīn-ngee" means "sun going down."

We will now resume the narrative at the point where the novices were shown the bullroarer (mooroonga). Men and boys now start for the women's camp, and on their way thither the former go into a waterhole or creek and wash the black paint off their bodies. On arrival at their destination, the novices are taken to a bough enclosure called *watyoor*, where they are exhibited to their mothers with certain formalities, after which they are conducted to a camp by themselves, not far from the single men's quarters.

The foregoing is a very brief outline of the initiation ceremonies, the reader being referred for fuller details to the article on the *Bunan*, written by one of us in 1896.[1] A novice who has been admitted to the status of manhood by means of the Kudsha is required to attend the next Bunan which takes place among his people, for the purpose of receiving further instruction, and being advanced to a higher degree. It is necessary that each neophyte must participate in three or more inaugural ceremonies before he is fully qualified to take his place as a man of the tribe.

[1] R. H. Mathews, "The Bunan Ceremony of New South Wales"—American Anthropologist, (Washington) Vol. IX, pp. 327 – 344, plate vi.

It has occurred to us that the ceremony witnessed by Mr. D. Collins in 1795[2] was the Kudsha, because he makes no mention of the large circles raised upon the ground, nor is any reference made to the conspicuously marked trees always used at the Bunan ceremony. Many of the particulars given by Mr. Collins correspond with our statements, but it would appear that he was not permitted to see the more sacred portions of the rite.

TABLES TO FACILITATE THE LOCATION OF THE CUBIC PARABOLA.

By C. J. Merfield, F.R.A S.

[*Read before the Royal Society of N. S. Wales, December 5, 1900.*]

Introduction.—In a note,[2] read before the Engineering Section of this Society, the writer demonstrated a simple method of applying the cubic parabola, as a transition to connect the straights with the circular curves of railway lines; three tables are appended that are applicable to any radius. When it is desirable to apply a transition, and tables are not available, some difficulty presents itself to the engineer, this difficulty the appended table is designed to overcome.

The Railway Departments of this State adopt usually four chain transitions to all circular curves of radius twenty chains and less; tables[3] to facilitate the field operations in these cases have been published by the writer in the Journal of this Society. Adopting a fixed length for the transition has certain practical advantages, but circumstances occur when such practice becomes inconvenient. In other cases it would certainly be advantageous to eliminate

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[1] Account of the English Colony in New South Wales, (London, 1798) Vol. I., pp. 563 – 583, plates i. – viii.

[2] Vol. XXXI., p. LVI. [3] Vol. XXIX., p. 51.

the circular curve completely, this is very simply done in all cases, so long as the deflection angle of the tangents does not exceed 48° 11′ 22·″9, methods for so doing are explained in the note above referred to. When tables are accessible, then there is no more difficulty in laying out a cubic parabola than the circular curve, and little, if any, additional time involved in the location.

Method of preparing the tables.—The second column of the table contains ϕ the angle between the axis of X and the tangent to the transition and circular curve at the point of contact, where the radius of curvature ρ of the parabola must be equal to the radius R of the circular curve. It is therefore necessary to determine the coefficient of the adopted equation

$$y = mx^3 \text{.................} 1.$$

so that ρ equals R at the point of tangency.

From equation (1) we have

$$\frac{dy}{dx} = 3\,mx^2 = \tan\,\phi \text{..............} 2$$

$$\frac{d^2y}{dx^2} = 6\,mx$$

substituting these values in the equation

$$\rho = \left\{ 1 + \left(\frac{dy}{dx}\right)^2 \right\}^{\frac{3}{2}} \div \frac{d^2y}{dx^2} \text{..............} 3$$

it will be found after reduction, that

$$x/2\rho = \sin\,\phi\,\cos^2\phi \text{..............} 4$$

Making ρ equal to unity and adopting a suitable value of x, denoted by x_c, and which should not exceed $0{\cdot}68\ldots\rho$, then putting β in place of $x_c/2$ and writing μ for sin ϕ the above equation (4) becomes

$$\mu^3 - \mu + \beta = 0 \text{..............} 5$$

from which μ can be found and hence sin ϕ.

The solution of either equation 4 or 5 may be facilitated in the following way. Between the limits of the table this equation has three real roots, two positive and one negative, and at the limit,[1]

[1] It has been demonstrated that the practical application of the cubic parabola as a transition is limited. The cosine of the angle ϕ must not exceed $\sqrt{\frac{5}{6}}$, the congruous value of x_c/ρ being equal to $5\sqrt{\frac{1}{54}}$. See Journal of the Royal Society, N.S. Wales. 1897, Vol. XXXI., p. LIX.

when β equals $5\sqrt{\frac{1}{216}}$, there are two equal and positive, and one negative root. Under these conditions the following method of solution is available.

If we put

$$\text{Cos } 3\,a = -\frac{4\,\beta}{n^3}; \qquad n = 2\sqrt{\tfrac{1}{3}} \quad \text{Log } n = 0{\cdot}06246935$$

therefore

$$\text{Cos } 3\,a = -\beta\,[0{\cdot}4146520] \ldots\ldots\ldots\ldots 6$$

then

$$\text{Sin } \phi = n \cos\,(120° - a) \ldots\ldots\ldots\ldots\ldots 7$$

will be the root required. The quantity within brackets being a logarithm.

From a table of trigonometrical ratios, the angle ϕ may now be obtained, and from equation (2) the coefficient m may be determined. In the computation of the remaining quantities of the table, the following formulæ[1] have been used and require no explanation.

$$x' = \text{Sin } \phi$$

$$y_c = m\,x_c^3$$

$$h = y_c - \text{versin } \phi$$

$$S = x_c\,(1 + \tfrac{1}{10}\tan^2\phi - \tfrac{1}{72}\tan^4\phi + \tfrac{1}{208}\tan^6\phi \ldots\ldots \text{etc.}).$$

The final column contains the circular measure of 2ϕ.

In the tabulation of the several quantities, simplicity is gained by removing the factor R from the formulæ. The table therefore involves this quantity and contains the constants for the cubic parabola when R equals unity. For any other value of R the quantities must be multiplied by the radius of the circular curve to be used, with the exception of the angle ϕ and log m. A practical example will shew how the table is to be used.

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[1] The notation here used is that adopted in a paper to be found in Journal of the Royal Society of N. S. Wales, 1895, Vol. XXIX., p. 51. See also plate 10 of the same volume. x' = Distance along the axis x between the point x_c and a point at right angles to the tangent point of the circular curve. y_c = Value of the co-ordinate, to the point of contact of the transition and circular curve, measured along the axis X at the distance x_c from the origin. h = Distance between the parallel tangents. s = Length of the arc of the cubic parabola.

Practical example.—Let it be required to find the constants for a transition curve when

$$x_c = 8 \qquad x_c/R = 0\cdot32$$
$$R = 25 \qquad 2 \log R = 2\cdot795880$$

The argument of the table being x_c/R we find opposite 0·32 the following quantities with which are written the operations required to reduce them to the values for R.

$$\phi = 9^\circ\ 27'\ 54\cdot''4$$
$$\text{Log } m + 2 \log R = 9\cdot734558$$
$$2 \log R = 2\cdot795880$$
$$\log m = 6\cdot938678$$

$$x' = 0\cdot164447 \times R$$
$$y_c = 0\cdot017783 \times R$$
$$h = 0\cdot004169 \times R$$
$$s = 0\cdot320886 \times R.$$

The value of y at any other point may be found from the equation

$$y = m\,x^3$$

or

$$y = y_c \times \left(\frac{x}{x_c}\right)^3$$

Remarks.—It is not necessary that R be integral, any value may be used, also any unit of measurement may be adopted for R, feet, chains, metres, etc., etc. To avoid interpolation in general cases, always take x_c so that when divided by R the result will give two significant figures, thus if it be desired to apply a transition when x_c equals about 5 say, and R equals 9, it will be better to take

$$x_c = 4\cdot95 \text{ or } x_c = 5\cdot04$$

so that the argument will be either 0·55 or 0·56 respectively.

TRANSITION CURVE TABLE.

$\frac{x_c}{R}$	ϕ °	′	″	Log $(m R^2)$	$\frac{x'}{R}$	$\frac{y_c}{R}$	$\frac{h}{R}$	$\frac{S}{R}$	$\frac{K}{R} = \frac{2\phi}{R}$
0·00	0	0	0·0	∞	0·000000	0·000000	0·000000	0·000000	0·000000
0·01	0	17	11·3	1·221855	0·005000	0·000017	0·000004	0·010000	0·010001
0·02	0	34	22·9	0·920878	0·010001	0·000067	0·000017	0·020000	0·020002
0·03	0	51	34·8	0·744872	0·015003	0·000150	0·000038	0·030001	0·030008
0·04	1	8	47·2	0·620049	0·020008	0·000267	0·000067	0·040002	0·040019
0·05	1	26	0·4	0·523287	0·025016	0·000417	0·000104	0·050004	0·050037
0·06	1	43	14·5	0·444376	0·030027	0·000601	0·000150	0·060006	0·060063
0·07	2	0	29·6	0·377552	0·035043	0·000818	0·000204	0·070009	0·070100
0·08	2	17	46·1	0·319806	0·040064	0·001069	0·000266	0·080013	0·080150
0·09	2	35	4·0	0·268932	0·045092	0·001354	0·000337	0·090018	0·090214
0·10	2	52	23·6	0·223487	0·050126	0·001673	0·000416	0·100025	0·100294
0·11	3	9	45·0	0·182442	0·055168	0·002026	0·000503	0·110034	0·110392
0·12	3	27	8·5	0·145034	0·060218	0·002413	0·000599	0·120044	0·120510
0·13	3	44	34·2	0·110687	0·065278	0·002835	0·000703	0·130056	0·130650
0·14	4	2	2·4	0·078953	0.070348	0·003291	0·000814	0·140070	0·140813
0·15	4	19	33·2	0·049474	0·075429	0·003782	0·000933	0·150086	0·151002
0·16	4	37	6·9	0·021966	0·080522	0·004308	0·001061	0·160104	0·161219
0·17	4	54	43·7	9·996194	0·085628	0·004870	0·001197	0·170125	0·171465
0·18	5	12	23·7	9·971962	0·090747	0·005467	0·001341	0·180149	0·181744
0·19	5	30	7·4	9·949111	0·095881	0·006100	0·001493	0·190176	0·192058
0·20	5	47	54·8	9·927502	0·101031	0·006770	0·001653	0·200206	0·202408
0·21	6	5	46·2	9·907018	0·106198	0·007476	0·001821	0·210239	0·212797
0·22	6	23	41·9	9·887559	0·111382	0·008219	0·001997	0·220276	0·223227
0·23	6	41	42·1	9·869036	0·116585	0·009000	0·002181	0·230317	0·233701
0·24	6	59	47·1	9·851375	0·121808	0·009818	0·002372	0·240361	0·244221
0·25	7	17	57·2	9·834510	0·127051	0·010674	0·002571	0·250409	0·254790
0·26	7	36	12·5	9·818382	0·132317	0·011569	0·002777	0·260462	0·265411
0·27	7	54	33·6	9·802939	0·137606	0·012503	0·002991	0·270520	0·276087
0·28	8	13	0·5	9·788135	0·142919	0·013477	0·003212	0·280582	0·286420
0·29	8	31	33·8	9·773930	0·148258	0·014491	0·003440	0·290650	0·297614
0·30	8	50	13·6	9·760287	0·153625	0·015547	0·003676	0·300723	0·308473
0·31	9	9	0·4	9·747173	0·159021	0·016644	0·003919	0·310802	0·319399
0·32	9	27	54·4	9·734558	0·164447	0·017783	0·004169	0·320886	0·330395
0·33	9	46	56·2	9·722417	0·169905	0·018965	0·004426	0·330977	0·341466
0·34	10	6	6·1	9·710725	0·175396	0·020191	0·004689	0·341074	0·352616
0·35	10	25	24·5	9·699461	0·180922	0·021462	0·004959	0·351179	0·363848
0·36	10	44	51·9	9·688605	0·186485	0·022778	0·005236	0·361291	0·375167
0·37	11	4	28·7	9·678139	0·192087	0·024140	0·005519	0·371410	0·386578
0·38	11	24	15·5	9·668046	0·197730	0·025550	0·005807	0·381538	0·398085
0·39	11	44	12·7	9·658313	0·203417	0·027009	0·006101	0·391674	0·409693
0·40	12	4	20·0	9·648927	0·209149	0·028517	0·006401	0·401818	0·421408
0·41	12	24	40·8	9·639875	0·214928	0·030077	0·006706	0·411972	0·433237
0·42	12	45	13·0	9·631147	0·220758	0·031668	0·007016	0·422137	0·445185
0·43	13	5	58·0	2·622733	0·226642	0·033353	0·007331	0·432312	0·457257
0·44	13	26	56·8	9·614624	0·232581	0·035074	0·007651	0·442497	0·469462
0·45	13	48	9·9	9·606814	0·238580	0·036851	0·007974	0·452694	0·481807
0·46	14	9	38·4	9·599295	0·244642	0·038687	0·008301	0·462903	0·494301
0·47	14	31	23·1	9·592062	0·250770	0·040583	0·008631	0·473125	0·506951
0·48	14	53	24·9	9·585110	0·256968	0·042543	0·008963	0·483361	0·519768
0·49	15	15	45·0	9·578435	0·263242	0·044568	0·009298	0·493612	0·532762
0·50	15	38	24·5	9·572035	0·269595	0·046660	0·009634	0·503878	0·545944
0·51	16	1	24·7	9·565907	0·276032	0·048822	0·009970	0·514160	0·559326
0·52	16	24	46·9	9·560051	0·282560	0·051058	0·010307	0·524460	0·572923
0·53	16	48	32·8	9·554465	0·289184	0·053370	0·010643	0·534778	0·586748
0·54	17	12	43·8	9·549151	0·295911	0·055761	0·010976	0·545116	0·600818
0·55	17	37	22·1	9·544112	0·302749	0·058236	0·011306	0·555475	0·615152
0·56	18	2	29·6	9·539349	0·309706	0·060801	0·011633	0·565857	0·629769
0·57	18	28	8·6	9·534869	0·316792	0·063459	0·011954	0·576264	0·644692
0·58	18	54	21·9	9·530677	0·324018	0·066216	0·012267	0·586698	0·659947
0·59	19	21	12·4	9·526782	0·331395	0·069078	0·012570	0·597160	0·675563
0·60	19	48	43·5	9·523193	0·338937	0·072052	0·012861	0·607654	0·691572
0·61	20	16	59·2	9·519923	0·346659	0·075147	0·013138	0·618182	0·708014
0·62	20	46	4·0	9·516987	0·354581	0·078372	0·013397	0·628748	0·724932
0·63	21	16	3·1	9·514405	0·362723	0·081738	0·013635	0·639355	0·742376
0·64	21	47	2·9	9·512199	0·371111	0·085259	0·013847	0·650009	0·760409
0·65	22	19	11·0	9·510399	0·379774	0·088949	0·014028	0·660715	0·779105
0·66	22	52	36·5	9·509041	0·388751	0·092827	0·014170	0·671479	0·798551
0·67	23	27	20·8	9·508171	0·398085	0·096916	0·014265	0·682310	0·818858
0·68	24	4	8·0	9·507848	0·407835	0·101245	0·014301	0·693219	0·840163

On a NEW AROMATIC ALDEHYDE OCCURRING in EUCALYPTUS OILS.

By Henry G. Smith, F.C.S., Assistant Curator, Technological Museum, Sydney.

[*Read before the Royal Society of N. S. Wales, December 5, 1900.*]

In a paper read before this Society in June of this year,[1] the announcement was made that the aldehyde occurring in Eucalyptus oils, and which for a long time had been supposed to be cuminaldehyde, was most probably not that substance, the reasons, then available for that conclusion, being given. I was induced to investigate this subject because it was found that this aldehyde occurs in a very large number of Eucalyptus oils in varying amounts, and is probably present in the majority of them.

In the oils obtained from the true "boxes," *Eucalyptus hemiphloia*, *E. albens*, *E. Woollsiana*, etc., this constituent occurs in greatest amount, and if we take *E. hemiphloia* as the extreme end of the list of those species in which this aldehyde occurs most plentifully, we can descend the scale through the "boxes" into the "gums," and so onward to those species the oils of which contain the greatest quantity of eucalyptol or cineol.

From the results of this research this appears to be quite feasible, as it is probable that the natural eucalyptol in Eucalyptus oils is derived directly or indirectly from this aldehyde, and we may assume that it will eventually be proven that the yellowish tint in Eucalyptus oils of the better class, or those richest in eucalyptol, is due to the original presence of this aldehyde, as the oils containing this aldehyde when rectified are all more or less yellow, and are generally not rich in eucalyptol. Oils very rich in phellandrene, such as *E. dives*, *E. radiata*, etc., do not appear to contain this aldehyde, it being replaced in those oils by the ketone of peppermint odour, consequently these oils are generally almost

[1] On the amyl ester of eudesmic acid occurring in Eucalyptus oils, p. 72.

colourless and often water-white, especially when rectified; they usually also contain very little eucalyptol.

Now oils rich in this aldehyde do not appear to contain phellandrene, as it is not found in the oils of the "boxes" above mentioned, but it does not follow that phellandrene is always absent in the oils of species which contain this aldehyde, in minute quantity, because in several both these constituents have been found together. Phellandrene is a most unsatisfactory constituent when only occurring in small quantity in the oil of any species of Eucalyptus at certain times of the year; as at other times of the year no phellandrene can be detected in the oil. It appears to be very unstable, and this fact must always be taken into consideration.

The oils from the "boxes" above named, although containing no phellandrene, and but little pinene, were all lævorotatory, showing that the rotation must be due to the presence of some substance having a high boiling point, and as the principal constituent in the higher fractions appeared to be this aldehyde, it was assumed that the rotation must be due to that substance, and this has been proved to be the case.

The optical rotations in a 100 mm. tube for the oil of *E. hemiphloia*, obtained in September, were as follows:—

Crude oil...	= – 6·8°
Fraction boiling below 183° C.... ...	= – 3·2
Fraction 183 – 215° C.	= – 10·3
Fraction 215 – 230° C.	= – 25·0

The optical rotations in a 100 mm. tube for the oil of *E. albens*, obtained in June, were as follows:—

Crude oil...	= – 6·5°
Fraction boiling below 183° C.... ...	= – 5·6
Fraction 183 – 225° C.	= – 6·0
Fraction 225 – 255° C.	= – 14·6

Corresponding results were also obtained from the oils of several other species.

The reason why the oil of *E. cnerifolia* of South Australia is lævorotatory is now explained, it is due to the presence of this aldehyde. Messrs. Faulding and Co., of Adelaide, South Australia, kindly sent us a sample of the crude oil of this species from which the pure aldehyde was obtained. The optical rotations of this oil in a 100 mm. tube, were as follows:—

Crude oil...	=	– 5·4°
Fraction boiling below 190° C.... ...	=	– 3·0
Fraction 190 – 220° C.	=	– 5·35

I have seen an analysis of the oil of *E. cnerifolia*, by Mr. R. H. Davis, F.C.S., made several years ago, the most interesting point being where he states the deviation of the oil to be, in a 100 mm. tube, 3·53 degrees to the left.

There is a remarkable constancy (within certain limits) in the characters of the oils obtained from identical species of Eucalypts. We have numerous instances of this fact, one of which will now suffice, that of the "Mallee Box," *E. Woollsiana*, the oil of which contains this aldehyde in fair quantity. This is a species growing in the western portion of this State, and has just been named and described by my colleague Mr. R. T. Baker, F.L.S.[1] In working out this species, four different quantities of material were obtained from various localities where it grows plentifully; the results from these were as follows :—

	No. 1.	No. 2.	No. 3.	No. 4.
Yield in percentage of oil on a commercial basis ...	0·493	0·4435	0·524	0·517
Rotation crude oil, 100 mm. tube	– 12·2	– 9·5	– 15·8	– 12·7
Specific gravity, at 15° C. ...	0·889	0·8917	0·8947	0·8977

These oils were all free from phellandrene, and the rotation shows them all to contain about the same amount of the aldehyde. Only a small quantity of eucalyptol was present in either sample. This constancy in constituents of the oils of the various species of Eucalypts can be taken advantage of, in obtaining those several constituents now known to occur in the oils of this remarkable group of trees.

[1] Proc. Linn. Soc. N. S. Wales., 1900.

So far as the Eucalypts of New South Wales are concerned, it is now fairly well known in which particular species any constituent occurs in greatest amount. This fact was taken advantage of in the preparation of this aldehyde. Our researches had shown that this aldehyde occurs probably in greatest amount in the oil obtained from *E. hemiphloia.* Our sample of *E. hemiphloia* had been obtained from Emu Plains. But as this species grows in abundance at Belmore, in the neighbourhood of Sydney, and this locality is easy of access, fresh material was obtained from there, with the result that the oil was found to be practically identical with that obtained a year previous from Emu Plains.

It is well known that the oil of *E. cneroifolia* of South Australia is rich in eucalyptol. In the fraction of the oil of *E. hemiphloia* distilling below 183° C. (representing 73 per cent. of crude oil) 24 per cent. of eucalyptol was found, while the same fraction of the oil of *E. albens* contained 37 per cent. of eucalyptol. Our results indicate that in the majority of instances the maximum amount of eucalyptol in Eucalyptus oil is reached during the fall of the year and towards the winter months, but that as the spring advances and the trees become more vigorous in growth, the minimum amount of eucalyptol is present, while the yield of oil obtainable from the leaves is greater, the tendency being for the constituents to form eucalyptol as the year advances.

When the pure aldehyde was treated with an alkaline solution of potassium permanganate, oxidation took place rapidly with the generation of a considerable amount of heat. One of the products thus formed was apparently eucalyptol, and although (owing to want of sufficient material) it has not yet been isolated so that its physical characters might be determined, yet, from its characteristic odour and pungency I have no doubt but that eucalyptol is formed when the aldehyde is thus treated. Several determinations were made and always with the same result. When the oxidation was carried out with potassium bichromate in sulphuric acid, the acid formed was quite different from that obtained by potassium permanganate; eucalyptol was not formed by this method, simple oxidation of the aldehyde group to carboxyl alone taking place, this was proved by the analysis of the silver salt of the acid. These results open up a very interesting line for research, and further investigations will eventually be undertaken on this subject.

In a paper[1] read before this Society, August 2nd, 1899, p. 90, it was shown that by natural oxidation of the oil of *E. eugenoides* eucalyptol had been formed. This interesting fact has also been noticed in the oil obtained from the "Red Box" of Rylstone, *E. ovalifolia*, an oil which contains this aldehyde, but in which phellandrene is also present. Eighteen months after distillation and analysis, having occasion to again investigate the sample, it was found that the oil had increased considerably in eucalyptol content, and that the rectified oil had reduced its rotation in 100 mm. tube $-14{\cdot}1°$ to $-12°$. As phellandrene was originally present in this oil, the lævorotation was of course partly due to that substance and partly to the presence of the aldehyde.

By acting upon an alcoholic solution of the aldehyde with sodium an odoriferous oil was obtained; this is probably the alcohol corresponding to the aldehyde. Subsequent investigation will prove whether it is that substance. The oil of *E. patentinervis* has already been shown to contain an aromatic alcohol (amyl ester of eudesmic acid, *loc. cit.*) which could not satisfactorily be located; the saponified oil had an odour identical with that of the oil obtained by reduction of the aldehyde, and it is thus probable that this alcohol occurs naturally in some Eucalyptus oils.

Experimental.

Preparation of the pure aldehyde.—1000 cc. of the crude oil of *Eucalyptus hemiphloia* obtained at Belmore, near Sydney, in September, was distilled. Constituents boiling below 190° C. were removed, the remainder was agitated with acid sodium sulphite and a crystalline mass thus obtained. After twenty-four hours this was purified by well washing with ether-alcohol, drying the

[1] On the crystalline camphor of Eucalyptus oil (eudesmol) and natural formation of eucalyptol (cineol).

crystalline mass on porous plate, and decomposing with sodium carbonate. The separated oil was well washed and then steam-distilled; 33 cc. of the aldehyde was thus obtained from a litre of crude oil, equal to 3·3 per cent. The aldehyde was slightly yellowish in tint, very mobile, and had a not unpleasant odour, being more aromatic than cuminaldehyde. It is soluble in the usual solvents for such substances.

Specific gravity of the aldehyde.—The aldehyde was carefully cooled to 15° C. in a pyknometer standardised at 15° C. The specific gravity was 0·9478. Another determination in a different pyknometer gave 0·9476, this was also cooled to 15° C., this gives a mean specific gravity of 0·9477 at 15° C.

Specific rotation of the aldehyde.—The rotation of the aldehyde in a 100 mm. tube at 22° C. was $-46·6°$, thus the specific rotation is $[\alpha]_D$ $-49·19°$.

Preparation of the oxime.—The aldehyde was dissolved in alcohol a saturated aqueous solution of hydroxylamine hydrochloride added, and then a solution of sodium carbonate. This was afterwards heated some time at about 80° C. and poured into water; the oily substance which separated soon crystallised in fine colourless crystals, showing faces having a fine lustre. The crystals were then drained on a pcrous plate, when they were obtained almost pure. The crystals were purified from alcohol until of constant melting point. The pure oxime melted at 84° C. When the base was separated with caustic potash instead of sodium carbonate, identical crystals were obtained, but the oily product was much darker and the yield of crystals was not so large.

This is the only aldehyde of this character occurring in this class of oils, as several of the higher boiling fractions from various oils were added together, including those of *E. cneroifolia*, *E. albens*, and *E. Woollsiana.* The aldehyde was extracted with acid sodium sulphite in the usual way, purified, and the oxime formed; this oxime also melted at 84° C.

Preparation of the hydrazone.—The aldehyde reacts readily with phenylhydrazine. The hydrazone was prepared as follows: The aldehyde was dissolved in glacial acetic acid and phenylhydrazine added; the solution was then heated on the water bath with the addition of a little sodium acetate. On adding dilute acetic acid a copious yellow crystalline mass was obtained, this was well washed with acetic acid, dried on slab and purified several times from alcohol. The hydrazone melted quite sharply at 105° C. with decomposition. The determination of the melting point was best taken on cover-slip on the surface of mercury, the closed tube method not being so satisfactory.

Preparation of the naphthocinchoninic acid.—A solution of β-naphthylamine in absolute alcohol was added to a mixture of the aldehyde and pyruvic acid also dissolved in absolute alcohol, this was heated on the water bath with upright condenser. In less than fifteen minutes after the alcohol boiled, a yellow crystalline mass had formed, this was filtered off and washed with ether until quite pure. The alkyl-β-naphthocinchoninic acid thus formed was sulphur-yellow in colour, it melted sharply at 247° C. with decomposition. The formation of the product with this aldehyde is easy of accomplishment, the reaction taking place readily.

Boiling point of the aldehyde.—The boiling point of the aldehyde was 210° C., it is doubtful if the aldehyde be at all decomposed at this temperature, but at an increased temperature sufficient to entirely volatilise it slight decomposition takes place; for this reason attempts to determine its vapour density were not satisfactory, concordant results not being obtained.

The aldehyde reduced an alkaline silver solution with the formation of a mirror, and it also answered to Schiff's reaction.

Analysis of the aldehyde.—The aldehyde on analysis gave the following results:—

0·1416 gave 0·4101 CO_2 and 0·1293 H_2O
C = 79·03; H = 10·141

0·1271 gave 0·3711 CO_2 and 0·1157 H_2O
C = 79·62; H = 10·119

From the mean of these results, or from either, we may consider the formula for the aldehyde to be $C_{10}H_{14}O$, especially as this formula was confirmed by analysis of the silver salt of the corresponding acid.

$C_{10}H_{14}O$ requires 80 C., and 9·33 H. per cent.

Oxidation of the aldehyde with potassium bichromate.—It was found that an alkaline solution of potassium permanganate acted very energetically on the aldehyde, so potsassium bichromate in sulphuric acid was used instead; this substance acted much more slowly. By heating directly over a low flame using an upright condenser, or for some hours on the water-bath, a dark coloured cake eventually formed on the surface of the liquid, on cooling, this became quite brittle. The solid portion was collected, powdered, boiled in a dilute soda solution when the chromium salt was decomposed. The filtrate was acidified with hydrochloric acid, when a colourless acid was precipitated, this was well washed with water and purified from dilute alcohol from which it was obtained in interlaced crystals which gave the material a soft matted appearance. The purified substance melted sharply at 110° C.; on allowing the melted acid to cool, it crystallised in stout microscopic prisms which melted again at 110° C. The acid was soluble in boiling water, but little soluble in cold water, very soluble in alcohol and in ether, from which it crystallised well. The acid is saturated, as its aqueous solution did not bleach bromine water. The ammonium salt crystallised well, it formed a silver salt readily, also a light blue copper salt with copper sulphate; barium and calcium chlorides did not give precipitates. Ferric chloride gave no coloration in alcoholic solution. The formula for this acid is $C_{10}H_{14}O_2$ the aldehyde group alone being oxidised to carboxyl; this is shown by the determination of the silver salt. 0·1905 gramme of the silver salt gave 0·0755 gramme metallic silver, equal to 39·63 per cent. silver, $C_{10}H_{13}AgO_2$ contains 39·49 per cent. silver. The molecular weight of the silver salt $=272$ giving a molecular value for the acid between 165 and 166. $C_{10}H_{14}O_2=166$. This is, therefore, the corresponding acid of the aldehyde, or aromadendric acid.

Oxidation of the aldehyde with potassium permanganate.—The aldehyde was readily and energetically attacked by an alkaline solution of potassium permanganate. The odour of the original aldehyde soon changed to one indicating somewhat that of cinnamon. This odour soon vanished and was eventually replaced by the characteristic odour of pure eucalyptol. The excess of permanganate was reduced, the clear filtrate acidified with hyrdochloric acid and evaporated down to a small bulk; a white solid acid was thus obtained, this was filtered off, well washed, and purified from a boiling mixture of two parts alcohol and one part water; on boiling off the alcohol most of the acid precipitated, it being not readily soluble in boiling water. It was easily soluble in alcohol and in ether. This acid melted at 259 – 260° C. with formation of the anhydride. The acid readily sublimed on melting, forming a well crystallised sublimate which melted at 152° C. Both the acid and the anhydride are crystallised bodies before and also after melting. The anhydride readily sublimed, it being easily driven from one watch glass to another; it dissolved easily in a small quantity of boiling water, and crystallised out beautifully on cooling, it being practically insoluble in cold water; it was very soluble in alcohol and in ether. The original acid was apparently not regenerated by boiling the anhydride in water, as the separated crystals melted again at the same temperature as the sublimate. The anhydride commenced to sublime at about 135° C., but if the heating was somewhat rapid it melted sharply at 152° C.

From the characters of the acid and its anhydride, formed by the oxidation of the aldehyde with potassium permanganate, and the formation at the same time of eucalyptol, it might be considered that the products were cineolic acid and its corresponding anhydride; but the melting points obtained do not agree with those given for cineolic acid and its anhydride, consequently further investigation of these oxidation products is required.

The name proposed for this aldehyde is *aromadendral*, utilising the name for the genus given by Dr. W. Anderson, the surgeon of Captain Cook's second and third expeditions. The corresponding alcohol would then be *aromadendrol.* The acid obtained by oxidising the aldehyde group with potassium bichromate is thus *aromadendric acid.* It would have been preferable if the name eucalyptal could have been adopted, but there are already two substances that have been given the name eucalyptic acid, namely: that of L. Rummel for a substance obtained from the wood of *E. globulus* (art. *E. globulus*, Eucalyptographia), and that of H. Weber for one from the leaves of *E. globulus* (Wittstein's Organic constituents, p. 80). Utilisation of the most appropriate nomenclature is thus barred.

I wish to express my thanks to my colleague Mr. R. T. Baker, F.L.S., for botanical help in the preparation of this paper, and also for the material, which is thus of undoubted authenticity.

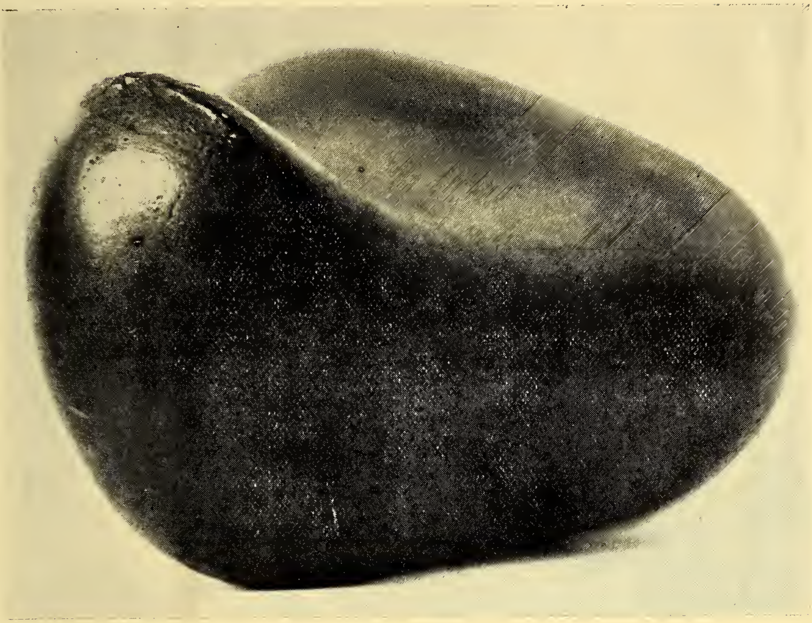


Fig. 1.

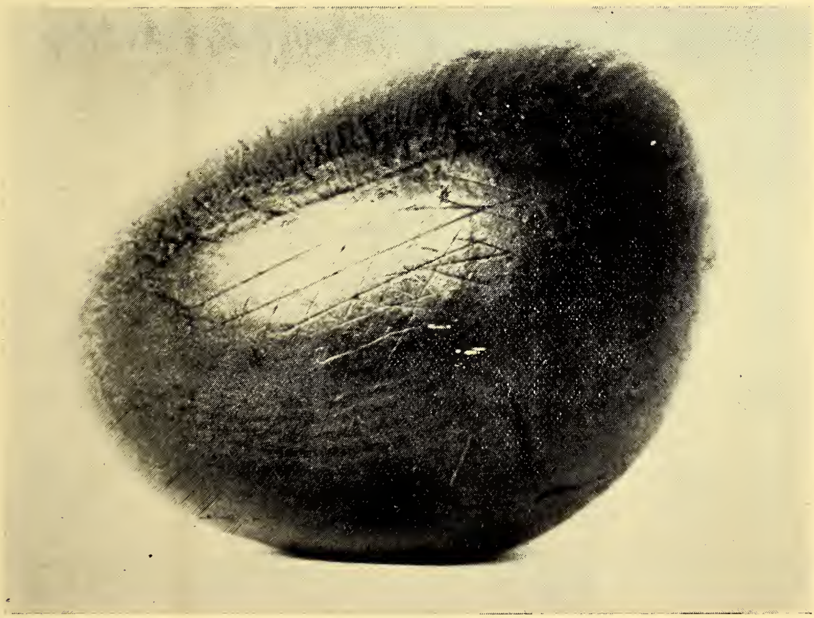
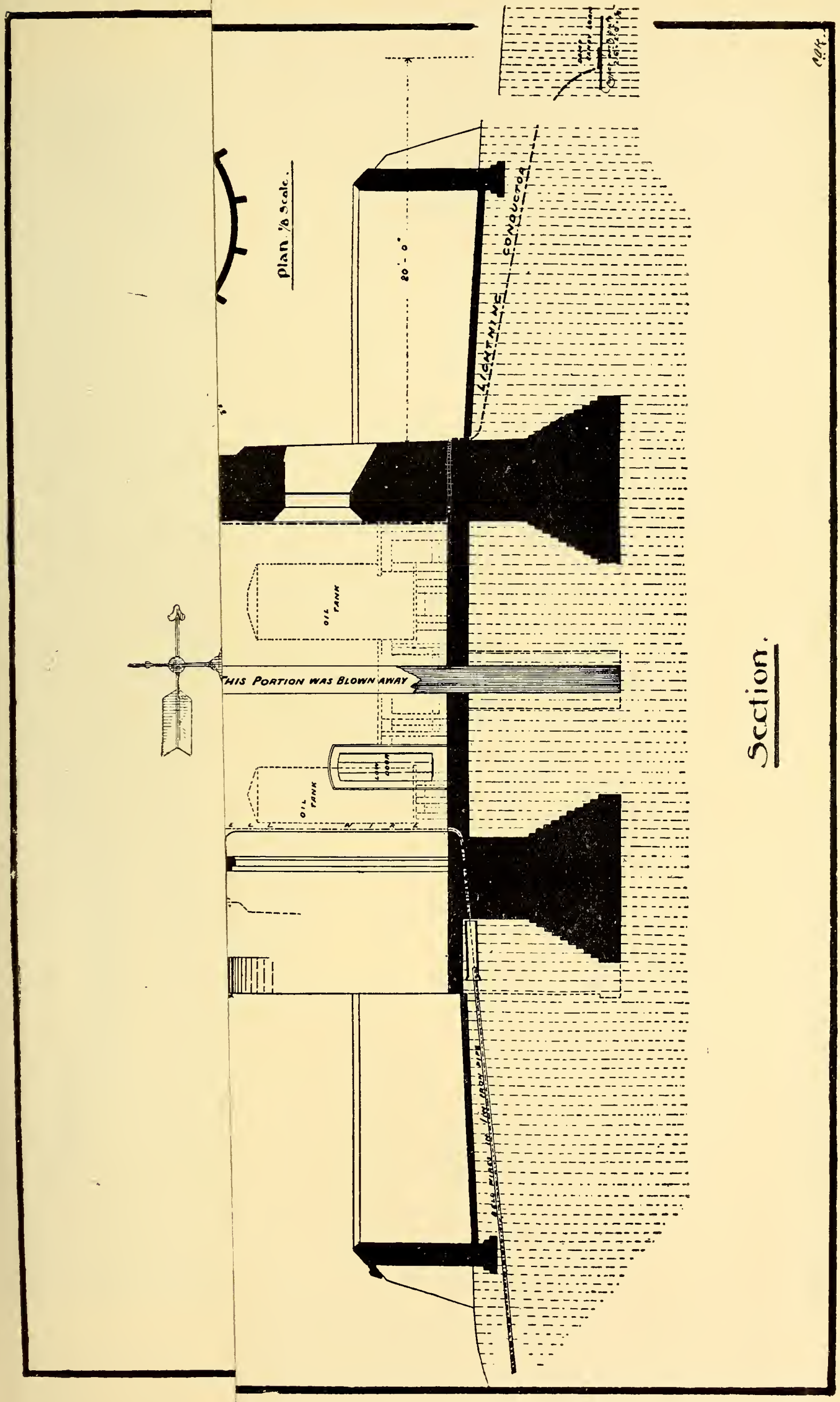
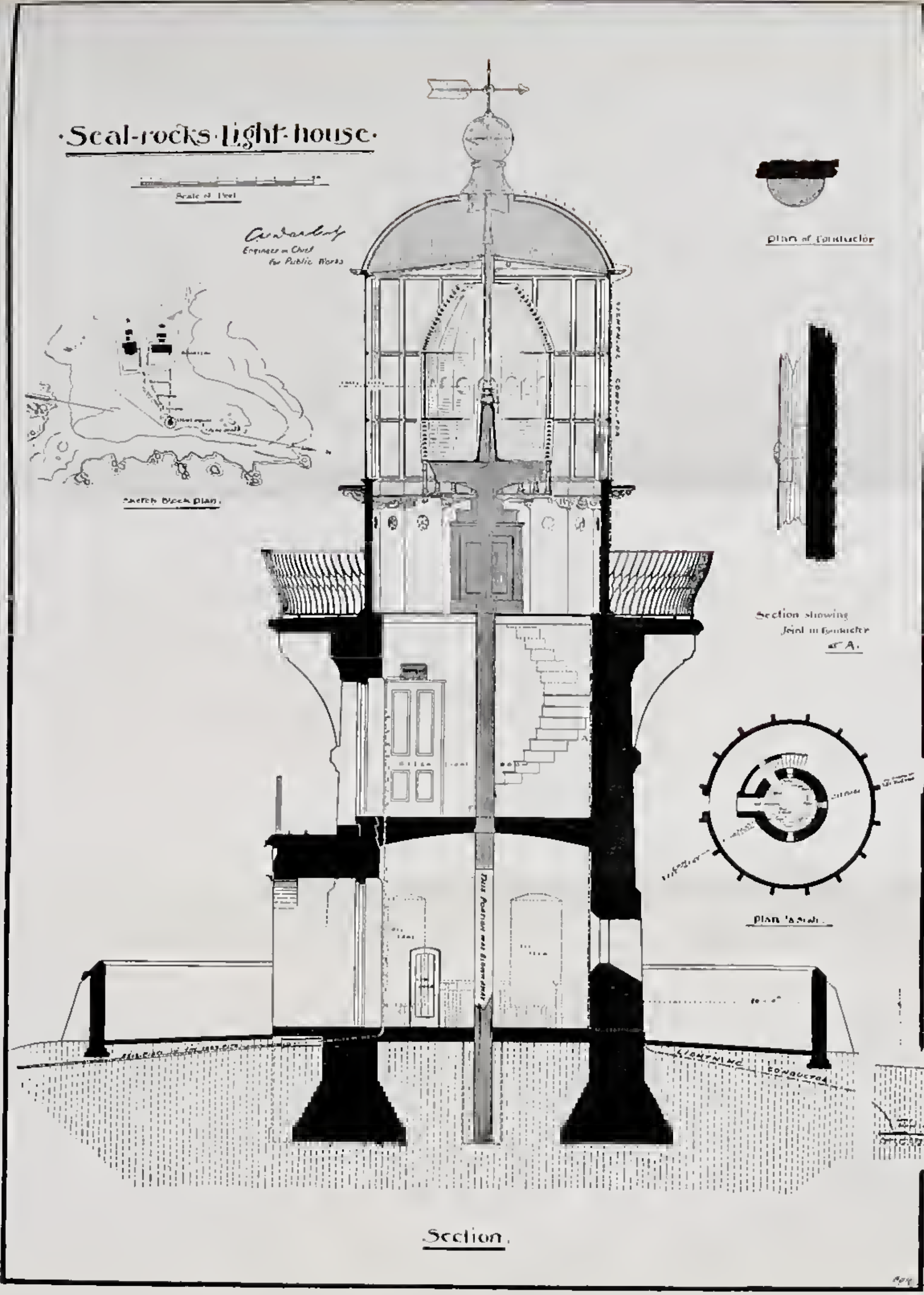


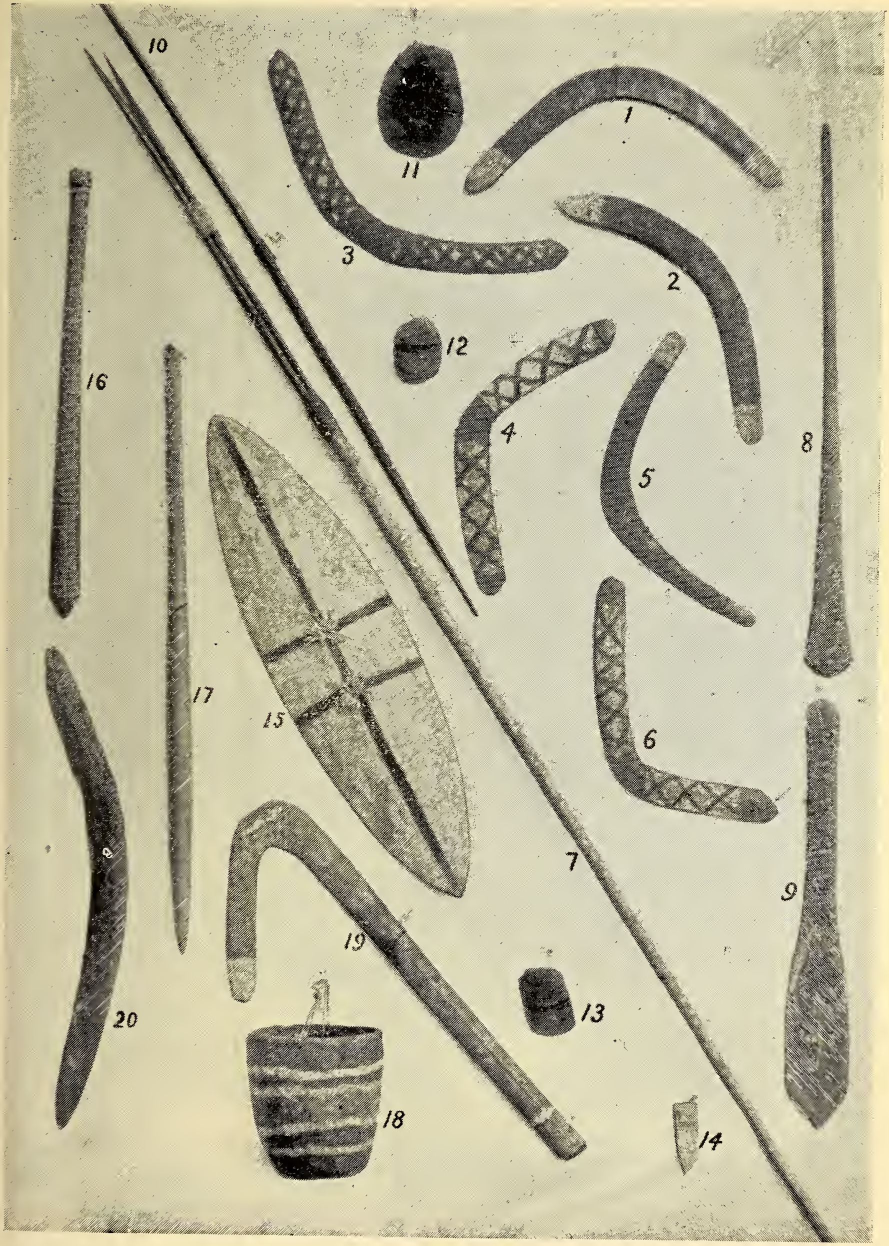
Fig. 2.

Fig. 1.—Foreshortened view of meteorite showing details on smaller end.

Fig. 2.—Larger end, showing Widmanstatten figures: these are distinctly shown on the original, but are somewhat emphasised in the photograph.


Plan 1/8 Scale.
LIGHTNING CONDUCTOR
20' - 0"
OIL TANK
THIS PORTION WAS BLOWN AWAY
OIL TANK
Section.


·Seal-rocks·Light·house·
Scale of Feet
Engineer in Chief for Public Works
Sketch Block plan
plan of Conductor
Section showing
Joint in Conductor
at A.
Lightning Conductor
Section.


10
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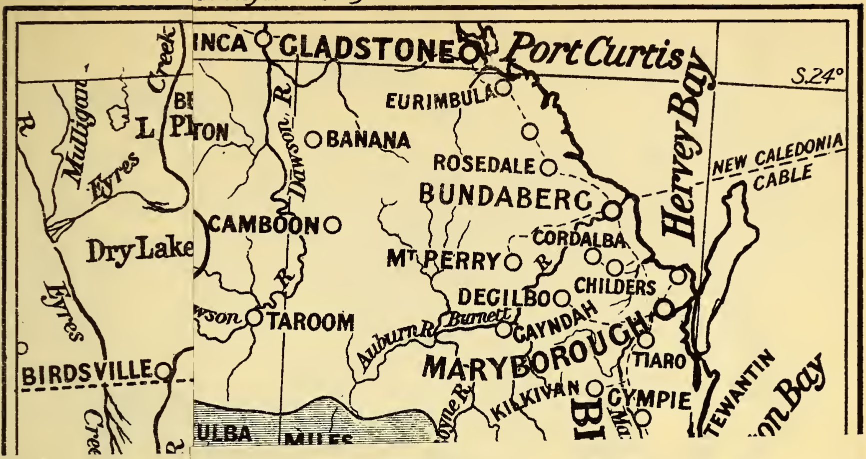
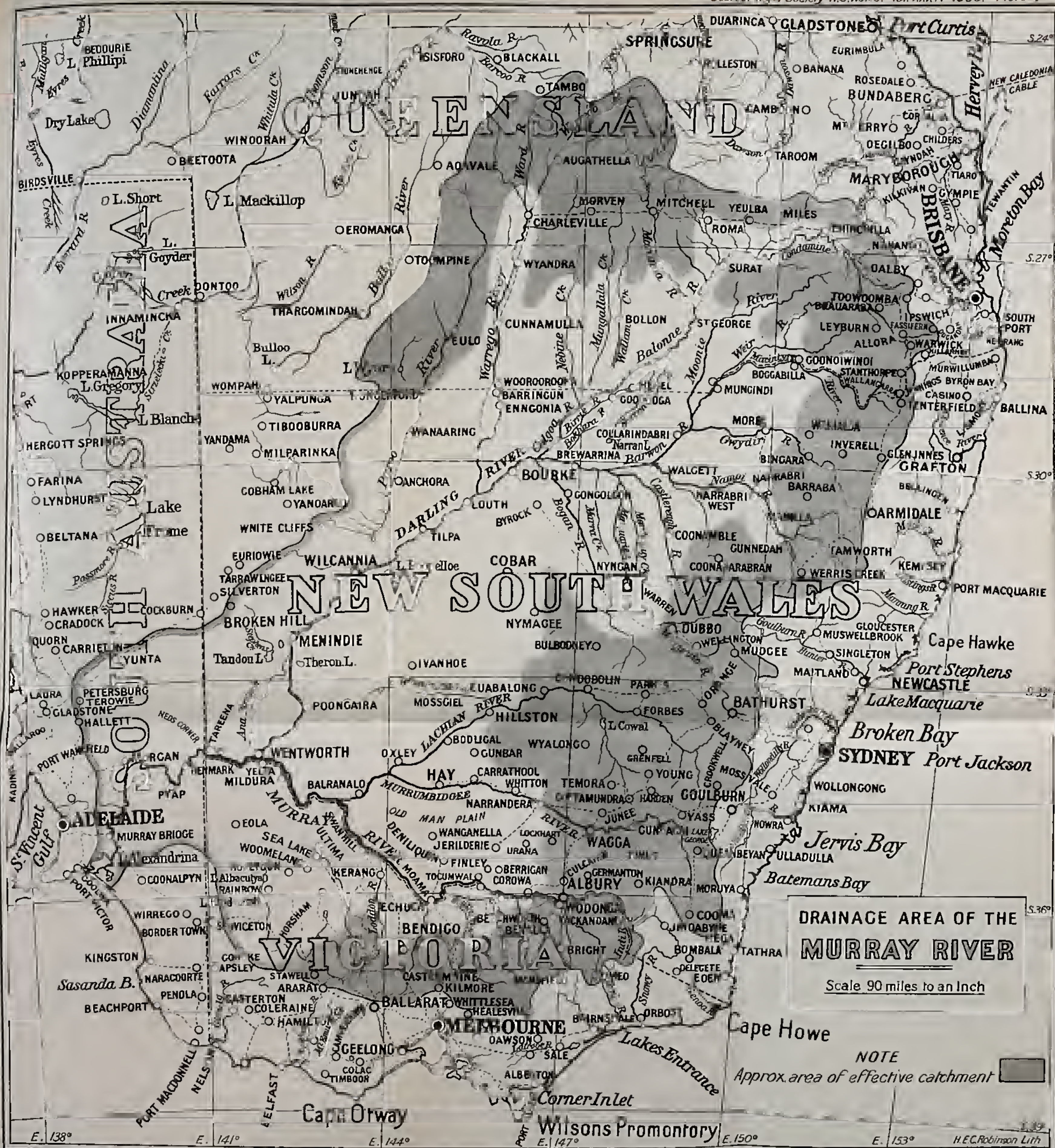
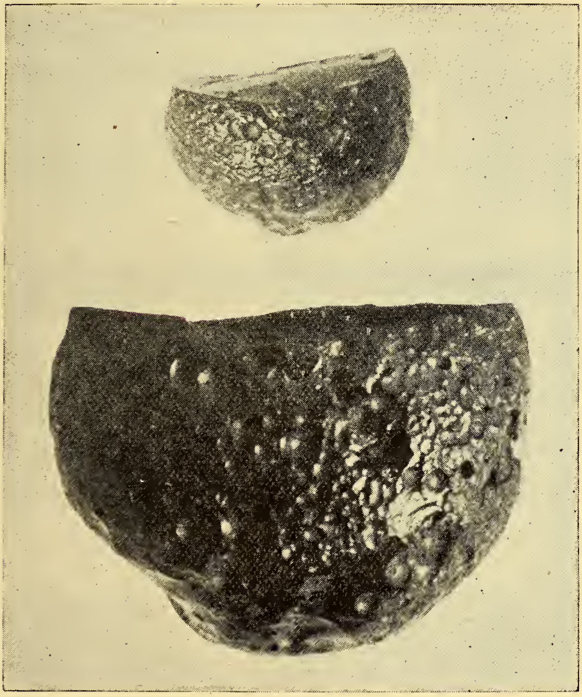

INCA
GLADSTONE
Port Curtis
S.24°
EURIMBULA
Hervey Bay
BANANA
ROSEDALE
NEW CALEDONIA CABLE
BUNDABERG
Mulligan
Eyres
Creek
Dawson R.
CAMBOON
Dry Lake
CORDALBA
Mt PERRY
CHILDERS
DECILBO
TAROOM
Burnett
CAYNDAH
Auburn R.
MARYBOROUGH
TIARO
BIRDSVILLE
KILKIVAN
GYMPIE
TEWANTIN
ULBA
MILES


DRAINAGE AREA OF THE
MURRAY RIVER
Scale 90 miles to an Inch
NOTE
Approx. area of effective catchment
QUEENSLAND
NEW SOUTH WALES
VICTORIA
SOUTH AUSTRALIA
SYDNEY
Port Jackson
BRISBANE
Moreton Bay
ADELAIDE
MELBOURNE
NEWCASTLE
Port Stephens
Lake Macquarie
Broken Bay
Jervis Bay
Batemans Bay
Cape Howe
Lakes Entrance
Corner Inlet
Wilsons Promontory
Cape Hawke
Port Curtis
Hervey B.
St Vincent Gulf
L. Alexandrina
Lake Frome
L. Blanche
L. Gregory
Dry Lake
L. Phillipi
L. Mackillop
DARLING
MURRAY
MURRUMBIDGEE
LACHLAN RIVER
Barwon
Gwydir
Condamine
Balonne
Warrego
Bulloo
Paroo
Moonie
Castlereagh
Bogan
Namoi
Diamantina
Thomson
Barcoo R.
Wilson R.
Strzelecki Ck.
Cooper
Creek
OLD MAN PLAIN
BOURKE
BROKEN HILL
WILCANNIA
MENINDIE
WENTWORTH
MILDURA
HAY
WAGGA
ALBURY
WODONGA
ECHUCA
BENDIGO
BALLARAT
GEELONG
BATHURST
GOULBURN
DUBBO
MUDGEE
ORANGE
FORBES
HILLSTON
BALRANALD
COBAR
NYNGAN
WALGETT
MOREE
TAMWORTH
ARMIDALE
GRAFTON
WARWICK
TOOWOOMBA
DALBY
ROMA
MITCHELL
CHARLEVILLE
CUNNAMULLA
ST GEORGE
GOONDIWINDI
BUNDABERG
MARYBOROUGH
GYMPIE
SPRINGSURE
TAMBO
BLACKALL
THARGOMINDAH
BIRDSVILLE
BEETOOTA
WINDORAH
EROMANGA
INNAMINCKA
KOPPERAMANNA
FARINA
BELTANA
HAWKER
QUORN
PETERSBURG
PORT MACQUARIE
MAITLAND
WOLLONGONG
KIAMA
YASS
COOMA
BOMBALA
BRIGHT
KINGSTON
BEACHPORT
NARACOORTE
HAMILTON
PORT MACDONNELL
Cape Otway
E. 138°
E. 141°
E. 144°
E. 147°
E. 150°
E. 153°
S. 24°
S. 27°
S. 30°
S. 36°
NEW CALEDONIA CABLE
H.E.C. Robinson Lith.



Obsidian Bomb from near Bathurst, New South Wales.
Smaller figure natural size. See pp. 118 - 120.

Fig. 1—Section of a silver nugget, Lake Superior. 2 diams.

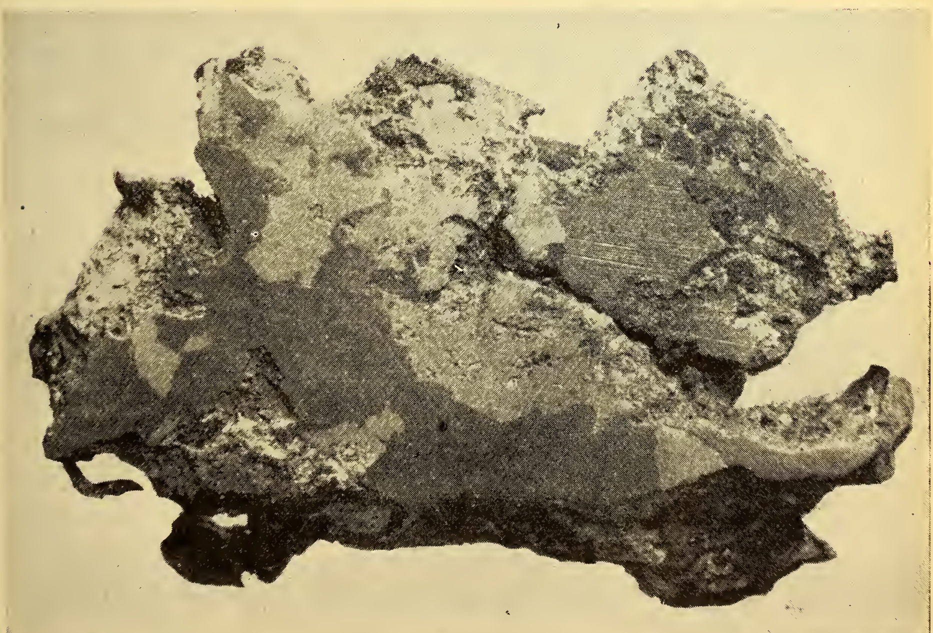


Fig. 2—Section of a nugget of native silver and copper, Lake Superior. 2 diams.
The light parts are silver and the dark copper.

Fig. 3—Crystals of Native Silver seated on a crystal of native copper, Lake Superior. 2 diams.

Fig. 4—Section of the preceding, No. 10, 2 diams. No silver is shown.

Fig. 5—Section of a nugget of native copper, Bolivia. 2 diams.

Fig. 6—Section of a nugget of native copper, Burra Burra, South Australia. 2 diams.

Fig. 1—Exterior of a gold nugget, Gippsland, ? Victoria. 2 diams.

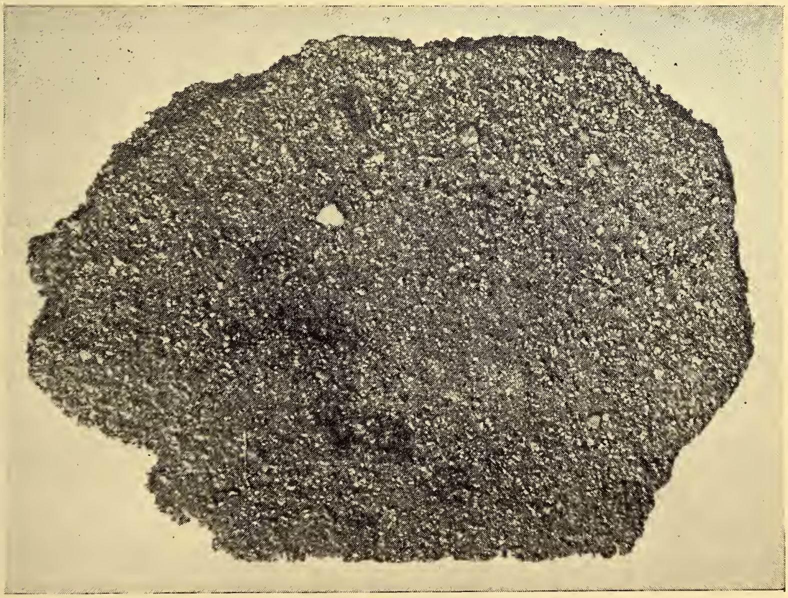


Fig. 2—Etched section of the above, showing quartz. 2 diams.

Fig. 3—Section of a gold nugget, Queenstown, Victoria. 2 diams.

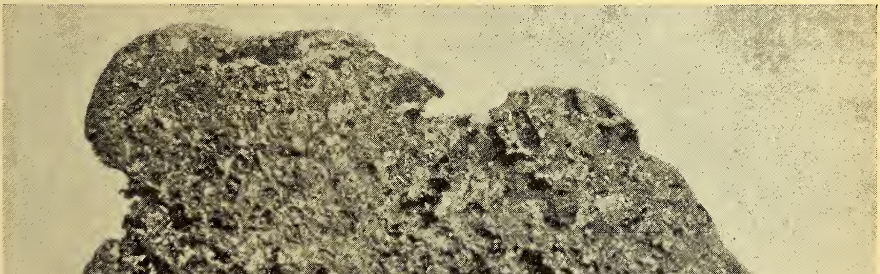


Fig. 4—Section of a gold nugget, Molyneux River, New Zealand. 3 diams.

Fig. 5—Gold nugget, Klondyke. 2 diams.

Fig. 6—Sections of the above. 2 diams.

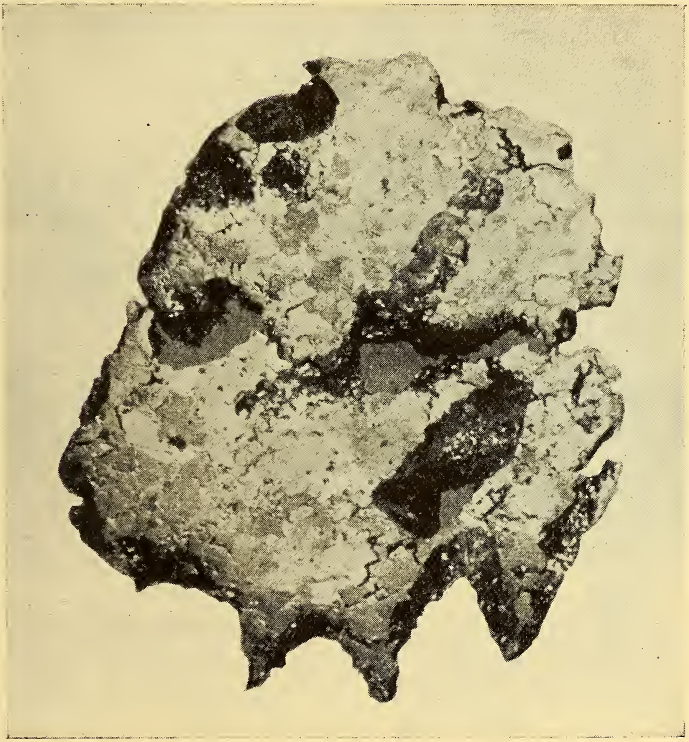


Fig. 7—Section of a gold nugget, Klondyke. 3 diams.

ABSTRACT OF PROCEEDINGS

ABSTRACT OF PROCEEDINGS

OF THE

Royal Society of New South Wales.

ABSTRACT OF PROCEEDINGS, MAY 2, 1900.

The Annual General Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, May 2nd, 1900.

The President, W. M. Hamlet, F.C.S., in the Chair.

Forty-eight members and six visitors were present.

The minutes of the preceding meeting were read and confirmed.

Three new members enrolled their names and were introduced.

The following Financial Statement for the year ended 31st March, 1900, was presented by the Hon. Treasurer, and adopted:

GENERAL ACCOUNT.

Receipts.		£	s.	d.	£	s.	d.
Subscriptions	One Guinea	93	9	0			
	Two Guineas	375	18	0			
	Arrears	64	1	0	534	9	0
	Advances	1	1	0			
Entrance Fees and Compositions					54	12	0
Parliamentary Grant on Subscriptions received—							
Vote for 1899-1900		500	0	0			
					500	0	0
Rent...					15	0	0
Sundries					13	13	3
Total Receipts					1117	14	3
Balance on 1st April, 1899					35	18	4
					£1153	12	7

Payments.	£	s.	d.	£	s.	d.
Advertisements	24	3	6			
Assistant Secretary	250	0	0			
Books and Periodicals	126	9	6			
Bookbinding	2	6	0			
Freight, Charges, Packing, &c....	2	17	5			
Furniture and Effects	2	5	6			
Gas	26	2	5			
Housekeeper	10	0	0			
Insurance	11	12	0			
Interest on Mortgage	56	0	0			
Office Boy	17	14	8			
Petty Cash Expenses	11	2	6			
Postage and Duty Stamps	23	0	0			
Printing	21	18	6			
Printing and Publishing Journal	232	19	5			
Printing Extra Copies of Papers	6	6	0			
Rates	52	9	0			
Refreshments and attendance at Meetings ...	25	7	6			
Repairs	32	12	7			
Stationery	11	8	0			
Sundries	20	3	8			
Total Payments				966	18	2
Repayment to Clarke Memorial Fund... ...				150	0	0
Balance on 31st March, 1900, viz.:—						
Cash in Union Bank, General Account ...	18	13	11			
" " B. & I. Fund ...	8	0	6			
Cash in hand...	10	0	0			
				36	14	5
				£1153	12	7

BUILDING AND INVESTMENT FUND.

Receipts.	£	s.	d.
Loan on Mortgage at 4%	1400	0	0
Clarke Memorial Fund—			
Loan at current Savings Bank rate of interest	64	19	2
	£1464	19	2

Payments.	£	s.	d.
Advance to General Account 31st March, 1897	8	0	6
Balance 31st March, 1900	1456	18	8
	£1464	19	2

CLARKE MEMORIAL FUND.

RECEIPTS.	£	s.	d.
Amount of Fund, 31 March, 1899	408	14	0
Interest to 31 March, 1900	11	10	2
	£420	4	2

	£	s.	d.
Deposit in Savings Bankof New South Wales, March 31, 1900	205	5	0
Deposit in Government Savings Bank, March 31, 1900 ...	150	0	0
Loan to Building and Investment Fund, March 31, 1900 ...	64	19	2
	£420	4	2

AUDITED AND FOUND CORRECT,

DAVID FELL, C.A.A. } *Honorary*
H. O. WALKER ...... } *Auditors.*

SYDNEY, 20th April, 1900.

H. G. A. WRIGHT, *Honorary Treasurer.*
W. H. WEBB, *Assistant Secretary.*

Messrs. C. Hedley and S. H. Barraclough were appointed Scrutineers, and Dr. H. G. A. Wright deputed to preside at the Ballot Box.

A ballot was then taken, and the following gentlemen were elected officers and members of Council for the current year :—

President:

PROF. LIVERSIDGE, M.A., LL.D., F.R.S.

Vice-Presidents:

CHARLES MOORE, F.L.S.
PROF. T. W. E. DAVID, B.A., F.G.S.
HENRY DEANE, M.A., M. Inst. C.E.
W. M. HAMLET, F.C.S., F.I.C.

Hon. Treasurer:

H. G. A. WRIGHT, M.R.C.S. *Eng.*, L.S.A. *Lond.*

Hon. Secretaries:

J. H. MAIDEN, F.L.S.
G. H. KNIBBS, F.R.A.S.

Members of Council:

C. O. BURGE, M. Inst. C.E.
C. W. DARLEY, M. Inst. C.E.
F. B. GUTHRIE, F.C.S.
H. A. LENEHAN, F.R.A.S.
F. H. QUAIFE, M.A., M.D.
H. C. RUSSELL, B.A., C.M.G., F.R.S.
HENRY G. SMITH, F.C.S.
PROF. ANDERSON STUART, M.D.
J. STUART THOM
F. TIDSWELL, M.B., D.P.H.

The certificate of one candidate was read for the third time, of two for the second time, and of four for the first time.

The following gentleman was duly elected an ordinary member of the Society :—

Bender, Ferdinand, Accountant, 21 Elizabeth-street N.

The following announcements were made :—

1. That the Society's Journal for 1899, Vol. XXXIII., was in the hands of the binder, and would shortly be ready for delivery.

2. That the Officers and Committee of the Engineering Section had been elected for the ensuing Session, and the dates fixed for their meetings as follows :—

SECTION MEETINGS.

	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
ENGINEERING—Wednesday, (8 p.m.)	16	20	18	15	19	17	21	19

SECTIONAL COMMITTEES—SESSION 1900.

Section K.—Engineering.

Chairman—Norman Selfe, M. Inst. C.E.

Hon. Secretary and Treasurer—S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E.

Committee—Henry Deane, M. Inst. C. E., Percy Allan, Assoc. M. Inst. C.E., G. R. Cowdery, Assoc M. Inst. C.E., J. M. Smail, M. Inst. C.E., J. I. Haycroft, M.E., M.I.C.E., I., T. J. Bush, H. H. Dare, M.E., Assoc. M. Inst. C.E., and Lee Murray, M.C.E.

Past-Chairmen, *ex officio* Members of Committee for three years :— C. O. Burge, M. Inst. C.E., T. H. Houghton, M. Inst. C.E., M. Inst. M.E., and H. R. Carleton, M. Inst. C.E.

3. That the Officers and Committee of the Medical Section would be elected and the dates fixed for their meetings on the 18th May.

4. That the alterations to the rules passed at the General Monthly Meeting, November 1st, 1899, would be submitted for confirmation this evening, it being the Annual General Meeting. On the motion of Mr. G. H. Knibbs, seconded by Mr. Lewis Whitfeld, it was unanimously resolved that the following amendments be agreed to :—

Rule III. was amended to read as follows :—

The other Officers of the Society shall consist of the President, who shall hold office for not more than one year continuously, but shall be eligible for re-election after the lapse of one year; four Vice-Presidents, an Honorary Treasurer, and two Honorary Secretaries, who, with ten other members, shall constitute the Council for the management of the affairs of the Society.

The last clause of Rule V., was repealed, and the following substituted in lieu thereof :—

Such list shall be exhibited in the Society's Rooms at least one calendar month before the day appointed for the Annual General Meeting. Any member of the Society not disqualified by Rules XIII, XIV., or XIVA., may be nominated for the position of President, Vice-President, Honorary Treasurer, Honorary Secretary, or Member of the Council, provided that his candidature shall have been notified to the Honorary Secretary or Secretaries under the hands of two qualified voters—such notification being countersigned by the nominee—at least fourteen days before the day appointed for the Annual General Meeting.

A complete list showing the names of those recommended for election by the Council, and those nominated as in the last preceding clause, shall be sent to each member of the Society, at least seven days before the day appointed for the Annual General Meeting.

Rule VA. was repealed.

Rule VI. was amended as follows:—In lieu of the first paragraph of the above Rule, read :—

The balloting list for the election of Officers and Members of Council shall contain a list of the names of those recommended by the Council and also of those otherwise nominated as provided for in Rule V. Heading the former, the words "Recommended by Council" shall be inserted, and opposite the latter the names of the nominators.

Mr. W. M. Hamlet, F.C.S., F.I.C., then read his address.

After some introductory remarks, the state of the Society was reported to be in a satisfactory condition, the papers contributed and the work done during the year being well up to the average, while the monthly general meetings were well attended and appreciated by members. The feature of modern chemistry is the vast accumulation of facts relating to a great number of bodies of interest to widely varying departments of human life. Enumerating the various branches of the science he said that pure chemistry dealt essentially with the properties and transformations of what we provisionally term 'matter.' The known properties and behaviour of matter carry us back in imagination to remote periods of this planet's history, when as yet silicon and oxygen had not united to give us material for the sister science of geology to deal with. Coming down to historic periods we found the early history of Chemistry in the land of the Nile, but in considering the historic periods of the north of Africa, it was almost impossible to avoid digressing for a moment or two on what is taking place in the south of the same continent, events which are regarded by the man of science as ugly survivals, not of the fittest, but of the undesirable. Going back to the ancient land of Egypt, modern discovery gives us some interesting facts that awaken sympathy in the chemist as well as the antiquarian, such as the origin of the words:—alchemy, chemistry, nitre, ammonia, Rame (a name for copper that has probably been handed down from Ra the Sun-god of the old Egyptians). Four words of Arabic or Egyptian source were taken as the text or frame work of this address, namely, alchemy, alkali, alkaloid and alcohol. Under the first came a brief review of the most prominent alchemists. The second afforded scope for the derivation of the word denoting the volatile alkali—the alkaline air—ammonia. In the case of the term alkaloid the researches of Fischer were referred to as showing the constitution of such alkaloids as theobromine and caffeine from structural formulæ of uric acid. Under the generic term 'alcohol' the fermentation of other substances than those in use for the production of spirits of wine were dealt with. Commencing with the organisms that cause the fermentation of urine, yielding the compound ammonia carbonate, detailed reference was made to the application of the principles of fermentation to the crude sewage from large cities, and to the process now so widely known as the 'septic tank system,' the 'biolysis of sewage,' or as the author would call it—the zymolysis of sewage. Particulars are given of the method of experiment, both in England and in Australia. It is shown that over fifty per cent. of purification is effected without the aid of chemicals of any kind, the effluents being of sufficient degree of purity as to sustain the life of various kinds of fish, and to occasion no harmful influence when run into streams. The process is summed up as being the readiest and the cheapest method of purification known. The *rationale* of the method is, that first of all a fermentation is allowed to go on by which the proteid or albuminous matters are changed into ammonia, marsh gas, and carbonic acid gas, afterwards the process of nitrification by minute micro-organisms finishes the change from ammonia to nitrous and nitric acids—compounds all ready to become assimilated by plant life. Thus, it is a simple natural process, and may be looked upon as *the* natural process of sewage purification, but subject to control; in this respect differing from all other processes, which are *not* subject to control. The birth of chemistry showed man searching for a stone that would turn all the baser metals into gold, and an elixir or—

'A tincture
Of force to flush Old Age with Youth.'

But while men were engaged in these things, some valuable lessons were learned, and as a result, we have our present day chemistry and the means of solving many problems of Sanitation and the Public Health.

A vote of thanks was passed to the retiring President, and Professor Liversidge, M.A., LL.D., F.R.S., was installed as President for the ensuing year.

Professor Liversidge thanked the members for the honour conferred upon him.

The following donations were laid upon the table and acknowledged:—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*).

Bristol—Bristol Naturalists' Society. Proceedings, New Series Vol. ix., Part i., 1898. *The Society*

Cambridge—Cambridge Philosophical Society. Proceedings, Vol. x., Parts iii. and iv., 1899. ,,

Public Free Library. Annual Report (44th) 1898-9. *The Library*

Dublin—Royal Irish Academy. Proceedings, Third Series, Vol. v., No. 3, November 1899. *The Academy*

Easton, Pa.—American Chemical Society. Journal, Vol. xxi., Nos. 11, 12, 1899; Vol. xxii., Nos. 1, 2, 1900. *The Society*

Edinburgh—Royal Physical Society. Proceedings, Vol. xiv., Part ii., Session 1898-99. ,,

Royal Scottish Geographical Society. *Scottish Geographical Magazine*, Vol. xv., Nos 11, 12, 1899; Vol. xvi., Nos. 1, 2, 1900. ,,

Fort Monroe.—United States Artillery. Journal, Vol. xii., Nos. 1, 2, 3, (Whole Nos. 39 and 40) 1899. *The School*

Glasgow—Philosophical Society of Glasgow. Proceedings, Vol. xxx., 1898-99. *The Society*

Leeds—Yorkshire College. Annual Report (25th) 1898-9. *The College*

Liverpool—Literary and Philosophical Society. Proceedings, Vol. liii., 1898-99. *The Society*

London—Anthropological Institute of Great Britain and Ireland. Journal, New Series, Vol. ii., Nos. 1, 2, 1899. *The Institute*

Chemical News, Vol. lxxx., Nos. 2083 – 2092, 1899; Vol. lxxxi., Nos. 2092 - 2103, 1900. *The Editor*

Electrical Engineer, Old Series, Vol. xxxi., New Series, Vol. xxv., Nos. 1—9, 1900. ,,

Geological Society. Quarterly Journal, Vol. lv., Part iv., No. 220, 1899. Vol. lvi., Part i., No. 221, 1900. List of Fellows 1899. *The Society*

Imperial Institute. Journal, Vol. v., Nos. 59 and 60, 1899; Vol vi., Nos. 61, 62, 1900. *The Institute*

Institution of Civil Engineers. Minutes of Proceedings, Vol. cxxxviii., Part iv., 1898-9; Subject Index, Vols. cxix. - cxxxviii., Sessions 1894-95 to 1898-99. *The Institution*

Institution of Mechanical Engineers. Proceedings, Nos. 2, and 3, 1899. ,,

Iron and Steel Institute. Journal, Vol. lvi., No. 2, 1899. *The Institute*

Linnean Society. Journal, Botany, Vol. xxvi., No. 178; Vol. xxxiv., No. 239, 1899. Zoology, Vol. xxvii., Nos. 176, 177, 1899. List of Fellows 1899-1900. Proceedings, from November 1898 to June 1899. *The Society*

Meteorological Office. Meteorological Observations at Stations of the Second Order 1895, Official No. 137. Report of the Meteorological Council for the year ending 31st March, 1899, Official No. 140. *The Office*

LONDON—*continued.*

Mineralogical Society. Mineralogical Magazine and Journal, Vol. XII., No. 56, October 1899. *The Society*

Pharmaceutical Society of Great Britain. Calendar 1900. Pharmaceutical Journal, Fourth Series, Vol. IX., Nos. 1531 - 1540, 1899; Vol. X., Nos. 1541 - 1545, 1547, 1549, 1900. „

Physical Society of London. Proceedings, Vol. XVI., Parts vii., viii., 1899. Science Abstracts, Vol. II., Parts xi., xii., Nos. 23, 24, 1899 and Index; Vol. III., Parts i., ii., Nos. 25, 26, 1900. „

Quekett Microscopical Club. Journal, Vol. VII., No. 45, 1899. *The Club*

Royal Agricultural Society of England. Journal, Ser. 3, Vol. X., Part iv., No. 40, 1899. *The Society*

Royal Astronomical Society. Monthly Notices, Vol. LIX., No 10, Supplementary Number; Vol. LX., Nos. 1, 2, November and December, 1899; No. 3, January, 1900. „

Royal Geographical Society. The Geographical Journal, Vol. XIV., Nos. 5, 6, 1899; Vol. XV., Nos. 1, 2, 1900. „

Royal Institution of Great Britain. Proceedings, Vol. XV., Part iii., No. 92, 1898. *The Institution*

Royal Meteorological Society. Quarterly Journal, Vol. XXV., No. 112, 1899. Meteorological Record, Vol. XIX., No. 73, 1899. *The Society*

Royal Microscopical Society. Journal, Parts v., vi., Nos. 132, 133, 1899; Part i., No. 134, 1900. „

Royal Society. Year Book, No. 4, 1900. „

Royal Society of Literature. Transactions, Series 2, Vol. XXI., Parts i., ii., 1899. „

Royal United Service Institution. Journal, Vol. XLIII., Nos. 260, 261, 262, 1899. *The Institution*

Sanitary Institute. Journal, Vol. XX., Part iv., 1900. *The Institute*

Society of Arts. Journal, Vol. XLVII., Nos 2449 - 2451, 1899; Vol. XLVIIII., Nos. 2452 - 2469, 1899-1900. *The Society*

Zoological Society of London. Transactions, Vol. XV., Part iv., 1899. „

MADISON—Wisconsin Academy of Sciences, Arts and Letters. Transactions, Vol XII., Part i., 1898. *The Academy*

MANCHESTER—Conchological Society of Great Britain and Ireland. Journal, Vol. IX., No. 9, 1900. *The Society*

Manchester Geological Society. Transactions, Vol. XXVI., Parts ix. - xii., Sessions 1898-99 - 1899-1900. „

Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol XLIII., Part v., 1898-99; Vol. XLIV., Part i., 1899-1900. „

NANTES—Société des Sciences Naturelles de l'Ouest de la France. Bulletin, Tome IX., Trimestre 3, 1899. „

NEW YORK—American Geographical Society. Bulletin, Vol. XXXI., No. 4, 1899. *The Academy*

NEW YORK—*continued.*

American Institute of Electrical Engineers. Transactions, Vol. XVI., Nos. 6 - 10, 1899. *The Institute*

American Institute of Mining Engineers. Transactions, Vol. XXVIII., 1898. ,,

American Mathematical Society. Transactions, Vol. I., No. 1, 1900. *The Society*

School of Mines, Columbia University. The School of Mines Quarterly, Vol. XXI., No. 1, 1899. *The School*

OXFORD—Radcliffe Library. Catalogue of Books added during the year 1899. *The Library*

PARIS—Ecole d' Anthropologie de Paris. Revue, Année X., Nos. 1, 2, 1900. *The Director*

Ecole Nationale des Mines de Paris. Statistique de l'Industrie Minérale et des appareils à vapeur en France et en Algérie pour l'année, 1898. *Ministère des Travaux Publics.*

Feuille des Jeunes Naturalistes. Catalogue de la Bibliothèque, Fascicule Nos. 27, 28. 1899-1900. Revue Mensuelle d'Histoire Naturelle, 3 Ser., Année XXX., Nos. 349, 350, 1899; Nos. 351 - 353, 1900. *The Editor*

Société d'Anthropologie de Paris. Bulletins, Série 4, Tome X., Fasc 3, 1899. *The Society*

Société de Biologie. Comptes Rendus Hebdomadaires, Série 11, Tome I., Nos. 29 - 39, 1899; Tome LII., Nos. 1 - 7, 1900. ,,

Société Entomologique de France. Annales, Vol. LXVII., Trimestre 1 - 4, 1898; Bulletin, Année 1898. ,,

Société Française de Minéralogie. Bulletin, Tome XXII., Nos. 7, 8, 1899. ,,

Société Française de Physique. Bulletin Bimensuel, Nos. 137 - 139, 1899; Nos. 140 - 145, 1900. Séances, Année 1899, Fasc. 2. ,,

Société de Géographie. Bulletin, Sér. 7, Tome XX., Trimestre 3, 4, 1899. Comptes Rendus des Séances, No. 7, 1899. ,,

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PHILADELPHIA—American Entomological Society. Transactions, Vol. XXVI., No. 2, 1899. ,,

Franklin Institute. Journal, Vol. CXLVIII., Nos. 5, 6, 1899; Vol. CXLIX., Nos. 1, 2, 1900. *The Institute*

Philadelphia Commercial Museum. American Trade with India 1898. The World's Commerce and the United States share of it, second edition 1899. *The Museum*

University of Pennsylvania. Catalogue 1899-1900. Contributions from the Botanical Laboratory, Vol. II., No. 1, 1899. University Bulletin, Vol. IV., Nos. 1, 2, 1899. *The University*

Wagner Free Institute of Science. Transactions, Vol. VI., 1899. *The Institute*

ABSTRACT OF PROCEEDINGS, JUNE 6, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, June 6th, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

Thirty-one members and one visitor were present.

The minutes of the preceding meeting were read and confirmed.

One new member enrolled his name and was introduced.

Dr. Marden and Mr. T. H. Houghton were appointed Scrutineers, and Mr. C. O. Burge deputed to preside at the Ballot Box.

The certificates of two candidates were read for the third time, of four for the second time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

McKay, G. A., Chief Mining Surveyor, Department of Mines.
Wallach, Bernhard, B.E. *Syd.*; Darlinghurst.

THE FOLLOWING PAPERS WERE READ:—

1. "On the relation, in determining the volumes of solids, whose parallel transverse sections are n^{ic} functions of their position on the axis, between the position and coefficients of the section and the (positive) indices of the functions," by G. H. KNIBBS, F.R.A.S.

The integral of the function

$$A_z = A + Bz^p + Cz^q + Dz^r + \text{etc} \ldots\ldots\ldots\ldots (1)$$

viz.

$$V = \int A_z dz = z\left(A + \frac{Bz^p}{p+1} + \frac{Cz^q}{q+1} + \frac{Dz^r}{r+1} + \text{etc.}\right) \ldots\ldots (2)$$

will represent an *area* if A_z be an ordinate, or a *volume* if it be an *xy* plane. In the former case the boundaries of the area are the curve, the axis, and the ordinates at z_1 and z_2; in the latter case the *xy* planes at those abscissæ are the parallel terminal planes of a volume generated by the motion of one of them, its area however changing in terms of the function. No loss of generality occurs by making $z_2 - z_1$ unity in (2), since the origin and unit will not affect the degree of the equation: any fractions of the axis must however be raised to the powers of the original function (1) in order to determine its value for z, plus the fraction. Let

$$V = \frac{1}{\alpha + \beta \text{ etc.}} \left\{ \alpha A_a + \beta A_b + \text{etc.} \right\} \text{.........} (3)$$

where A_a is the value of the original function for $z_1 + a/(z_2 - z_1)$ and so on; then (3) may be written

$$V = A + \frac{B}{\sigma}(\alpha a^p + \beta b^p + \ldots) + \frac{C}{\sigma}(\alpha a^q + \beta b^q + \;) + \text{etc.} \text{........} (4)$$

Equating (4) with (1); remembering that z in the latter is to be considered unity, and u being any index as p, q, r, etc., we have

$$\alpha\left(a^u - \frac{1}{u+1}\right) + \beta\left(b^u - \frac{1}{u+1}\right) + \text{etc.} = 0 \text{.........} (5)$$

as the fundamental equation in determining the relations between the indices, the position of the sections of the axis, the number of sections to be taken, and the weight-coefficients of the section. The divisions of the subject as treated in the paper are as follows:

1. Problem defined.
2. General relation between indices, number and position of sections, and weight-coefficients.
3. Determination of the ratio of the $m+1$ weight-coefficients, when the number m of indices is one less than the number of values of the variable.
4. Number of indices greater than the number of values of the variable, diminished by unity.
5. Number of indices less than the number of values of the variable, diminished by unity.
6. Determination of the $n - k = m$ weights.
7. Position of a single section.
8. Positions of two sections.
9. Limiting positions of two symmetrically situated sections.
10. Two symmetrically situated sections and their conjugate indices.
11. Asymmetrical positions of two sections.
12. Three symmetrical sections, viz., a middle and the terminal sections.
13. A middle section, and two other sections equidistant therefrom, all of equal weight.
14. Two terminal and one intermediate section.
15. General result of the method of finite differences.
16. General theory of symmetrically situated sections with symmetrical weight-coefficients.
17. Examples of the application of the general formula.
18. The number of indices satisfied by a given number of symmetrical sections.
19. Manifold infinity of possible formulæ with symmetrical sections.

The paper contained a number of tables of formulæ, and was illustrated by figures shewing the graphs of the functions. It is demonstrated that when the axis is divided into p an even number of parts, and the weight-coefficients suitably determined are identical for sections equidistant from the mid-section, the terminal sections being included, then the integral satisfies a $(p+1)^{ic}$ function of the variable; but when similarly the axis is divided into an i, odd number of parts, then only an i^{ic} function is satisfied. That is to say when there is a middle section, the function satisfied is of the same degree as when the number of parts into which the axis divided is one greater, there being in the latter case, of course, no middle section.

2. "On the amyl ester of Eudesmic acid occurring in Eucalyptus Oils," by Henry G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

In a paper read before this Society, July 1898, on the "Stringybark Trees of New South Wales," Mr. R. T. Baker and the author show that an ester was present in the oil of *Eucalyptus macrorhyncha.* Since then esters have been found to be present in several Eucalyptus oils. The oil of the "Black Gum" *Eucalyptus aggregata* contains an ester in large amount 57·7 per cent. being calculated on the assumption that only one ester is present in the oil. Dextropinene is the other principal constituent in this oil, this had a specific rotation $[a]_D + 27·13$. The crude oil of this species is very fluid, and it had, for a Eucalyptus oil, a very high specific gravity 0·956 at 15° C., only $2\frac{1}{2}$ ounces of oil was obtained from 400 lbs of leaves, so that the yield of oil is very small. Neither phellandrene nor eucalyptol were present in the oil. The alcohol of the ester was found to be amyl alcohol proved by the formation of its characteristic acetate and oxidation to valeric acid. The acid of the ester is new, it crystallises finely in rhombic prisms and in appearance resembles salicylic acid. It melts at 160° C., sublimes with difficulty unchanged. It is but little soluble in cold water (1 in 1,355 parts) easily soluble in hot water, alcohol, ether, acetone, and chloroform; but insoluble in benzene, carbon disulphide and petroleum spirit. It forms a well crystallised silver salt. Ferric chloride gives a light orange precipitate in the solution of the ammonium salt. Copper sulphate forms a bluish-green precipitate. Barium or calcium chlorides do not give precipitates. The acid is unsaturated and forms a dibromide. The molecular weight of the acid, determined by its silver salt was near 215. An acid having the formula $C_{14}H_{18}O_2$ has a molecular weight 218, and considering the acid as monobasic the formula of the ester would be $C_{13}H_{17}COOC_5H_{11}$. Solution in nitric acid gave a crystalline acid melting at 113° C., this is the melting point of cumic acid, it had also other characteristic of that acid. If it is proved to be cumic acid, then we may consider eudesmic acid to be cumyl-angelic acid $C_{14}H_{18}O_2$. By oxidation of the side chain of this, cuminaldehyde might be obtained. Cuminaldehyde is a frequently occurring constituent in Eucalyptus oils, and it may be that this has some connection with eudesmic acid. The valeraldehyde known to be present in Eucalyptus oils may also be connected with the amyl alcohol. It is suggested that it is the presence of this ester that gives to Eucalyptus oils their characteristic odour. The author shows that esters are present in fair amount in the oils of *E. botryoides*, *E. saligna* and *E. rostrata*, and that an aromatic alcohol, either linaloöl or geraniol, is present in the oil of *E. patentinervis*, over 16% of free alcohol being proved. The saponified oil of *E. patentinervis* has a fine odour. Citral also occurs in this oil, proved by its characteristic reactions. The name eudesmic acid is from Robert Brown's name for the genus "Eudesmia."

3. "Note on a new meteorite from New South Wales," by R. T. BAKER, F.L.S., Curator, Technological Museum, Sydney.

The meteorite described in this paper was found early in January of this year, two miles from Bugaldi, a postal town fifteen miles north-west of Coonabarabran. It is pear shaped and is nearly five inches long and three inches wide at the broadest part. It belongs to that class of meteorites known as siderites, and is probably composed of iron and nickel. It has a well defined, closely adhering "skin" of black magnetic material, while the metal immediately beneath this coating is silvery-white in appearance. On the smooth portion at the extremity of the larger end can be seen very distinctly Widmanstatten's figures. The specimen has an exceedingly new appearance as if it had only just arrived upon the earth, and shows no signs of oxidation.

4. Dr. Frank Tidswell, D.P.H. *(Camb.)*, gave a lantern demonstration showing photomicrographs of certain disease germs, including those of anthrax, typhoid fever, tuberculosis, leprosy, and plague.

EXHIBITS.

Section of Wooden Water Pipe, partially blocked by a solid fibrous incrustation of barytic carbonate of lime. This pipe, which was taken from the 768 feet level in the Birthday Shaft, Sydney Harbour Colliery, Balmain, was used for conveying the water made in the sinking, from the water-ring fixed at 768 feet level to bottom of shaft. Exhibited by Mr. J. L. C. Rae.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The names of the Donors are in *Italics.*)

Albany N.Y.—University of the State of New York. State Library Bulletin, Legislation Nos. 11, 12, 1900. *The University*

Annapolis, Md.—U.S. Naval Institute. Proceedings, Vol. xxv., Nos. 3, 4, Whole Nos. 91, 92, 1899; Vol. xxvi. Nos. 1, 2, Whole Nos. 93, 94, 1900. *The Institute*

Berkeley—University of California. Agricultural Experiment Station Bulletin, Nos. 122 - 126, 1899. Annual Report of the Secretary to the Board of Regents for the year ending June 30, 1899. Bulletin of the Department of Geology, Vol. ii., Nos. 5, 6, 1899. Library Bulletin, No. 13, 1899. Pamphlets (Reprints) 3. Quarterly Bulletins New Series, Vol. i., Nos. 1, 2, 1899. University Chronicle Vol. ii., Nos. 1 - 6, 1899. Report of Final Competitions for the Phœbe A. Hearst Architectural Plan of the University of California. *The University*

Boston, Mass.—American Academy of Arts and Sciences. Proceedings, Vol. xxxv., Nos. 1 - 16, 1899 - 1900. *The Academy*

Boston Society of Natural History. Proceedings, Vol. xxix., Nos. 1 - 8, 1899. *The Society*

Buffalo—Buffalo Society of Natural Sciences, Bulletin, Vol. vi., Nos. 2, 3, 4, 1899. ,,

Cambridge—Cambridge University Library. Report of the Library Syndicate for the year ending, 31st December, 1899. *The Library*

CAMBRIDGE—Cambridge Philosophical Society. Proceedings, Vol. x., Part v., 1900. Transactions, Vol. XVIII., Vol. XIX., Part i., 1900. *The Society*

CAMBRIDGE (Mass.)—Museum of Comparative Zoölogy at Harvard College. Bulletin, Vol. XXXIV., [Geological Series, Vol. IV.] 1899; Vol. XXXV., Nos. 3 – 8, 1899-1900. Memoirs, XXIII., No. 2; Vol. XXIV, 1899. *The Museum*

CHICAGO—Field Columbian Museum. Botanical Series, Vol. I., No. 5, Pub. 39. Report Series, Vol. I., No. 5, Pub. 42, Zoological Series, Vol. I., Nos. 16, 17, Pub. 40, 41. The Birds of Eastern North America, Part i. Water Birds, Part ii. Land Birds, 1899. ,,

University of Chicago Press. Astrophysical Journal, Vol. x., Nos. 3 – 5, 1899; Vol. XI., Nos. 1 – 5, 1900. Journal of Geology, Vol. VII., Nos. 6 – 8, 1899; Vol. VIII., Nos. 1 – 3, 1900. *The University*

CINCINNATI—Cincinnati Society of Natural History. Journal, Vol. XIX., No. 5, 1900. *The Society*

DAVENPORT (Iowa)—Davenport Academy of Natural Sciences. Proceedings, Vol. VII., 1897-1899. *The Academy*

DENVER—Colorado Scientific Society. Bulletin, Nos. 1, 2, 1900. Papers read January 6 and February 3, 1900. *The Society*

DES MOINES—Iowa Geological Survey. Annual Report, 1898, with accompanying papers, Vol. IX. *The Survey*

DUBLIN—Royal Irish Academy. Proceedings, Third Series, Vol. v., Nos. 4, 5, 1900. *The Academy*

EASTON, PA.—American Association for the Advancement of Science. Proceedings, Columbus Ohio, Meeting, Vol. XLVIII., 1899. *The Association*

American Chemical Society. Journal, Vol. XXII., Nos. 3 – 7, 1900. *The Society*

EDINBURGH—Royal Scottish Geographical Society. *The Scottish Geographical Magazine*, Vol. XVI., Nos. 3 - 7, 1900. ,,

Scottish Microscopical Society. Proceedings, Vol. II., No. 4, Session 1898-99. ,,

University. Edinburgh University Calendar 1900 – 1901. *The University*

FORT MONROE.—United States Artillery School. Journal, Vol. XIII., Nos. 1 – 3, (Whole Nos. 41 – 43) 1900. *The School*

GLASGOW—University. Glasgow University Calendar, 1900 – 1901. *The University*

INDIANAPOLIS—State of Indiana, Department of Geology and Natural Resources. Annual Reports (23rd and 24th) 1898 and 1899. *The State Geologist*

KEW—Royal Gardens. Hooker's Icones Plantarum, Vol. VII., Part ii., May 1900. *The Director*

LINCOLN—University of Nebraska. Bulletin of the U.S. Agricultural Experiment Station, Vol. XI., Nos. 55 – 59, 1898-99. Press Bulletin, No. 11, 1899. *The University*

ABSTRACT OF PROCEEDINGS, JULY 4, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, July 4th, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

About seventy members and visitors were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. H. E. Barff and R. R. Garran were appointed Scrutineers, and Dr. H. G. A. Wright deputed to preside at the Ballot Box.

The certificates of four candidates were read for the third time, and of two for the second time.

The following gentlemen were duly elected ordinary members of the Society :—

Helms, Richard, Experimentalist, Department of Agriculture.
Jarman, A., A.R.S.M., Demonstrator, University of Sydney.
Stewart, James Douglas, M.R.C.V.S. *Edin.*; Cowper-street, Randwick.
Turner, Basil William, A.R.S.M., F.C.S., Lecturer in Metallurgy, University of Sydney; 14 Castlereagh-street.

The meeting then resolved itself into an informal Conversazione and Smoke evening.

THE FOLLOWING EXHIBITS WERE SHEWN :—

BAKER, R. T., F.L.S.—1. Model of Chinese Lady's foot. 2. Edible birds' nests from North Borneo. 3. Models of edible fishes.

BRUCE, J. L.—1. Pipe illustrating galvanic action of hot Sydney water on lead pipe. The pipe formed part of a hot-water pipe circulation, having a wrought-iron boiler at one end, a copper cylinder at the other end. 2. Examples of lead pipe destroyed by galvanic action in cold-water cisterns, Sydney water. The couple was constituted by contact of a copper cylinder or cistern and the lead pipe, under the ordinary Sydney water. 3. Example of cast-iron pipe from Hunter River District water supply, effect of galvanic action. 4. Exhibits shewing importance of good sanitary plumbing, also of defective work.

Burge, C. O., M. Inst. C.E.—1. Breeches Bible. The Genevan edition of 1560. Tyndale's translation; illustrated. 2. Ricaut's Greek Church 1679. 3. Bossuet's History of the World 1686. 4. Lord Bacon's Advancement of Learning; edition of 1633.

Darley, C. W., M. Inst. C.E.—Model of suction dredge "Antleon" for working without moorings on a rough bar.

David, Prof. T. W. E., B.A., F.G.S.—Microscopes shewing some N. S. Wales Internal Parasites:—1. The common liver fluke (sheep) *Distomum hepaticum*, Abildg. 2. The lanceolate fluke *Distomum lanceolatum*, Mehlis, from bile-ducts of sheep. 3. *Holostomum sp.* from Gull. 4. L.S. *Holostomum sp.* from Gull. 5. *Holostomum sp.* from Jackass. 6. T.S. and L.S. *Holostomum sp.* from Jackass.

Halligan, G. H., F.G.S.—Miscellaneous articles fished up by special apparatus from the Bore at Trangie, diameter 7½ inches, depth of 570 feet.

Hamlet, W. M., F.C.S., F.I.C.—New patent dirt-box for private dwelling house.

Hargrave, L.—1. Winch for flying cellular kites in tandem with wire. 2. Three kites. 3. Clamps and tension spring balance. 4. Snatch block. On December 4, 1899, two of the kites attained a height of 484 yards: *i.e.*, more than five times as high as the truck on the Post Office flagstaff. There were 500 yards of wire and 100 yards of string out on this occasion. The angle of elevation was 50° 45′. Pull on the wire 20 ℔s. max. Surface wind velocity 12 to 15 miles; pressure ·7 to 1·1 ℔s. Line 2·4 mills. diam. B.S. 75 ℔s. 100 yards weigh ¾ ℔s. Wire 20 g. 1·0 mills. diam. B.S. 140 ℔s. 100 yards weigh 1 ℔. 500 yards wire equal 4·93 sq. ft. section; 100 yards string equal 2·36 sq. ft. section. Total 7·29 sq. ft. of string and wire pushing downward. The kites are of the latest pattern, specially made for tandem flying and high wind velocities. Lifting surface of each kite, 25 square feet.

HASWELL, Prof. W. A., M.A., D.Sc., F.R.S.—1. *Caryophyllæopsis* an unsegmented Tape-worm from the intestine of the Port Jackson shark. 2. *Stratiodrilus* a new primitive worm found among the gills of Tasmanian crayfishes, and regarded as intermediate between the Wheel-Animalcules or Rotifera and the ringed-worms such as Earthworms. 3. Museum microscope, so constructed as to admit of a series of slides being shewn, without microscope being exposed.

JOHNSTON, S. J., B.A —Microscopical sections of hæmatode worms from sheep and birds.

LIVERSIDGE, Prof., M.A., LL.D., F.R S.—1. Photo-micrometer. 2. Tous-les-mois starch. 3. Gold crystals from potassium cyanide solutions. 4. Colour of gold by transmitted light. 5. Spectrum of Didymium glass. 6. Photo-spectrometer.

MARDEN, Dr. JOHN, M.A.—Microscope and series of slides shewing objects of interest.

POLLOCK, Prof., B.E., B.Sc.—1. Boomerang made by G. T. Walker Esq., M.A., B.Sc., Fellow of Trinity College, Cambridge, author of paper on 'Boomerangs' in Phil. Trans. Vol. 109A, pp. 23 – 41, 1897. 2. Photograph of a falling drop of water by Lord Rayleigh.

PORTUS, A. P., Assoc. M. Inst. C.E.—1. Album of views of Old Sydney. 2. Photograph of first steamer built in Australia "William IV." (Old Billy) [afterwards lengthened]. Built in 1831 by Marshall and Lowe, Williams River, employed at coasting work for thirty years, then sent to trade at China. 3. Photograph of the "Rose" pioneer steamer of the A.S.N. Co., then called Hunter River S. N. Co. Length 150 feet, beam 20 feet, engines 100 H.P., side lever; pressure 7 lbs. per square inch; boilers flue type. Speed 11 miles per hour. The "Rose" arrived in Sydney in April 1841, and was the first *iron* ocean steamer imported.

QUAIFE, F. H., M.A., M.D.—1. 'Electrical Movement in Air and Water with Theoretical Inferences' and supplement, by Lord Armstrong, C.B., F.R.S. 2. Optical experiments.

RONALDSON, J. H.—Chinese painting of the Palace at Pekin.

RUSSELL, H. C., B.A., C.M.G., F.R.S.—1. Diagram of seismographic apparatus to be erected at the Sydney Observatory. 2. Books containing valuable astronomical and meteorological plates (coloured.)

SMITH, HENRY G., F.C.S.—A collection of twenty-five specimens of the principal constituents found in essential oils, including aromatic alcohols, aldehydes, ketones, esters, etc. (Schimmel & Co.)

STEEL, Dr. JOHN—1. 'A Right Profitable Booke for all Diseases called The Path-way to Health,' by Peter Leuens, London 1632. 2. Old Latin Dictionary.

TAYLOR, JAMES, B.Sc., A.R.S.M.—Hardened Steel welded under pressure in the cold, (*vide* Journ. Iron and Steel Inst., No. 1, 1885, pp. 29 and 30.)

TIDSWELL, Dr. FRANK, D.P.H. *Camb.*—1. Specimens illustrating the preservation of colour in Museum preparations, Formalin process. 2. A case of Snake "Cannibalism."

WALKER, J. T.—1. 'Sketches of Sheep' drawn by Sir Edwin Landseer, R.A., when a boy eight years old, 1810. 2. 'Dog's Head' by Sir Edwin Landseer, R.A., when fourteen years of age, 1816. 3. 'The Well of Haran,' (Jacob and Rachel), engraving by Martin Hemskirk, celebrated Dutch Engraver, 1541 (?) or 1549. 4. 'Hindoo and Mohammedan Buildings,' engraving printed in oil colours, 1835. 5. 'Royal Grant,' dated 11th March, 1608, of agricultural lands at Coldingham, known as West Reston, in fen-farm for ever; bearing the Great Seal of King James I.

WRIGHT, H. G. A., M.R.C.S., E.—Microscopic slides of Plague bacillus.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*)

LONDON—*Chemical News*, Vol. LXXXI., Nos. 2105 – 2118, 1900; Vol. LXXXII., Nos. 2119 - 2121, 1900. *The Editor*

Electrical Engineer, Old Series, Vol. XXXI., New Series, Vol. XXV., Nos. 10 – 26, 1900; Old Series Vol. XXXII., New Series Vol. XXVI., Nos. 1 – 4, 1900. ,, LONDON—Geological Society. Geological Literature added to the Society's Library during the year ended 31 Dec., 1899, No. 6. Quarterly Journal, Vol. LVI., Part ii., No. 222, 1900. *The Society*

Imperial Institute. Journal, Vol. VI., Nos. 63 – 67, 1900. *The Institute*

Institute of Chemistry of Great Britain and Ireland. Proceedings, Part i., 1900. Register of Fellows, Associates, and Students 1900 – 1901. „

Institution of Civil Engineers. Minutes of Proceedings, Vol. CXXXIX., Part i., 1899-1900. *The Institution*

Institution of Mechanical Engineers. Proceedings, No. 4, 1899. List of Members, Feb. 1900, Articles and By-Laws. „

Linnean Society. Journal, Botany, Vol. XXXIV., No. 240, 1900. Zoology, Vol. XXVII., No. 178, 1900. *The Society*

Meteorological Office. Meteorological Observations at Stations of the Second Order for the year 1896, (Official No. 139). *The Office*

Pharmaceutical Society of Great Britain. Pharmaceutical Journal, Fourth Series, Vol. x., Nos. 1551 – 1563, 1565 – 1570, 1900. *The Society*

Physical Society of London. Proceedings, Vol. XVII., Parts i., ii., 1900. List of Officers and Fellows, April 1, 1900. Science Abstracts, Vol. III., Parts iii. – vii., Nos. 27 – 30, 1900. „

Quekett Microscopical Club. Journal, Series 2, Vol. VII., No. 46, 1900. *The Club*

Royal Agricultural Society of England. Journal, Ser. 3, Vol. XI., Parts i., ii., Nos. 41, 42, 1900. *The Society*

Royal Astronomical Society. Monthly Notices, Vol. LX., Nos. 4 – 9, 1900. „

Royal College of Physicians. List of Fellows, Members, Extra Licentiates and Licentiates, 1900. *The College*

Royal Geographical Society. The Geographical Journal, Vol. XV., Nos. 3 – 6, 1900; Vol. XVI., No. 1, 1900. *The Society*

Royal Institution of Great Britain. Proceedings, Vol. XV., Part ii., No. 91, 1898. *The Institution*

Royal Microscopical Society. Journal, Parts ii., iii., Nos. 135, 136, 1900. *The Society*

Royal Society. Philosophical Transactions, Vol. CXCI., Series B, 1899; Vol. CXCII., Series A, 1899; Vol. CXCIII., Series A, 1900. Proceedings, Vol. LXV., No. 423; Vol. LXVI., Nos. 424 – 432, 1900. Reports to the Malaria Committee, 1899-1900. „

Royal Society of Literature. Transactions, Series 2, Vol. XXI., Part iii., and List of Fellows, 1900. „

Royal United Service Institution. Journal, Vol. XLIV., Nos. 263 – 266, 1900. *The Institution*

Sanitary Institute. Journal, Vol. XXI., Parts i., ii., 1900. *The Institute*

Society of Arts. Journal, Vol. XLVIII., Nos. 2470 – 2488, 1900. *The Society*

Zoological Society of London. Proceedings, Part iv., 1899; Part i., 1900. „

MANCHESTER—Conchological Society of Great Britain and Ireland. Journal of Conchology, Vol. IX., Nos. 8, 10, 11, 1900. *The Society*

Manchester Geological Society. Transactions, Vol. XXVI., Part xiii., Sessions 1899-1900. ,,

Manchester Literary and Philosophical Society. Memoirs and Proceedings, Vol. XLIV., Parts ii., iii., 1899-1900. ,,

MIRFIELD—Yorkshire Geological and Polytechnic Society. Proceedings, N.S. Vol. XIII., Part ii., 1897. ,,

NEWCASTLE-UPON-TYNE—Natural History Society of Northumberland, Durham and Newcastle-upon-Tyne. Transactions, Vol. XIII., Part iii., 1900. ,,

North of England Institute of Mining and Mechanical Engineers. Transactions, Vol. XLVIII., Parts v., vi., and Annual Report of the Council; Vol. XLIX., Parts i., ii., 1899-1900. *The Institute*

NEW YORK—American Geographical Society. Bulletin, Vol. XXXI., No. 5, 1899; Vol. XXXII., Nos. 1 - 2, 1900. *The Society*

American Institute of Electrical Engineers. Transactions, Vol. XVI., Nos. 11, 12, 1899; Vol. XVII., Nos. 1, 2, 1900. *The Institute*

American Museum of Natural History. Bulletin, Vol. XI., Part ii., 1899. *The Museum*

Columbia University. The School of Mines Quarterly, Vol. XXI., Nos. 2, 3, 1900. *The School*

New York Academy of Sciences. Memoirs, Vol. II., Part i., 1899. *The Academy*

The Mineral Industry, Vols. I. - VIII., 1892 – 1900. *Richard P. Rothwell, Editor*

PARIS—Académie des Sciences de l'Institut de France. Comptes Rendus, Tome CXXIX., Nos. 16 - 26, 1899; Tome CXXX., No 1, 1900. *The Academy*

Ecole d' Anthropologie de Paris. Revue Mensuelle, Année IX., Nos. 10 – 12, 1899. *The Director*

PENZANCE—Royal Geological Society of Cornwall. Transactions, Vol. XII., Part V., 1900. *The Society*

PHILADELPHIA—Academy of Natural Sciences. Catalogue of Duplicate Books and Pamphlets in the Library. Proceedings, Parts ii. and iii., 1899. *The Academy*

American Philosophical Society. Proceedings, Vol. XXXVIII., No. 160, 1899. *The Society*

Franklin Institute. Journal, Vol. CXLIX., Nos. 3 – 6; Vol. CL., No. 1. *The Institute*

University of Pennsylvania. University Bulletin, Vol. IV., Nos. 3 – 6, 1899-1900. *The University*

Zoological Society. Annual Report (28th) of the Board of Directors, 26 April, 1900. *The Society*

PLYMOUTH—Plymouth Institution and Devon and Cornwall Natural History Society. Annual Report and Transactions, Vol. XIII., Part i., 1898-99. ,,

ABSTRACT OF PROCEEDINGS, AUGUST 8, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, August 8th, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

About thirty members and visitors were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. T. H. Houghton and R. T. Baker were appointed Scrutineers, and Mr. W. M. Hamlet deputed to preside at the Ballot Box.

The certificates of two candidates were read for the third time, and of four for the first time.

The following gentlemen were duly elected ordinary members of the Society:—

Gray, J. G., Grazier, "Kentucky," Corowa.

Hadley, A., F.C.S., Brewer, Standard Brewery, Sydney.

The President announced that the Third Science Lecture of the Royal Society of New South Wales' series for 1900, viz., "A study of the Mechanics of the Human-Frame work," by Professor T. P. ANDERSON STUART, M.D., LL.D., etc., Professor of Physiology, University of Sydney, would be given in the Royal Society's House on the 22nd instant.

THE FOLLOWING PAPERS WERE READ:—

1. "Notes on Rack Railways," by C. O. BURGE, M. Inst. C.E.

The author, after adverting to the early efforts which were made to make use of a rack and cog-wheel to enable excessively steep railway inclines to be surmounted by an engine with its load, pointed out how, from a line of iron plates laid along a common road in order to diminish friction, the modern railway was developed. It brought with it, however, the drawback of want of adhesion owing to the smooth surface of the metal when the weight of the load to be drawn bears an undue proportion to that on the driving wheels of the engine, thus causing slipping of the wheels, there being no purchase or bite, to enable the power applied to take effect. This is counteracted by sanding the rail, thus increasing the angle of friction, but this has its limit, and when the traction due to the load, enhanced by gravity on a very steep grade, is excessive, the purchase on the road by the wheel must be obtained by some device in the nature of a rack and pinion. After some early attempts, the rack and pinion system invented by Abt, seems to have found the most favour, and about one hundred rack lines on this and other systems in various parts of the world, including some of the Australian Colonies, have been successfully worked.

The author then proceeded to describe the Abt construction as generally consisting of two or more rack bars, laid centrally and vertically between the ordinary bearing rails, the rack being engaged with corresponding pinions driven by special cylinders inside the engine, the ordinary adhesion driving wheels being actuated by separate outside cylinders. The advantage of duplicating or triplicating the rack bars, being not only to give increased purchase, but to furnish a reserve of holding power in the event of one set breaking. The Nilgiri Hills, metre gauge, rack railway in India, was then described as well as the engines in use, and their performances; also the permanent way and rack for standard gauge with three rack bars, which had been suggested by the Abt Company for a steep incline now under survey in this colony. Some other lines were referred to, more or less fully, and also the Staub rack system, which differs from the Abt, and which, for special reasons given, has been adopted for the Jungfrau electric rack line, in Switzerland.

The grades dealt with by the rack seldom exceed that of the Jungfrau, which is 1 in 4, though there is a 1 in 2 line also in Switzerland, on what is called the Lochar system, which was described. Except in special instances of light passenger traffic, 1 in 12½ should not be generally exceeded, this grade being the steepest which could be surmounted by an ordinary adhesion engine, with no load behind it, hence any steeper grade would prevent free passage for locomotive stock between the railway systems, connected by the rack. And there is also the greater special precautions as to brakes etc., which would be required. When grades are easier than about 1 in 25, the difficulties of want of adhesion diminish so much, that the extra complication of the rack makes its adoption of doubtful advantage. The question of the easy entry of the engine into the rack, of vertical curves, of special care in construction and maintenance, of points and crossings, of brakes, of precautions against creeping, of disadvantages of sharp curvature, of safety sidings, and of speed are fully discussed.

Two systems of working have been applied to lines of which a rack length forms a part, that of having one or more special engines to work the rack part only, and that of having combined rack and adhesion engines working the whole or neighbouring systems, using the pinions only on the rack division, and the relative advantages and otherwise of these are entered into.

In many cases the alternative presents itself of adopting for the ascent of a given height, a comparatively long but easily graded adhesion line, or a short and steep rack one, this being the phase of the question which only, up to the present, has had to be considered in this colony. These alternatives are carefully discussed in the paper, the author deprecating the frequent practice, in published papers and discussions, of comparing results from trials of various rival systems, in all branches of engineering, under totally different conditions, and made in different localities, as wholly misleading, not only on that account, but because generally omitting the personal element, on which so much of success or failure depends. The author comes to the conclusion that as a rule, if the same load has to be lifted the same height, in the same time, on two such lines, the working expenses cannot greatly differ, as the mechanical effort is the same, and items of working expenses not affected by this tend to neutralize one another, the greater length of the one line going against the extra repairs, mile for mile, of the other. Hence the relative cost of construction must be the main guiding factor.

The paper concludes with an extract from a recent report by an Italian Commission to the Public Works Department of the Government of Italy, which is generally favourable to the rack rather than the adhesion principle in alternatives such as that referred to, and stating its suitability to many localities and circumstances in that country.

2. "On the damage done to the Seal Rocks Lighthouse by lightning on July 10th," by C. W. Darley, M. Inst. C.E.

Mr. C. W. Darley said that the lighthouse tower was fitted with a solid copper lightning conductor extending half round, and was attached at the top to the copper roof of the lantern. The electric fluid evidently entered the vane on top of the lantern dome, the end being bent and fused, and thence passed down the lightning rod. A portion of the current was communicated to the electric bell wires on the middle floor. These wires led to the principal and assistant light-keepers' quarters, and were laid underground in a 1 in. iron pipe for a distance of 300 ft. The current had tried to make earth at three places, for the pipe was burst and the earth above blown away. The wires led up the verandah posts, and the wooden casing had been torn off and split into fragments. A piece of sheet iron had been blown off and thrown with such force that it cut a passage through a pailing fence six feet away. The iron ceiling and staircase must have been thoroughly charged, for numerous spots appeared where the paint had been blown off and the bare iron underneath was fused. The iron ceiling under this floor was fastened with screws, and the heads of several had been blown off. One piece of stout zinc was blown for a distance of forty feet, and the lids of the oil tanks were blown off and destroyed. The concrete flooring was also damaged. He thought the whole cause of the damage was due to the lightning conductor not making an efficient earth connection. In conclusion the author said that a lesson to be learnt from this occurrence was the necessity for insulating the bell wires.

Some exhibits were shown by the author, and they added a good deal of interest to his paper.

ABSTRACT OF PROCEEDINGS, SEPTEMBER 5, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, September 5th, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

Thirty members and four visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of four candidates were read for the second time, and of three for the first time.

The President made the following announcements, viz.:—

1. That the Fourth Science Lecture of the Royal Society of New South Wales' series for 1900, "On the Building of the Australian Continent," by Professor T. W. EDGEWORTH DAVID, B.A., F.G.S., F.R.S., Professor of Geology, University of Sydney, would be given in the Society's House, on Thursday, September 27th.
2. That the Fifth Lecture on "Some phases of Mammalian Development," would be given by Professor WILSON, with Lantern Illustrations.
3. That a Conversazione would be held in March 1901.
4. That an Annual Dinner would take place in April 1901.

THE FOLLOWING PAPERS WERE READ:—

1. "The Language, Weapons, and Manufactures of the Aborigines of Port Stephens, New South Wales," with two plates, by W. J. ENRIGHT, B.A., (Communicated by R. H. MATHEWS, L.S., Corres. Memb. Soc. d'Anthrop. de Paris).

This paper furnished a grammar and comprehensive vocabulary of the language of the Kutthung, one of a number of tribes inhabiting the country around Port Stephens and the Karuah River, New South Wales. Two large plates accompanied the article, containing photographs of the weapons, utensils, etc., in use among the natives of the district dealt with. Mr. R. H.

Mathews, who communicated the paper, remarked that it afforded him peculiar gratification to have the opportunity of bringing before the Society the labours of other investigators in the wide but little known field of Australian anthropology.

2. "The past droughts and recent flood at Lake George," by H. C. Russell, B.A., C.M.G., F.R.S.

It was shewn that at the end of 1874 Lake George was at its maximum depth during the past seventy years, the depth then being 24 ft.; from that date the water gradually decreased, rising sometimes during heavy rains, and on 25th February, 1877, the water was only 10 ft. 9 in. deep. At this time the author put up an automatic gauge, which recorded every change until it became too low for the machine to work, and exact measures were then carried on by hand. Meantime the level varied with the seasons, until in 1890, a very wet year, the lake was 12 ft. 11 in. deep; and after this the lake level fell faster than ever recorded before, and on March 28th, 1900, the depth was only 0 ft. 10 in., a fall of 12 ft. 1 in. in six years. During 1895 the evaporation was most rapid, the hot and windy weather carried the water away, not only by evaporation but also as spray into the forest, and the total loss of water in that year was 5 ft. 4 in. A loss of water which can I think only be accounted for by the great heat and force of the wind, which carried away great quantities of water as *spray*. As proof that it was not due to percolation, I may mention that, at my request, very careful observations were made during the recent rise, when there were great fissures in the mud which proved the dryness. As the water rose it was carefully watched to see if it was percolating, and during the first day, about one inch only was lost, and no further loss from that cause could be discovered.

3. "Note on an Obsidian 'Bomb,'" by R. T. Baker, F.L.S., Curator Technological Museum, Sydney.

The specimen described in this note is not quite perfect—a portion having been broken off when it was discovered. It has a form quite unusual to those previously recorded from Eastern

Australia, but resembles those from Western Australia and the interior of the continent. It is not unlike one found in Tasmania in 1897. It is sub-globose in shape, the surface being much indented with air pores and globulites; it has a very dark green or almost black, glassy appearance, and measures 1 in. in diameter, and $\frac{3}{8}$ in. in thickness, and has a specific gravity of 2·456 at 15° C. It was found at O'Connell near Bathurst, by Messrs. A. Walkes and Lester, some feet below the surface, whilst sinking for gold. Much attention at the present time is being given by scientists in Europe in regard to the origin of these bombs, a fact which adds to the interest of this find.

4. Demonstrations by W. Camac Wilkinson, B.A., M.D. *Lond.*, M.R.C.P., Lecturer on Pathology, University of Sydney. i. Demonstration of Influenza bacillus, with exhibits. ii. Demonstration of new method of staining flagella of bacteria, with exhibits.

The following donations were laid upon the table and acknowledged :—

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics.*)

Rochester, N.Y.—Geological Society of America. Bulletin, Vol. x., 1899. *The Society*

San Francisco—California Academy of Sciences. Occasional Papers, Vol. vi., 1899. Proceedings, Third Series, Botany, Vol. i., Nos. 6–9; Geology, Vol. i., Nos. 5, 6, Zoology, Vol. i., Nos. 11, 12, 1899. *The Academy*

Scranton—Colliery Engineer Co. Mines and Minerals, Vol. xx., Nos. 3–5, 1899; Nos. 6–11, 1900. *The Colliery Engineer Co.*

St. Louis—Missouri Botanic Garden. Annual Report (11th) 1900. *The Director*

Stockholm—Kongl. Svenska Vetenskaps Akademiens. Handlingar, Band xxxii., 1899-1900. *The Academy*

Stuttgart—Königliches Statistisches Landesamt. Wurttembergische Jahrbücher für Statistik und Landeskunde, Jahrgang 1899, Teil i. *The 'Landesamt'*

Sydney—Department of Agriculture. *Agricultural Gazette of N. S. Wales,* Vol. x., Part xii., 1899; Vol. xi., Parts i., ii., 1900. *The Department*

Institution of Surveyors, N. S. Wales. The Surveyor, Vol. xii., No. 12, 1899; Vol. xiii., Nos. 1, 2, 1900. *The Institution*

SYDNEY—*continued.*

The Colonial Treasurer. History of New South Wales, Vols. I., II.; Historical Records of New South Wales, Vols. I. – VI. *Government Printer*

URBANA, Ill.—Illinois State Laboratory of Natural History. Bulletin of the Illinois Museum of Natural History, No. 1, 1876. Bulletin, Index to Vol. I., (Bulletins 1 – 6). Bulletins—Vol. II., Nos. 2, 5, 6, 7, 8, 1886 – 1890; Vol. III., Nos. 1 – 15, 1887 – 1895; Vol. IV., Nos. 1 – 8, 10, 1892 - 1897; Vol. V., Nos. 3 – 7, 1897 – 1899. Bulletin No. 2 1878, Vol. V., Art. 10, 11, 1900. *The State Laboratory*

WASHINGTON—American Historical Association. Annual Report for the year 1898. *The Association*

Commissioner of Education. Report for the year 1897-98, Vols. I. and II. *The Commissioner*

Department of Agriculture. Crop Circulars for November 1899. Crop Reporter, Vol. II., Nos. 1, 2, 3, 1900. Division of Biological Survey: Bulletin No. 12, 1900. Division of Botany: Bulletin Nos. 22, 24, 1899-1900. Division of Vegetable Physiology and Pathology: Bulletin Nos. 16 – 19, 1899-1900. Monthly Weather Review, Vol. XXVII., Nos. 8 – 12, and Annual Summary for 1899; Vol. XXVIII., Nos. 1 – 3, 1900; Bulletin F., Report on the Kite Observations of 1898. North American Fauna: No. 17, 1900. Office of Experiment Stations: Bulletin, Nos. 58, 60, 70, 73, 1899. Year Book, 1898, 1899. *The Department*

Department of the Interior. Report of the Secretary for the Fiscal year ended June 30, 1896, Vols. I. – III.; Vol. I., 1897. Report of the Commissioner of the General Land Office, 1897. Report of the Commissioner of Indian Affairs, 1897. Miscellaneous Reports. ,,

National Academy of Sciences. Memoirs, Vol. VIII., No. 1, 1896; No. 4, 1899. Proceedings, Vol. I., 1877. *The Academy*

Navy Department—Office of Naval Intelligence. Coaling, Docking, and Repairing Facilities of the Ports of the World, with analyses of different kinds of coal (Fourth Edition) 1900. Notes on Naval Progress, November 1899. The Spanish-American War, War Notes, Nos. 6, 7, 1899. The Squadron of Admiral Cervera by Capt. Victor M. Concas y Palau, 1900. *The Department*

Surgeon-General, U.S. Navy. Annual Report 1899. *The Surgeon General*

Smithsonian Institution. Smithsonian Miscellaneous Collections, Vol. XLI., No. 1173. Index to the Literature of Zirconium by A. C. Langmuir, PH. D., and Charles Baskerville, PH. D., 1899. *The Institution*

U.S. Coast and Geodetic Survey. Bulletin, No. 40, Second Edition, 1900. *The Survey*

U.S. Geological Survey. Annual Report (19th) 1897-8, Parts iii., v., and Atlas; (20th) 1898-9, Parts i., vi. and vi. continued. ,,

U.S. Hydrographic Office. Notices to Mariners, Nos. 43, 44, and Index 1899; Nos. 1 – 20, 1900. *The Office*

ABSTRACT OF PROCEEDINGS, OCTOBER 3, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, October 3rd, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

Twenty-four members were present.

The minutes of the preceding meeting were read and confirmed.

Mr. L. Whitfeld and His Honor Judge Docker were appointed Scrutineers, and Dr. F. H. Quaife deputed to preside at the Ballot Box.

The certificates of four candidates were read for the third time, and of three for the second time.

The following gentlemen were duly elected ordinary members of the Society:—

Canty, M., Registrar, Land Tax Department; 13 York-st.
Flashman, James Froude, Doctor of Medicine; 'Totnes,' Temple-street, Petersham.
Ralston, John Thompson, Solicitor; 86 Pitt-street.
Simpson, Richard Christopher, Demonstrator of Physics; Physics Department, Sydney University.

The President announced that the Fifth Science Lecture of the Royal Society of New South Wales' series for 1900, viz., "Some phases of Mammalian Development" by J. T. WILSON, M.B., Ch.M. *Edin.*, Professor of Anatomy, University of Sydney, would be given in the Royal Society's House on the 17th instant.

THE FOLLOWING PAPERS WERE READ:—

1. "Marriage and Descent among the Australian Aborigines," by R. H. MATHEWS, L.S., Corres. Memb. Anthrop. Soc., Washington, U.S.A.

In this short paper the author dealt with the social laws of some tribes in New South Wales, Queensland, and elsewhere. Tables and genealogies were supplied illustrating the marriage restrictions, and the descent of the resulting progeny. A brief description was given of certain inaugural ceremonies through which the youths have to graduate in order to reach the status of aboriginal manhood. Bull-roarers and message sticks were also dealt with, and a cursory reference made to infanticide, abortion, and cannibalism—customs still practised in some districts where the natives are in a comparatively wild state.

2. "On the constituent of peppermint odour occurring in many Eucalyptus oils—Part I.," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

The first Eucalyptus oil was distilled by Dr. White in 1788, at Sydney, and owing to the great resemblance between this oil and that obtained from the peppermint, *Mentha piperita*, he named the tree from which he had obtained the oil the "Peppermint Tree." Its botanical name is *Eucalyptus piperita*. Since then many other species of Eucalyptus have been found to have this peppermint odour, and are generally known as "peppermints." The constituent giving this odour has now been isolated. It occurs in greatest amount in the oil obtained from the leaves of *E. dives*, next in that of *E. radiata*, and in fair amount in the oils of several other species. It is usually found in those Eucalyptus oils in which the principal terpene is phellandrene, although this is not always so, but generally there is an almost entire absence of Eucalyptol in those oils in which it occurs most abundantly. The crude oil of *E. dives* was taken for the preparation of this peppermint constituent. The oil of this species has a specific gravity ranging from 0·882 to 0·888 at 15° C., and its optical rotation varies from − 55·7 to − 63·9 in 100 mm. tube; 20 per cent. of a sample of this oil distilled between 227° and 240°, this portion contains the peppermint constituent, as thus obtained it had a specific gravity 0·9318 at 15° C., and its rotation was − 9·4°. For commercial purposes it may be steam distilled, that is, if it is found to be of special value. The peppermint constituent was removed from the fraction 227° – 240° by agitating frequently for about three weeks with a concentrated solution of sodium bisulphite. The combination does not readily take place. The aqueous portion, treating with caustic soda solution, separates an oil which was afterwards steam distilled. As thus obtained it is almost colourless, and has a very strong taste of peppermint, and an odour of peppermint which becomes more marked on diffusion. Its specific gravity was 0·9393 at $\frac{17^\circ C.}{15^\circ C.}$ and it boiled at 224 – 225° C. Its rotation was 0·35° to the left, but probably the constituent itself is inactive as a small portion of an aldehyde having left rotation was detected. On reduction with metallic sodium in alcoholic solution, a crystalline substance was obtained which was but slightly soluble in alcohol and in ether, but exceedingly soluble in chloroform; it melted at 155° – 156° C. and crystallises in oblique prisms which polarise very well. This peppermint constituent is not menthone, and is probably a new ketone, a molecular determination gave 155, so that probably its formula may eventually be found to be $C_{10}H_{18}O$. The second part of the paper will deal with its chemical reactions and peculiarities.

3. On the crystalline structure of gold nuggets from Klondyke, Victoria and New Zealand," by Professor LIVERSIDGE, M.A., LL.D., F.R.S.

Sections of three nuggets from Klondyke were shown. The crystal faces are comparatively small, and the nuggets have a granular structure, as if built up of separate grains, of one or two millimetres in diameter. They are also more fissured and contain more cavities than usual. The sections of Victorian (Australian) and New Zealand nuggets are also made up of small crystals, and they present numerous small cavities after the removal of the quartz and iron oxide by treatment with hydrofluoric and hydrochloric acids, so that the sections present quite a different appearance to the very compact and largely crystallised nuggets from West Australia.[1]

The following donations were laid upon the table and acknowledged:—

[1] See Journ. Roy. Soc. N. S. Wales, 1896.

TRANSACTIONS, JOURNALS, REPORTS, &c.

(The Names of the Donors are in *Italics*)

AACHEN—Meteorologische Station I. Ordnung. Deutches Meteorologisches Jahrbuch für 1898, Jahrgang IV. Ergebnisse der 1899. Reprints etc. (3) *The Director*

ADELAIDE—Department of Mines. Record of the Mines of South Australia:—Report on the Gold Discovery at Tarcoola by H. Y. L. Brown, F.G.S., 1900. *The Department*

Public Library, Museum, and Art Gallery of South Australia. Report of the Board of Governors for 1898-9. *The Board*

Royal Society of South Australia. Memoirs, Vol. I., Part ii., 1900. Transactions, Vol. XXIII., Part ii., 1899; Vol. XXIV., Part i., 1900. *The Society*

AGRAM—Kr. Hrv.-Slav.-Dalm. Zem. Arkiva. Vjestnik, Godina II., Svezak. 1, 3, 4, 1900. Nove Serije Sveska IV., 1899-1900. ,,

ALBANY—New York State Library. University of the State of New York—College Department, Second Annual Report 1899, Vol. II. Professional Education in the United States. *The University*

AMSTERDAM—Académie Royale des Sciences. Jaarboek, 1898. Proceedings of the Section of Sciences, Vol. I., 1899. Verslag van de Gewone Vergaderingen der Wis- en Natuurkundige. Adfeeling van 28 Mei 1898 tot 22 April 1899. Verhandelingen (Eerste Sectie) Deel VI., Nos. 6, 7, 1899; (Tweede Sectie) Deel VI., Nos. 3 – 8, 1899. *The Academy*

BALTIMORE—Johns Hopkins University. American Chemical Journal, Vol. XXI., No. 6; XXII., Nos 1 - 6, 1899; Vol. XXIII., Nos. 1 – 3, 1900. American Journal of Mathematics, Vol. XXI., Nos. 3, 4, 1899; Vol. XXII., No. 1, 1900. American Journal of Philology, Vol. XX., Nos. 1 – 4. Circulars, Vol. XIX., Nos. 142, 143, 1899, 1900. Studies in Historical and Political Science, Vol. XVII., Nos. 6 – to 12, 1899; Vol. XVIII., Nos. 1 – 4, 1900. *The University*

Maryland Geological Survey. Maryland Weather Service, Vol. I., 1899. Report, Vol. III. 1899. *The Survey*

BATAVIA—Dept. de l'Instruction Publique, des Cultes et de l'Industrie aux Indes Neerlandaises. Kort Verslag over de Aardbeving te Soekaboemi (Preanger-Regentschappen) op 14 Januari 1900 door Dr. R. D. M. Verbeek. Kort Verslag over de Aaard-en Zeebeving op Ceram den 30 Sept. 1899 door Dr. R. D. M. Verbeek. Voorloopig Verslag over eene Geologische Reis door het Oostelijk Gedeelte van den Indischen Archipel in 1899 door Dr. R. D. M. Verbeek. *The Director*

Koninklijke Natuurkundige Vereeniging in Nederl-Indië. Natuurkundig Tijdschrift, Deel LIX., 1900. *The Society*

BERGEN—Museums. Aarbog 1899. An account of the Crustacea of Norway by G. O. Sars, Vol. III., Cumacea, Parts i. – viii., 1899-1900. *The Museum*

BERNE—Département de l'Interieur de la Confédération Suisse-Section des Travaux Publics. Bassin du Rhône depuis ses sources jusqu' au lac Léman, 1898. *The Department*

ABSTRACT OF PROCEEDINGS, NOVEMBER 7, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, November 7th, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

Thirty members were present.

The minutes of the preceding meeting were read and confirmed.

Messrs. R. T. Baker and W. R. George were appointed Scrutineers, and Dr. H. G. A. Wright deputed to preside at the Ballot Box.

The certificates of three candidates were read for the third time, and of two for the first time.

The following gentlemen were duly elected ordinary members of the Society :—

Bale, Ernest, Civil Engineer, Public Works Department.
Hawkins, William Edward, Solicitor, 88 Pitt-street.
MacTaggart, Archibald H., Doctor of Dental Surgery, Phil. U.S.A., King and Phillip-streets.

THE FOLLOWING PAPERS WERE READ :—

1. "Current Papers, No. 5," by H. C. RUSSELL, B.A., C.M.G., F.R.S.

This paper includes the records of one hundred and eight current papers collected during the past thirteen months. The total number of papers recorded in the whole series is now six hundred and two; these have been published in the Royal Society's Proceedings. At this stage it is worth while to see what important results have been attained. Beginning then in the Indian Ocean it is found that north of the Equator current papers drift to the eastward, but the number of papers found is too small to determine the rate of drift. From the Equator to latitude 10° south, current papers drift easterly on to equatorial Africa ; five papers in this area made an average drift of 13·3 miles per day. Taking the next section, that is, from 10° south to 23° south, the average daily rate derived from eleven papers is 16·5 miles. From 23°

south to 33° south, no papers have been found drifting westerly or easterly, except a few papers put afloat close to Australia, and they as usual went ashore. In the next area, *i.e.*, between 33° south and 43° south, in the Indian Ocean, the current papers drift easterly, or more accurately east-north-east; twenty-one long distance papers in this area give an average daily drift of 7·6 miles. In the next section, *i.e.*, 43° south to 50° south, twenty current papers shew a daily easterly drift of 9·4 miles. Tabulating the dates at which current papers are found, it appears, that the smallest number of current papers came ashore at the times of the *Equinoxes* (March and September) and the greatest number received in one month of each year is:—May 1897, ten papers; October 1898, twelve papers; August 1899, fourteen papers; and February 1900, fourteen papers.

2. "The Sun's Motion in Space."—Part I., History and Bibliography, by G. H. Knibbs, F.R.A.S., Lecturer in Surveying, University of Sydney.

Apart from its intrinsic interest, the determination of the direction and quantity of the Sun's motion in space is of importance, as the condition of further progress in developing a satisfactory system of defining the places of stars. The establishment of such fixed planes of reference as will be unaffected by the relative or absolute motions of the sun and stars, even for great periods of time, is clearly a desideratum if not essential in any thorough scheme of analysis of such movements. The preliminary paper (Part I) gives an account of the history and bibliography of the development of the idea of a motion of translation of the sun through space, and also of the determinations of the direction and amount of this motion, indicating briefly at the same time the general principles underlying those determinations. The conception of an indefinitely extended stellar universe, in which the sun and its planetary system is but a single and perhaps insignificant member, is one that the world owes to Giordano Bruno, in 1584. The part played by Bruno, Schyrleus, Fontenelle, Halley, Bradley, Wright, Kant, Mayer, Lambert, Michell, and

Lalande in establishing and extending the conception is indicated. The first deduction of the direction of the solar motion was made by Pierre Prévost in 1781 from twenty-six stars, the latest by Kobold from 2,262 stars. Herschel is generally credited with being the first to numerically estimate the direction in 1783, but wrongly so. The historical sequence of the various determinations is preserved in the development of the paper, and the bibliography is believed to be exhaustive.

3. "On an Eucalyptus Oil containing sixty per cent. of geranyl acetate, by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

In this paper the author shews that the oil of *Eucalyptus macarthuri*, known locally as Paddy's River Box, is very rich in geraniol, it containing 60 per cent. of geranyl acetate, and 10·64 per cent. of free alcohol, calculated as geraniol. The oil is somewhat analogous with that obtained from *Darwinia fascicularis*, brought under the notice of this Society by Mr. R. T. Baker and the author in December 1899. Both *Darwinia* and *Eucalyptus* belong to the natural order Myrtaceæ. The oil of *E. macarthuri* contains eudesmol (the stearoptene of Eucalyptus oil) the fraction distilling between 266 – 282° C., crystallising quite solid in the bottle. This substance is absent in the oil of *Darwinia*. The yield of oil from this Eucalypt collected in October from near Wingello, in this colony, and obtained by steam distillation from fresh leaves and branchlets was 0·112 per cent. The whole of the ester was saponified in the cold by alcoholic potash in one and a half hours. As no heat was applied, the separated oil was excellent, the geraniol not being interfered with. This fact of cold saponification of geranyl acetate might be used for quantitative determination of this ester, when it and other esters are present in essential oils. Citral was obtained by oxidation, and the pure geraniol prepared from the calcium chloride compound; this was a colourless oil boiling at 224 – 225° C. (uncor.) and had a specific gravity of ·885 at 20° C. The acid of the ester was shown to be acetic acid. The crude oil contained neither eucalyptol nor phellandrene, it was entirely different in appearance and constituents from ordinary Eucalyptus oil. It formed a clear solution with two volumes of 70 per cent. alcohol, it had an optical rotation of $+3 \cdot 6°$ in a 100 mm. tube, and specific gravity at 15° C. of ·9245, the comparatively high specific gravity being due to the presence of the stearoptene.

EXHIBITS.

Dr. F. H. Quaife exhibited a modification of the Wehnelt interrupter to obviate the cracking of the glass tube by keeping the metal conductor inside it cool, and to cause, if a crack occurs in the glass, any acid to be driven out by electrolysis and so to prevent corrosion. This was shown in action by a storage battery giving 36 volts and 9 amperes. The peculiar ribbon-like spark between the points of the coil as well as the ordinary lightning sparks in streams were shown, and also the screen shadows of the X rays. A Watson's Penetrator tube was used with a wet lint cover at the negative electrode.

Mr. W. M. Hamlet exhibited a new form of Phonograph.

The following donations were laid upon the table and acknowledged :—

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(The Names of the Donors are in *Italics*.)

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ABSTRACT OF PROCEEDINGS, DECEMBER 5, 1900.

The General Monthly Meeting of the Society was held at the Society's House, No. 5 Elizabeth-street North, on Wednesday evening, December 5th, 1900.

The President, Prof. LIVERSIDGE, M.A., LL.D., F.R.S., in the Chair.

Twenty-five members and four visitors were present.

The minutes of the preceding meeting were read and confirmed.

The certificates of two candidates were read for the second time.

Messrs. DAVID FELL and LAWRENCE HARGRAVE were appointed Auditors for the current year.

The President announced that the Council recommended the election of the following gentlemen as Honorary Members of the Society, viz :—

Sir WILLIAM CROOKES, F.R.S.

Sir W. TURNER THISELTON DYER, K.C.M.G., M.A., F.R.S.

The election was carried unanimously.

Printed copies of the alterations to the Rules, proposed by the Council were distributed among the members and agreed to unanimously.

It was further resolved that the Rules be consecutively re-numbered, so as to omit if possible, of the distinction of A and B; such re-numbering to be left in the hands of the Council.

THE FOLLOWING PAPERS WERE READ:—

1. "Intercolonial Water Rights as affected by Federation," by H. G. McKINNEY, M.E., M. Inst. C.E.

In explanation of the magnitude and importance of this question, it was pointed out that the drainage area of the Murray River is shared by four colonies as follows:—New South Wales 234,000 square miles, Queensland nearly 105,000 square miles, Victoria nearly 51,000 square miles, and South Australia over 24,000 square miles; making a gross area of 414,000 square miles. In seasons during which the rivers are high, the length of navigable river is 3,213 miles, as follows:

		Miles.	
River Murray from Goolwa to Wentworth	...	617	
Ditto from Wentworth to Murrumbidgee Junction		255	
Ditto from Murrumbidgee Junction to Corowa	...	485	
			1,357
River Murrumbidgee from Murray Junction to Narandera			500
River Darling from Wentworth to Mungindi	...	...	1,356
		Total in miles	3,213

While the Inter-State Commission to be appointed by the Federal Parliament will have charge of the navigation on these rivers, it is not to interfere with "the reasonable use of the waters of rivers for conservation or irrigation." As the navigation is liable to long interruptions on the River Darling owing to deficient and uncertain supply of water, and is intermittent even on the River Murray, it is obvious that in a dry country such as that watered by these rivers and their tributaries, conflicts between the interests of navigation on the one hand, and of water conservation and irrigation on the other, are certain to arise. The conditions on the principal tributary rivers were referred to in outline in the paper, and instances were given of the manner in which difficulties are likely to occur and of the complicated nature of the task with which the Inter-State Commission will have to deal.

In Queensland the question of water rights on the rivers is practically untouched. In New South Wales numerous rights to water have been granted, but they are on such a limited scale that they cannot be regarded as any infringement on navigation rights. But in Victoria extensive works for water conservation and irrigation have been constructed, and rights to large quantities of water have been granted, while in South Australia, the water rights which have been granted, though on a much more limited scale than in Victoria, are of far greater importance than those granted up till the present in New South Wales. The Inter-State Commission will thus find that, in the different colonies concerned, the conditions as regards water rights differ widely. By way of illustration of the value of some of our unused water rights, the paper referred to the evidence lately taken by a Board of Inquiry regarding weirs in the Murrumbidgee. A prominent pastoralist who is a first-class practical authority on the value of water in the Central and Western Divisions, stated in evidence that if the proposed Murrumbidgee Southern Canal Project had been in operation during the protracted drought which commenced in 1895, the entire outlay involved in its construction would have been returned to the country several times over. This evidence was supported by details regarding the area which could be irrigated and the crops which could be raised, these particulars being based on the witness' own experience.

2. "The Organisation, Language and Initiation Ceremonies of the Aborigines of the South-east Coast of New South Wales," by R. H. Mathews, L.S., and Miss M. M. Everitt.

This article described the laws of marriage, descent and relationship in force among the native tribes occupying the south-east coast of New South Wales from the Hawkesbury River to Cape Howe, on the Victorian frontier, and extending inland till met on the west by the Wiradjuri organisation. A grammar of the language of the Gundungurra, one of the principal tribes in the region dealt with, was also supplied, in which the structure of the native tongue was fully investigated and explained. The paper concluded with a short account of the Kudsha, or Narramang, a ceremony of initiation practised within the same geographical limits, by means of which the young men are admitted to the status and responsibilities of tribesmen.

3. "Tables to facilitate the location of the Cubic Parabola," by C. J. Merfield, F.R.A S.

In some brief remarks the author gives an outline of the general application of the cubic parabola, when used as a transition to connect the straights and circular curves of railway lines. The paper forms a contribution to the engineering profession, and will be found useful to those engaged in the location of railway lines.

A valuable table is appended, from which the constants of the curve for any case may be found. A complete numerical example illustrates the method of using the table. Details have been avoided, but they may be found in the papers, by the same author, that have been referred to in the notes.

4. "Boogaldi Meteorite," by Prof. LIVERSIDGE, M.A., LL.D., F.R.S.

This meteorite was exhibited by Mr. R. T. Baker, F.L.S., at the June meeting of the Royal Society of N.S. Wales, when he stated that it was found early in January this year at a place two miles from Boogaldi, a post town fifteen miles north-west of Coonanbarabran. Mr. Baker afterwards forwarded it to me for investigation and analysis.

Description—The meteorite is a metallic one or a siderite, and is somewhat pear-shaped; it is a little over five inches long by about three inches broad at the widest part, and it weighed before cutting 2057·5 grammes. Its sp. gr. at 14° C. was found to be 7·85. It was covered, as usual, with a closely adherent skin of fused oxides, except in one place where it had been detached, the exposed metal had a bright lustrous appearance like nickel iron. In places thin crack-like markings are present—some of these are evidently closely related to the crystalline structure of the mass within. A few pits are noticeable upon the surface, these were probably due to the presence of granules of troilite, inasmuch as some granules of this mineral (FeS) were found when making the sections of the interior, cracks in the skin are seen starting from these pits—these cracks appear to be distinct from the smaller and regular ones meeting at definite angles, previously referred to. In addition to the larger and deeper pits there are in places numerous small ones which do not appear to be confined to the fused skin of the meteorite, these small ones correspond to the burst gas bubbles met with in slags and fused iron scale. There is however a very remarkable structure in the skin, shown most clearly at the two ends of the meteorite, which I have never observed before in a meteorite. At the thick end of the meteorite the fused oxides forming the skin have been thrown into well defined concentric waves or rings with transverse furrows in the direction of the thinner end of the meteorite—the waves and furrows gradually fade away in this direction. I think that these waves and furrows clearly show that the meteorite travelled through the earth's atmosphere with the thick end in front, the waves of fused oxide being thrown up by the resistance of the air, just as waves are formed in sand by the wind. That the meteorite did travel with the thick end first is confirmed by the fact that at the thin end there are longitudinal ridges and furrows in the fused skin which clearly show where the excess of fused oxide was dragged off; the luminous streak usually seen behind a meteorite is, if not wholly, certainly in part, due to the fused incandescence left in its trail. Hence the waves and other markings in the skin not only show the direction in which the meteorite travelled but also its position, *i.e.*, with the curved point of the thin end downwards as represented in the photograph; for the fused oxides forming the skin are thickest on the lower side.

Sections—These were made by permission of Prof. Warren, by a steam hack-saw in the Engineering Department of the University. The sections were polished and etched with copper sulphate and with bromine; the latter yielded the best surfaces. The crystalline structure is well defined, and it is noticeable that the groups of crystals all intersect at about the same angle and pass across from side to side and some from end to end of the meteorite. One or two small specks of troilite are to be seen, and at the thick end are to be seen two well marked cracks which pass out also through the crust. The crystalline structure is quite distinct from that of any of the Australian and other meteorites that have come under my notice.

5. "On a new aromatic Aldehyde occurring in Eucalyptus oils," by HENRY G. SMITH, F.C.S., Assistant Curator, Technological Museum, Sydney.

In this paper the author records the results of his investigation (so far as he has gone) on the aldehyde occurring in so many Eucalyptus oils, and which had for a long time been supposed to be cumin-aldehyde. The aldehyde occurs in greatest amount in the oils obtained from members of the group of Eucalypts known in Australia as the "Boxes." The true boxes, *E. hemiphloia*, *E. albens*, and *E. Woollsiana*, contain it in the largest quantity. The oil was obtained from *E. hemiphloia*, this tree growing plentifully at Belmore, in the neighbourhood of Sydney. 1,000 cc. of the crude oil was distilled, and the constituents distilling below 190° C. removed, the remainder of the oil was agitated with acid sodium sulphite with which it readily formed a solid compound, the pure aldehyde was easily obtained from this by the usual methods. The product was steam distilled, 33 cc. of the pure aldehyde was thus obtained from a litre of the crude oil, equal to 3·3 per cent. The specific gravity of the aldehyde at 15° C. was ·9477. The specific rotation was $[a]_D$ – 49·17, this somewhat high laevorotation causes those oils containing it to be laevorotatory, although mostly devoid of phellandrene. It is this aldehyde that causes the oil of *E. cnerifolia* of South Australia to be laevorotatory. The pure aldehyde has an aromatic odour and is slightly yellowish in tint. It was soluble in the usual solvents. The oxime was readily formed, and when purified from alcohol, it melted at 84° C.; and by preparing the oxime from the pure aldehyde obtained from the higher fractions of several oils, as *E. cnerifolia*, *E. albens*, *E. Woollsiana*, etc., it was shown that only this aldehyde is present in this class of oils, as this oxime melted at 84° C. also. The hydrazone was also readily obtained, it melted at 105° C. The aldehyde reduced an alkaline silver solution with the formation of a silver mirror, and also answered to Schiff's reaction. Analysis showed the formula of the aldehyde to be $C_{10}H_{14}O$. When the aldehyde was oxidised with potassium bichromate a crystallised acid was obtained, the aldehyde group being oxidised to carboxyl in the usual way. This acid melted sharply at 110° C. It is soluble in boiling water, very soluble in alcohol and in ether. When the aldehyde was oxidised with an alkaline solution of potassium permanganate, energetic action took place, with the formation of eucalyptol or cineol as one of its products. The acid also obtained at the same time melted at

259 – 260° C. with decomposition, an anhydride being formed; the acid is but slightly soluble in boiling water, soluble in alcohol and ether. The anhydride can be readily obtained from the acid by sublimation after melting. The anhydride melted at 152° C.; it is readily soluble in a small quantity of boiling water and crystallises out on cooling, very soluble in alcohol and in ether. The alcohol formed by reduction of the aldehyde is aromatic, but has not yet been obtained in a pure state. The author proposes the name aromadendral for this aldehyde, and aromadendric acid for the corresponding acid.

The following donations were laid upon the table and acknowledged :—

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(The Names of the Donors are in *Italics*.)

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PROCEEDINGS OF SECTIONS.

PROCEEDINGS OF THE SECTIONS

(IN ABSTRACT.)

ENGINEERING SECTION.

The first meeting of the Session was held in the Large Hall of the Society's House on June 20th, 1900, at 8 p.m., when there were present Mr. Norman Selfe, M. Inst. C.E., (in the Chair), and twenty-one members and visitors.

The Chairman of the Section Mr. N. Selfe, then delivered his presidential address entitled "A century of Australian Engineering." A cordial vote of thanks to the Chairman was moved by Mr. C. O. Burge, seconded by Mr. A. B. Portus, and carried by acclamation.

Interesting exhibits were supplied by Mr. W. Thow and Mr. G. H. Halligan.

Meeting held September 19.

There were present Mr. N. Selfe, M. Inst. C.E., (in the Chair) and seven members and visitors.

Mr. S. J. Pollitzer gave an interesting demonstration of a new form of mine surveying instrument devised by himself, and was accorded a very hearty vote of thanks.

The remaining business of the evening was adjourned.

Meeting held December 19.

There were present Mr. N. Selfe, M. Inst. C.E., (in the Chair) and thirty-five members and visitors.

The following members were elected as Officers and Committee for the following year:—Chairman: J. M. Smail, M. Inst. C.E. Hon. Secretaries: S. H. Barraclough, M.M.E., Assoc. M. Inst. C.E., H. H. Dare, M.E., Assoc. M. Inst. C.E. Committee: Percy Allan, Assoc. M. Inst. C.E., G. R. COWDERY, Assoc. M. Inst. C.E., J. DAVIS, M. Inst. C.E., HENRY DEANE, M. Inst. C.E., J. I. HAYCROFT, M.E., M. Inst. C.E.I., LEE MURRAY, M.C.E., Assoc. M. Inst. C.E., M.I.E.E., HERBERT E. ROSS, Professor W. H. WARREN, M. Inst. C.E., M. Am Soc. C.E.

Mr. C. W. DARLEY, read a paper entitled "Curved concrete walls for storage reservoirs."

Mr. C. O. BURGE, presented some additional remarks on "Rack Railways."

Professor WARREN read a paper by himself and Mr. S. H. BARRACLOUGH, entitled "Experiments on the strength of brick-work, when subjected to compressive and transverse stresses."

Cordial votes of thanks to the authors of papers, and to the retiring Chairman and Hon. Secretary concluded the meeting.

ANNUAL ADDRESS.

By Norman Selfe, M. Inst. C.E., M. I. Mech. E.

[*Delivered to the Engineering Section of the Royal Society of N. S. Wales, June 20th, 1900.*]

In opening the present session of the Engineering Section of the Royal Society of New South Wales, I have first to thank the members for the honour they have done me in my election to this chair. I now propose, as this is the last year of the nineteenth century, that instead of attempting to catalogue the great engineering events of the past twelve months, you allow me to make my remarks more discursive. I have looked up some early accounts of engineering in Australia, and I trust it will interest members if my references to present day engineering are prefaced by some historical memoirs. Before going back to the year 1788 I would ask you to remember, that if the session of 1900 is to be successful, the members as a whole must exert themselves towards securing that success, by bringing forward papers and generally aiding the Committee in its work, so that there may be something of special interest at all the future meetings. Each of us has some engineering knowledge or experience not possessed by our fellows, and there are now so many branches in which we are desirous of being taught, that there will be no lack of listeners when a popular subject is discussed. As the greater number of our members are associated with the work of the civil engineer, the mathematician, and the surveyor, it will be appropriate if I commence my references to the early history of engineering in Australia by bringing before you the name of a pioneer whose memory seems to have been much neglected.

Australia's first engineer and surveyor.—The first engineer and surveyor of Australia was Augustus Theodore Henry Alt, whose services do not appear to have had much recognition at the hands of historians. He did not commence his career in this land as an inexperienced youth, like many other men who were afterwards sent out in order that a position might be found for them; but he had a reputation as an engineer and surveyor before he reached this State with Governor Phillip. In 1755 he was Ensign in the King's Eighth Regiment of Foot and served with his regiment in France. In 1760 he was Aide-de-Camp to Prince Ferdinand and several Generals. In 1763 he was Engineer of Roads in the Highlands of Scotland. As captain of the Manchester Corps at the Siege of Gibraltar, General Elliot made him assistant engineer. In 1785 he was appointed engineer of the island of Mauritius, and in 1786 when the Pitt Ministry required a capable engineer and land surveyor to proceed to the proposed settlement at Botany Bay, Captain Alt was selected; and on the 28th of October 1786, the King in Council signed his commission as surveyor of the Territory of New South Wales. Captain Alt's first important work in the State was the laying out of the town of Sydney in conjunction with Governor Phillip, who appears from statements made in his letters, to have had some knowledge as an engineer and surveyor. In the first design for the future "City of the South," dated July 1788 the principal street was intended to be two hundred feet wide, and the allotments were to have frontages of sixty feet with a depth of one hundred and fifty feet. The ground at first marked out for Government House was intended to include the Main Guard and Civil and Military Courts on the one block. The site chosen was about where new St. Phillip's church now stands. The hospital was to be built on the west side of Sydney Cove, about where the Mariner's church now is, and the storehouses to be by the water side where the Commissariat buildings—still standing—were afterwards erected by Governor Macquarie. The Military Barracks were to be erected near the grounds subsequently adopted, now the site of Wynyard Square; and the blocks to the west of it (the ground running to the southward of the officials' quarters being nearly level) was thought to be suitable for building the wide streets proposed. It was intended that the allotments should be granted with the condition that only one house should be erected on each block. Had these liberal views with regard to Sydney been adhered to, the city would not have been disfigured as it now is by such numbers of narrow and irregular streets. What was in many respects, one of the best sites in the world for a model city, has for more than a century been the field of narrow and disjointed enterprises put forward by individual and opposing interests. Authority that should have made itself felt in the improvement of the city and the welfare of the citizens, seems to have either lain dormant through ignorance or otherwise to have been kept down by the heel of private interest, until at length, when the fair fame of Sydney was nearly prostrate in the slough of neglect and abuse, but before it became quite a byeword and reproach among the nations, the strong arm of Government has been raised to rescue it.

In the first survey of the foreshores of the town of Sydney, Surveyor Alt was materially assisted by Captain Hunter, Lieutenant Bradley, and Lieutenant W. Dawes. He had nothing to do with the marine survey of Port Jackson, or of any of the coast, bays, and harbours. Governor Hunter, who seems from his plans as printed, to have been a good draughtsman, apparently did a great deal of this work personally; the land surveys however, were performed by Mr. Alt, with some assistance from Lieutenant Dawes, who had a taste for engineering, although his special work was astronomy. Dawes might have been of valuable service to the State had he stayed longer, but in 1791 he had a quarrel with Governor Phillip which led to his returning to England. (He appears to have had some humane objections to the military being sent out to destroy the natives, which Phillip resented). Dawes commenced the erection of an observatory on the point still known by his name, but he left the State before there was any thought of erecting the battery called after him. The only battery with which Dawes as an artillery officer was associated was an earth work around the Flagstaff, erected on a point in Sydney Cove, somewhere near where the Paragon hotel now stands.

During Governor Phillip's administration Surveyor Alt also appears to have designed and superintended the erection of, the following buildings:—Brickworks at Brickfield Hill; a strong wooden girder bridge to carry Bridge-street across the stream at Pitt-street; Military Barracks and Buildings, 60 ft. by 72 ft. near the present General Post Office; and two of the original barrack buildings which were on the west of Wynyard Square. The proposal to build Government House on the ridge overlooking Darling Harbour near the barracks being abandoned, he commenced its erection at Phillip-street and Bridge-street; it will be remembered that the foundation stone of this building was unearthed in March of last year. Other works were a log gaol, large public and military storehouses, a guard house, and two public wharves.

Surveyor-General Alt not only deepened the stream which flowed from swampy ground near to Park-street into Sydney Cove, and which supplied Sydney with water for thirty years afterwards, but he planned the excavation near to Hunter-street of the tanks in its sandstone bed which gave it the name of the "Tank Stream." The first tank was near the junction of Hunter and Spring-street, it held 7,996 gallons, and had a well in the centre 15 ft. deep, and the records inform us that a crowd assembled to see the water turned into it when it was finished. With regard to road making this pioneer appears to have laid out the whole line from Dawes Point through the young town, to the top of Brickfield Hill, (then in the country), and from thence to Parramatta. This town was also laid out by Alt, and most of its public buildings, such as the hospital and granaries, were part of his work. Many men of far less note and importance than Alt have monuments to them of some kind or other. The only place where the name of our first engineer seems to be perpetuated, is in "Alt-street," Ashfield, where two grants of land aggregating 330 acres were made to him.

In 1797 Surveyor-General Alt was invalided on account of his impaired eyesight, he died on January 9th 1815, and was buried at Parramatta.

Alt's successor was Mr. Charles Grimes, who had been Surveyor at Norfolk Island, and thence forward he carried on the surveys, and prepared plans for public buildings, besides laying out new roads. One of these roads extended from Parramatta to Mulgrave on the Hawkesbury River, where a very early settlement was established. Mr. Grimes lived at Parramatta, where he was for some years a resident magistrate.

In Governor King's time, Francis Barrallier, an Ensign of the New South Wales Corps, who had studied engineering and surveying, was given charge of the batteries and defences of the harbour. He designed the Parramatta Orphanage and made the first survey of the Hunter River in June 1801. Before the end of the same year he was surveying Western Port, in what is now Victoria. In 1802 he made made two trips over part of the Blue Mountains. It is apparently only by the recent researches that have been made, and which have resulted in Barrallier's charts being unearthed, that his forgotten name and works are now again on record.

Ensign George Bellasis succeeded Barrallier as Artillery Officer, he appears to have built the Battery on Dawes Point, and to have been engaged with batteries on Middle Head and Georges Head, as well as one on Benelong Point, now Fort Macquarie.

1804 Governor King began Fort Phillip on the Flagstaff Hill. In 1806 Lieutenant W. Minchin, Engineer and Artillery Officer, carried on the Fort Phillip work, and also built or repaired a stone bridge at Bridge-street which had replaced the timber bridge of Alt. This small stone arch as finally rebuilt in 1811 by Macquarie, is clearly seen in one of the early prints of the town of Sydney that has lately been reproduced.

During the interregnum of Grose and Patterson, and the Governorship of Hunter and King, the directions of the Home Office with regard to reserving the whole of the town of Sydney for the Crown, were violated. Phillip had acted up to his instructions, and had established a Common, which included what is now

Hyde Park and the Domain ; but his successors disposed of nearly half the township by leases which practically amounted to grants.

Bligh, who was Governor from August, 1806, to January, 1808, found the public reserve covered by huts and farms, and began operations to restore it to the Crown by cancelling leases of reserved lands, notably that on Church Hill, leased to MacArthur. Trespassers on the Domain—which then came up to Phillip-street—were warned, and many who did not move had their buildings razed.

Deputy Surveyor-General Meehan was then instructed by Bligh to prepare a new plan of the town, which provided, for the first time, for a proper aligning of the streets. Previously to this, the tenements were set down at the sweet will of the occupier, and more or less in line, in what were known as "The Rows." This was all changed under Meehan, but Governor Bligh's drastic reform brought him into conflict with the military, and led to a suspension of the civil authority—this is a matter of common history.

Suveyor-General Grimes (who had in the meantime surveyed Port Hunter, Port Stephen, and Bass' Straits) afterwards took a trip to England, and on his return joined the military faction in its opposition to Bligh's policy. Grimes then was again sent to England with Major Johnstone's despatches in connection with the deposition of Governor Bligh.

The military rule which followed under Major Johnstone, Colonel Foveaux, and Colonel Paterson, seems to have led to another period of non-progress, during which engineers were at a discount, and public works at a standstill. With the advent of Governor Macquarie, on January 1st, 1810, everything was changed, material progress became the order of the day, and engineering came to the front again.

It would be impossible to enumerate here the whole of the public works executed under the sway of this progressive ruler, for, including those in Tasmania, the list fills ten pages of a

Parliamentary report, the number is over two hundred and fifty, and many of them were of such a character that they are still in existence.

Macquarie encouraged the formation of regular streets and modified his original views as to width by making them sixty feet instead of fifty. He also made substantial grants of land to those who built to plans approved by him. Mr. William Greenway was the Civil Engineer of this epoch, and his works include the original Macquarie Light-house (recently pulled down), St. James' Church, the Hyde Park Barracks, the Benevolent Asylum, the Public Instruction Department building, an adjoining building pulled down to make way for the Lands' Office, the Police Court (afterwards the Post Office in George-street), and the Market House (afterwards the Central Police Office, recently pulled down to make way for the Queen Victoria Markets). A host of others are still standing, but many have disappeared with the progress of the State. Two books, containing a number of very neat drawings of public works, by Mr. Greenway, together with their bills of quantities, still exist in the Government Architect's Department, and are most interesting records of our early days. There appears to have been a third volume, which has unfortunately been lost.

Whether Macquarie's ideas were too advanced for his masters in England, or whether Mr. Greenway was too energetic, and produced public works in advance of the demand for them, cannot with certainty be decided now; but it is certain that on September 25th of the year 1819, Mr. Thomas Bigge arrived from England with the King's Commission, with the result that a great many of the Governor's plans were either modified or thrown out altogether. Bigge considered wooden buildings to be good enough for a convict colony, he stopped all further progress with the cathedral Mr. Greenway had designed for the site at the corner of George and Bathurst-streets, although the foundations were in. The Court House was then being built, as well as St. James Church, the tower and spire of which were added in after years.

Macquarie being thus frustrated in his efforts to make Sydney a model city, and blamed for his lavish expenditure, did not give up his ideas all at once; for he afterwards built without one penny of cost to the Crown, the great hospitals in Macquarie-street, the public section of which did duty for over eighty years, and has only recently disappeared. Opinions of course differ as to Macquarie's methods, Lord Liverpool censured him for them, but it is certain that the Imperial Government would never have found the £30,000 which he raised and expended on the Macquarie-street buildings. As a matter of history the Governor contracted with Messrs. Darcy Wentworth, G. Blaxcell, and A. Riley, in 1810, that they should have the right of buying fifteen thousand gallons of rum free of duty, as a return for erecting these structures. This work occupied five years, and although the central hospital has gone, the other sections are still in existence as part of Parliament House, and the Mint façade.

The Water Supply of Sydney.—Early historians speak of the fairy dells which graced the valley of the Tank Stream in the course of its short run; and they tell us of its great natural beauty, with wild flowers and ferns, and its banks fringed with heavy timber. There are few of us who are not sufficiently acquainted with similar gems of Australian undergrowth, as to be able to form a mental picture of this watercourse as it presented itself to the arrivals by the First Fleet. Governor Phillip ordered that no trees should be cut down within fifty feet of the water run of this stream. At the present day the General Post Office and other conspicuous buildings extend right over its valley from bank to bank, and there is nothing whatever above ground to even indicate its site. Our first Governor also took steps to secure the water from pollution, in 1791 he had an intercepting ditch dug on each side to keep out the surface drainage, and a fence erected for the protection of the beautiful shrubs within the area.

When Phillip left the colony on December 10th, 1792, and the Civil Government was changed to a Military Oligarchy under Captains Grose and Patterson, all Phillip's precautions seem to have been set at naught. The new rulers allowed their followers and others to build close to the stream, to keep pigs, and generally to pollute the water supply of the settlement.

On Governor Hunter assuming command in 1795, he restored the Civil Government, and in October had the fences repaired; he also abolished the pig-styes and the direct paths to the water. Orders were issued that people dipping from the stream, and not going to the Tanks, would be punished by having their houses pulled down, and such orders were repeated up to 1799, when the Governor pointed out that many deaths had resulted from the pollution of the waters. He then appointed a special constable to report daily on the fences and gardens which abutted on the stream.

Governor King, between 1800 and 1806, like his predecessors, was horrified to find persons cleansing fish and washing clothes, besides keeping pigs, on the borders of the stream. He appears to have been a quick-tempered gentleman, for he punished some offenders by pulling down their houses, others were fined £5, while old offenders were flogged and sent on to the roads.

Governor Bligh was also very determined about the preservation of this water supply, and his action in this matter may have hastened his deposition by the offending military officers before referred to. With the Governor got rid of, the military power was again uppermost, and all sorts of irregularities were apparently resumed, for on Governor Macquarie's arrival he found many evidences of civilisation (?) upon the watershed. These included a brewery, a distillery, a tannery, and a dye-works, all of which had been erected within a short distance of the banks of the stream which supplied the town. In 1810 he issued an order that no such industries, and no slaughter-houses, should be erected on or near this stream, and that those already there should be suppressed.

Major-General Sir Thomas Brisbane was Governor from 1821 to 1825, and during his reign the pollution of the stream still went on, and it is recorded that in 1826, during Governor Darling's administration, half-a-dozen boys were caught swimming in the water supply of the town.

At the time of the writer's first arrival in the State, the stream was still quite open to Hunter-street, and it could be seen at intervals still higher up the town, but it had become a sewer. One of the last cottages on its banks was occupied by the late Mr. Bayliss, the lighterman, on the western side of Hamilton-lane. As the adjoining ground was raised by the reclamation, an upper storey was added to his house, which opened to the level of Hamilton-lane, and the original apartments became practically cellars.

The Tunnel, or Busby's Bore.—In March, 1823, Mr. Thomas Busby was engaged by Earl Bathurst for three years, and sent out to New South Wales as Mineral Surveyor and Civil Engineer, at a salary of £200 a year and his passage expenses. On his arrival in February, 1824, he was instructed by Governor Brisbane to look into the question of a water supply for Sydney. After levels had been taken by Messrs. Hoddle and Finch—who, with Govett and others, were assistant surveyors—it was determined to drive a tunnel from the Lachlan Swamps (now part of the Centennial Park) to the south-east corner of Hyde Park. The work was commenced in September, 1827; Mr. Busby's son Alexander (afterwards a successful squatter), was appointed assistant engineer at £100 per annum, on the 25th August; and on December 7th, 1826, Mr. Thomas Busby was re-engaged by the local Government, with his salary advanced to £300 a year.

The length of the tunnel is two and a quarter miles, but owing to the springs tapped on the way, water was supplied to the Hyde Park reservoir long before the swamps were reached. The drive was to be five feet high by four feet wide; and the twenty-eight shafts from which it was worked were all shewn on the maps of Sydney which were current forty-five years ago. The original excavation is given at 255,930 cubic feet, which gives an average section of twenty-two feet. The total cost, including salaries of engineers and other expenses, was £22,971, which works out to about £2 8s. per cubic yard.

As the natural catchment of the portion of the swamps drained by the tunnel was only about two square miles, and as abundance of water close handy was running to waste across the Randwick-road and lower swamps to Botany Bay; subsequently, when the requirements of the city increased, an engine was erected at the road-side, near to the present Racecourse, to supplement the supply to the tunnel. My inquiries, so far, have not led to the date when this engine was erected, but it was well known to me as it was sold when the pumping-station was dismantled, and afterwards worked for many years in the steamer "Quandong," designed by me for the Balmain ferry. This was the first local steam vessel built with two sterns instead of two bows, and the one which led to the complete revolution since made in connection with the Sydney ferries. As the Hyde Park end of the tunnel is 104 ft. above high water-mark, the principal part of the then city was well supplied by gravitation; but the water-cart was a great institution, and in the early "Fifties" twopence was the common price per bucket for the water. The hydrant fountain at Hyde Park was a centre of great activity during the summer months. This supply fell into disuse when the Botany Waterworks, projected by the City Commissioners, were opened in 1858.

It is not desirable with the limited time at our disposal to go into details about the Botany engines, which for nearly forty years supplied Sydney with water. On the completion of the Prospect scheme their occupation was gone, and they were sold practically for old iron, together with a modern high speed auxiliary compound engine pumping plant, which was designed by the author for the City Council in the water famine scare of 1885-1886. This was a very notable work from the fact that it was made, erected, and put to work by the Atlas Company in sixty days from acceptance of tender. The three great beam-engines with their 40 in. steam cylinders in operation, were for many years, the greatest engineering sight of Sydney, but now with the exception of one set of valve gear, which at the request of the Engineering Association, the purchaser Mr. ——— presented to the Technological Museum, they were all broken up for old metal.—*Sic transit gloria mundi.*

Major Mitchell and Mount Victoria.—For some time after the Blue Mountains were first crossed in 1813, by Messrs. Wentworth, Lawson, and Blaxland, the descent into the Vale of Clwyd was right over the brow of "Big Mount York"; but the exact direction is now scarcely traceable in the worst places. This track was succeeded by the notable road made in Macquarie's time by William Cox, J.P. of Windsor, who in 1815 took the Governor to Bathurst over the new pass, which by means of convict labour he had completed in six months. This road descended by zig-zags into the valley running parallel to Darling Causeway, still known to the people of Hartly Vale as "Long Alley." It turns off from the Western Road at One Tree Hill (now Mount Victoria) and comes out at the Kerosene Mines; its formation must have involved for the period, an immense amount of labour and blasting. It is still negociable with a saddle horse, althongh the walls have given way in places, and trunks of big trees lie across the track. Since the establishment of the Hartly Vale platform on the railway, and the formation of a new road down thence into the vale, tourists and sightseers have this Long Alley road pretty much to themselves.

In 1827, during the Governorship of Lieutenant-General Darling, Major Mitchell, the Surveyor-General, proposed to construct a new pass down into the Vale of Clwyd by a deviation to the south of Mount York. In 1829 Major Lockyer, the Surveyor of Roads and Bridges, opposed this scheme on economical grounds, and it led to Governor Darling appointing a Commission to enquire into the matter. This resulted in the Mount Victoria route being adopted, and to Mr. John Nicholson, a Manchester Engineer, being appointed to the charge of roads and bridges under the Surveyor-General.

The great work was then put in hand of cutting down the hill sides and building up the walls for the Pass of Mount Vittoria, as it was called in honour of Wellington's then recent Peninsula victory. The work was under the direction of Mr. Phillip Elliot as assistant engineer in charge. Although the history of this pass, (the name of which has been since changed to Mount Victoria) is often discussed, it does not seem to be generally known how very far Major Lockyer had actually proceeded with the road which he favoured, before his route was abandoned for that of Major Mitchell. Over thirty years ago, when the author was engaged in opening up the Kerosene Mines near Hartley, and in laying out and constructing the company's railways and incline up the mountain, to connect with the Government railway, his Sunday excursions made him well acquainted with this mountain district, and on one or two occasions led him to the recesses of the bush where the remains of Major Lockyer's great rival pass to Mount Victoria are to be found. All along the ridge of the eastern branch of Mount York, there were hundreds of stumps, and the clean unfilled holes from which they had been grubbed forty years before, entirely undisturbed. Further on and down in the dark heavily timbered gorge which lies in the forked ends of this spur of the mountain, there were lengths of lofty stone walls. These walls had been built to hold up the projected road, like those at Mount Victoria where the cross section was too steep to allow an ordinary siding on the face of the mountain. No description of these remains has, so far as the author is aware, ever appeared in print.

It is said that faction fights waxed fiercely over the respective merits of these mountain routes seventy years ago, and the opinion has often been expressed in the district, that if the engineer for roads had been left to carry out his own proposal he would have secured quite as satisfactory if not better results, than were attained in the more favoured and pretentious scheme of the Surveyor-General. One thing seems certain from the published accounts, that the labour and time which Major Mitchell estimated would be required to fully complete his road, did not suffice to make even a practicable bridle track into the valley.

Perhaps the most notable work left by Major Mitchell is his beautiful three sheet feature map of the settled portion of New South Wales; this was engraved in the colony by Carmichael in 1834, and afterwards republished in London. The details of the features are said to be largely due to Mr. Assistant Surveyor Govett, the gentleman whose name is perpetuated by the waterfall at Blackheath. About Mr. Govett's doings the wildest stories are told, although his original sketches, still preserved, shew that he was a very hard worked man like ourselves. Mitchell utilised Govett's surveys of these mountain districts, and certainly no other map, up to the present, exhibits the physical characteristics of New South Wales so clearly. Having so far dealt with the progress of Civil Engineering in the young colony, let us for a while turn our attention to its advancement in the mechanical branches.

Mechanical Engineering in New South Wales—The First Mills.— Nothing seems to have thrown more responsibility upon the shoulders of the first Governors than the maintenance of the food supply for the young settlement; for, notwithstanding the despatch of vessels to the Cape and elsewhere, circumstances brought it to the brink of starvation several times. Bread being the staff of life, the ground was cultivated at once, and a farm was established where the Botanic Gardens now flourish (hence the name of Farm Cove). Grain was also grown, with seed brought by the new arrivals, at Rosehill (afterwards Parramatta). To convert grain into meal however, involves a mechanical process, even if it is only crushing it in a mortar. Next to that crude operation comes the hand-mill of metal or stone, and then follows the mill driven by power, which power may be obtained from the work of men, or horses, or cattle, or be supplied by the action of wind, water, or steam. At the beginning of the century, the mechanical engineer as we now know him, was only in embryo; and probably the most important craftsman of the day, certainly so far as the conversion of food products is concerned, was the now fast disappearing millwright. Although it is an out-of-date calling at present, the author is rather proud that one of the conditions embodied in his articles of apprenticeship—which he duly fulfilled —was that he should be taught the arts and crafts of a millwright.

With the the first fleet there arrived a few implements for grinding corn, but the want of mills for that purpose is specially alluded to in many of Governor Phillip's despatches to England. In 1791, when Lieutenant-Governor King was returning to the colony in the "Gorgon," he secured four pairs of mill-stones for hand power, at the Cape of Good Hope, to take the place of the original iron mills by that time rendered useless. Phillip had forcibly represented to the Home authorities that windmills were an absolute necessity, as the existing mills required so much labour, and in May, 1792, the British Government entered into a contract with Mr. Thomas Allan, an employee in the King's mills at Rotherhite, for a period of four years. Allen's salary was £52 10s. per annum as "Master Miller" of New South Wales; he came out in the "Royal Admiral," and commenced duty in the colony on the 6th October, 1792. Soon after his arrival in Sydney, Allen was sent to Parramatta to manage a mill about to be erected there. On 16th January, 1793, a millwright named James Thorpe arrived in Sydney from England, also under agreement with the British Government; he was called the "Master Millwright," and was placed under Allen the miller in a building used as a mill. On 16th February, 1793, Governor Grose wrote to the Right Hon. Henry Dundas, "I am sorry to say I do not expect much benefit from this man; he is by no means as expert as he pretends to be."

Early in October, 1793, the four pounds of wheat which had served as rations to the people was discontinued, and rice was substituted, it being intended to save the wheat for the purpose of having it properly milled and distributed as flour.

The primitive attempts at colonial mill making had up to this time all failed, owing, it was said, to the native timber employed being unseasoned. The records speak of the cogs breaking on this account as soon as the wheels began to work, but probably the shrinking of the timber of which the mortise wheels themselves were built was more to blame than the shrinking of the cogs, because that would throw the whole gear out of truth.

One of the prisoners who came to the colony in 1790, named James Wilkinson, was found to possess abilities as a millwright. Acting-Governor Grose, who sent for him, expressed surprise that his knowledge as a millwright had lain dormant so long. Wilkinson soon let it be known that his opinion of Thorpe's abilities was a very poor one, and that he was desirous of entering into competition with the official artificer. The Governor thereupon determined to give him a chance of shewing what he could do, and promised to well reward him if he turned out a workable mill on a fairly large scale. Wilkinson went to work, and after some time produced a "walking machine," the principal wheel of which was 15 ft. in diameter. This was operated by two men walking inside it, and was probably similar to the wheels of the old cranes at the London docks, before they were superseded by mechanical power. When the author used to visit these docks some fifty years ago, he has been in these wheels and been allowed to have a "walk" through the good offices of his guides. In the construction of Wilkinson's walking mill, the heavy part of the labour, such as cutting and bringing in the timber and preparing it, was performed by his fellow prisoners without charge, they being delighted that one of their own class was being brought into competition with Thorpe, the official millwright.

Some idea may be formed of the amount of labour expended on this experiment from the fact that it took three months and five days to perfect the work. When the time arrived for its first trial, early in October, 1793, there was quite a ceremony. It was found, however, to be anything but satisfactory, the old excuse being repeated that the timber was not properly seasoned. In grinding, its efficiency was very variable; at first it only ground two bushels, but afterwards with some alterations it produced four bushels of meal per hour. Governor Grose, however, was at the outset delighted with the result, and under date 12th October, 1793, in writing to the Secretary of State, on the subject of the corn crops supplying the wants of the ensuing year said, "and I have further the satisfaction to say that a convict carpenter, whose abilities have hitherto been concealed, has, for the hopes of reward, completed a most capital mill; equal to grind as much corn as can be consumed here. This is now at work, and has already contributed greatly to our comforts." But the Governor spoke before he was sure, and was destined to disappointment, for the mill ground less day after day, until at the end of the month scarcely a bushel an hour could be obtained from it. There appears to have been a concensus of opinion however, that if the mill had been on a larger scale the machinery would have given much better results. Wilkinson then again interviewed Governor Grose, whom he convinced that he knew what the defects were, and said he would undertake to build another mill, at Sydney, on a much larger scale and upon an improved plan.

The Governor not only humoured Wilkinson, but arranged that artificers and a gang of convicts should be brought down from Parramatta to a place which he had called Petersham; here a large timber yard, two hundred feet square was formed in which the timber for the mill was to be cut and seasoned for use. Sixty acres of Government ground were also cleared, and twenty of them sown with Indian corn for this mill; nine huts for the labouring people were also built, and in December, Wilkinson commenced his second experiment. The want of a flour mill was at this time evidently severely felt, because not only the convicts but the military also had to grind their own grain. Wilkinson's non success with his first mill, and his being allowed to make a second attempt, brought other millwrights into the field as rivals. Among these was an emancipist, named John Baughan, who proposed to build a machine on a different principle to that of Wilkinson. He was considered to be one of the most ingenious men in Sydney, and had the advantage of being promised assistance by the military artificers. The Governor therefore decided that two mills should be constructed and erected on the old marine parade ground, which was on the south side of Bridge-street.

In December Wilkinson and Baughan had both got up the frames and roofs of their respective mill houses, and while waiting for them to be tiled, they proceeded with the construction of their machines. By February 1794 Baughan's mill house was roofed in, and on the 10th of March, 1794, (the same day as the vessel "William" arrived with two pairs of mill stones and a dressing machine) the first trial of his handiwork was made. At first the mill went very heavily, but after a few days it ground 53 lbs. of wheat in seventeen minutes, with the labour of nine men who worked it by means of capstan bars walking in a circle. Wilkinson's second mill was started a month later near the close of April 1794, it was much larger than his first one at Parramatta, being worked by six men instead of two, and the diameter of the wheel in which the men walked was 22 ft. instead of 15 ft. Owing, however, to the number and variety of the wheels in Wilkinson's machinery, something was always going wrong. Governor Grose gave it a fair trial, and then on the advice of those who worked both mills it was condemned. Baughan's mill was found to be the superior, and Wilkinson much crestfallen was returned to Parramatta.

Governor Hunter, who assumed the reins of office on September 11th, 1795, brought with him on his return to the colony in H.M.S. "Reliance," the most material parts of a windmill, and a model to assist in its completion and erection. In May, 1796, Thorpe, the millwright was employed in collecting and preparing the timber for completing this mill at Parramatta, but he quarrelled with the Governor over the work before he had finished his engagement in July of that year. He appears to have been a failure in more ways than one, and he was dispensed with. The Governor, however, was much pleased to find a millwright on board the "Marquis Cornwallis," and in May 1796, he laid the first stone of a windmill. The last stone of this first windmill tower was laid in December of the same year, and sufficient of the machinery was erected to test it in February 1797. With half of its sails, and one pair of stones, it ground wheat at the rate of six bushels an hour; but it was many months before it was finished. After the completion of this windmill others followed rapidly, both at Sydney and at Parramatta, as Governor Hunter and his successors seemed to be much impressed with their efficiency. Those who take an interest in the early pictures of Sydney will remember that windmills are very prominent objects in the views of the town.

The site of the first windmill was on top of the hill at Charlotte Place—a little to the south of where the Grosvenor Hotel now stands—the ground is however now very much cut down from its original height. The second one was erected somewhere between the Observatory and the Fort-street School. After this the ridge east of Macquarie-street was surmounted by windmills, and lastly the Darlinghurst ridge, until in 1822 there were at least nine windmills in the city. The author does not remember more than three in the city, besides those on the Waverley road. Soon after the last of these windmills disappeared, an interesting but very imperfect account of them appeared in a daily paper, but their full history remains to be written.

Water Mills.—In May, 1823, Governor Brisbane granted six hundred acres of land at Botany to Mr. Simeon Lord, who had been an enterprising auctioneer and shipowner. This grant took in the mouth of the Lachlan Swamp, where the waters discharged into Botany Bay, and here Mr. Lord determined to erect a water mill. He had no sooner received his grant in 1824 than he constructed a mill dam, and then put up a wheel, which worked a fine and substantial brick and stone flour mill for very many years. He built the first house at Botany on Ti-tree piles, in consequence of the swampy nature of the ground. He also put up a tweed factory, and erected cottages near it for his employees. The works were continued until 1856, when the property was taken over in connection with the new Sydney water supply. A new dam was then built, and the mill-pond, when remodelled, became the supply reservoir for the pumping engines. At this time Mr. Castella's wool-wash, Mr. Darvell's tannery, and various other works established by Cooper and Levey along the Lachlan stream, were also suppressed, and Sydney for many years had one of the purest water supplies in the world from that source.

The only other water mill near Sydney, of which the writer can find any record, was at Paddington, in Barcom Glen, fitted up by Thomas West in 1813. This mill, apparently, had an overshot wheel, and must have been fed by a comparatively small stream. No details have been found of this, but there is an illustration of Lord's mill in the "Picture of Sydney," published in 1838, which shows a large weatherboard building and a breast-wheel. The accompanying description states that sixty persons were employed at the works in the manufacture of wool into tweed, blankets, etc.

The first settlers were much struck with the possibilities of manufacturing flax from the native plants. In 1799 four men were constantly employed making and repairing spinning wheels and looms. In 1805 two flax looms were weaving fabrics, but as we know the industry never became a permanent one.

The First Steam Engine in Australia.—The first steam engine in Australia, of which any record has been found, was imported by Mr. John Dickson in the vessel "Earl Spencer." This was erected soon after it was landed and started in the presence of the Governor, on the 28th May, 1815, in what was then a large mill which Mr. Dickson had built at the bottom of Goulburn-street, close to the waters of Darling Harbour. It was for many years afterwards known as "Dickson's Steam Engine," and is so indicated on old maps of Sydney. Dickson's mill is still standing and working, at the western end of Goulburn-street. Originally it was near the centre of a grant of fifteen acres three roods and four perches, and close to a wharf that ran a long way out into waters of the harbour; but this water frontage has long since been reclaimed, and the streets laid out upon it are a busy part of the city now. May, of 1815, must have been a momentous month for Sydney, because it not only saw the arrival of the first steam engine, but witnessed the important journey of William

Cox, of Windsor, when he took Governor Macquarie to Bathurst over the new Blue Mountain road already referred to.

A very antiquated old beam engine is still working at Dickson's mill, and it is said that some of the original condenser, and other parts, are in the foundations yet. It has, however, for many years worked "non-condensing," perhaps because the waters of the harbour (continually receding as reclamations were made) at last became too far away for the cold water pump. In spite of the generally ancient garb which this engine wears, it is evident to an expert eye that several of its most important parts are modern. This mill has been known by many names since Dickson made himself famous by his enterprise; but, alas for the instability of such fame! Dickson-street, which at least should perpetuate his memory, as it runs through his original grant, has recently, by some municipal vagary, had its spelling changed to Dixon-street.

The Second Steam Flour Mill.—After a lapse of eight years, the second steam flour mill appears to have been established in the year 1823 by Mr. Thomas Barker, who was a most successful mercantile man, and afterwards a member of the Legislature. This mill was erected about four hundred feet from the corner of Bathurst and Sussex-streets, and as steam engines were at this date, and even for ten years later, of great importance in public estimation, this mill—like Dickson's—was known as Barker's "Steam Engine," and both are so distinguished on the early maps of the town printed with the Sydney Directory as late as the year 1838.

Barker's mill stood on the grant of nearly seven acres, which was made to him, and comprised nearly all the block bounded by Bathurst-street, Sussex-street, Liverpool-street, and the waters of Darling Harbour. There were not a dozen houses in the locality at the time, and there were only two other wharves, besides the one which Mr. Barker built, in the whole of Darling Harbour. About the year 1830, Mr. Barker erected two new flour mills alongside his original one, and it was in those days considered a colossal undertaking. The work was so well done that the principal building is still in regular use. When I knew these mills first, the early condensing beam engines were still working, that at the eastern end driving a tweed factory. Old fashioned "wagon" boilers continued to furnish the steam, and the stand pipe for automatically supplying the feed water to it (at low pressure) had not then given way to a modern feed pump. The flour mill was at the end of the building next the harbour, the waters of which, as at Dickson's mill, had gradually receded so far away by the encroachment of the land, as to require new arrangements for the supply of the condensing water and its return to the bay. Mr. Thomas Barker visited England in the year 1837, and there saw further developments in milling machinery some of which he added to the Sydney mills on his return in 1840.

Steam mills henceforward multiplied fast both in the city and country. From a record of October 15th, 1829, we learn that the Darling mills at Parramatta, (now and for many years past converted into a tweed factory) were able to grind 1,000 bushels a week, and had just made such extensive purchases of grain as to account for the scanty supply on the previous Thursday at the Sydney market.

On the 13th Sepember, 1829, Mr. Singleton who gave his name to the well known northern railway town, advertised that his "John" mills on the Williams River are now in full work, to grind grain and return the meal, for 15d. sterling per bushel. He characteristically adds, "If the money is not sent toll will be taken at the market price of the day."

Mr. John Portus arrived in Australia by the ship "Hugh Crawford," in April 1825, from the well known firm of R. and W. Hawthorne, of Newcastle on Tyne, and at once set to work erecting machinery for Surveyor-General John Oxley at Camden, afterwards proceeding with the machinery for Mr. Macqueen at Kirkham, which was the object of his coming out. He was for years the leading millwright and engineer of the Hunter River district, making and erecting machinery for Segenhoe, Luskintyre, and other well known northern estates. In 1831 Mr. Portus started in business on his own account and erected a horse power flour mill at Black Creek, and afterwards designed and constructed a novel arrangement of bullock power motor. This consisted of a circular platform on a large bevel-wheel thirty feet diameter, which geared into the pinion of the driving shaft. The axis of the large wheel and circular platform was inclined about fifteen degrees from the perpendicular, and the bullocks being yoked up in such a position that they were always walking up hill, the platform revolved under their feet and gave motion to the machinery, just as it does in more modern horse powers which have endless chain platforms. Mr. Portus went to Morpeth in 1838 and started the erection of the well known steam mill in that town, with which he and his sons were for so many years associated, until he gave up business in 1855.

It may be interesting to note that the castings for this steam mill were made by Mr. William Bourne, of Sussex-street, the engineer who brought out the "Sophia Jane" with Lieutenant Biddulph in May, 1831, and who afterwards opened a machine shop near the Market Wharf; but Mr. Portus, senior, fitted up and erected all the more important parts of the machinery with his own hands. Unlike many other names herein referred to, and which have died out, the name of Portus is still well known in Australian engineering circles.

By the year 1838, there were, on the authority of the "Picture of Sydney," eight flour mills working in Sussex-street alone.

The First Australian Foundry.—The first foundry of which any record has been found was carried on by Mr. James Blanch, who originally had a grant near to Dickson's mill at Darling Harbour, where he was established in 1821. In 1823 he had an engineer's shop and foundry on a grant of one rood nineteen and a half perches next to the Royal Hotel, George-street. From information, accompanied by a photograph, which has been obtained by the author, it appears that there is at Dapto, in the remains of an early flour mill, a very old beam steam engine made by Blanch. This pioneer was succeeded by the enterprising engineer who is now so well known in New South Wales owing to his liberal endowment of the Engineering School at the University of Sydney—Mr. Peter Nicol Russell. During Mr. Russell's career an era of greater specialism dawned upon the young State, but in Blanch's time an engineer had to play many parts, all of which he (Blanch) was evidently quite willing to undertake, for we read in his advertisement that he could accommodate his friends with best double tin work; make handsome dish-covers, equal to any made in London; brass, iron, and foundry work, as usual; and, oh! what a fall for a finish—"umbrellas and parasols neatly repaired."

In 1833 Mr. Richard Dawson established the Australian Foundry at 622 Lower George-street, and it appears to have been the first important iron foundry in Australia, for in the forties he was able to produce single castings up to four tons weight. In 1837 he made, on the premises, a high pressure steam engine of eight horse power, which was used to drive the machinery of the establishment and was considered by Sydney people at the time a marvel of mechanism; and ran smoothly for more than twenty years afterwards. Dawson in many branches was the pioneer machinist of Australia. The arrangement of his blacksmith's shop made a considerable impression on visitors forty-five years ago. The Governor of the day and the leading people in the colony often visited Dawson's works, and his advice and services were in demand by mill owners, masters of ships, and squatters using wool presses, etc. Mr. Dawson was a prominent parishioner at old St. Philip's church. His business was carried on after his death until it was purchased and wound up by the late Mr. T. S. Mort. When the Kerosene Works on the Botany road were being erected by the author thirty years ago, the large cast-iron gothic head to the main chimney shaft was designed by him, and was one of the last works executed at Dawson's establishment.

Since the foregoing remarks were penned, the *Engineer* for the 4th of last month (May 1900) has reached Sydney. It contains a very full account of the portable coffer-dam which was made by

Mr. Dawson nearly half a century ago to enable the stern frame of the General Screw Steam Shipping Co's. ship "Crœsus" to be got at. This steamer arrived in Sydney harbour badly damaged in the year 1853, at which time there was no graving dock in the port and the repairs to this vessel were carried out by Mr. Dawson or "Dicky Dawson" as he was then generally called. The work accomplished was thought so much of, that it was often talked about after the author arrived in the colony two years later, and an account of it is now republished as a notable event in the annals of engineering and navigation.

In the Sydney papers of October 10th, 1829, it was announced that Mr. J. White who had lately arrived from England, was an engineer of great experience, his place of business adjoining the Royal Hotel in George-street. (This must have been on the north side, as Blanch was on the south). Mr. White undertook all kinds of engineer work and hydraulic pumps, and was equally at home with weighing machines, engines, cranes, and water closets. His newly invented lamp for lighting the public streets was only to be had direct from his works. He was evidently a large importer of ironmonger's sundries, and was also an inventor. His advertisement states that there is a filtering machine kept in use on his premises for inspection by the public. Inventors of those days were no more free from plagiarists and pirates than they are now, for in a subsequent notification, Mr. White warns his friends that there is a spurious imitation of his filtering machine in the neighbourhood, and trusts that a discerning public will admit that this is the highest praise that could be bestowed on the inventor. He epigrammatically adds "Incapable of invention themselves they descend to become copyists." The poor old Royal Hotel must have been very uncomfortable between these two engineers, complaints being frequent about the smoke from their furnaces, and on St. Patrick's day 1840, a fire from Blanch's foundry extended and burnt down the old building, together with Mr. Barnet Levey's Theatre Royal, which was within its walls.

Our consideration of pioneer mechanical engineers may be concluded for the present with the names of John Struth, William Orr, and the members of the firm of P. N. Russell & Co.

John Struth was born in Berwickshire, Scotland, on the 1st of January, 1804. He served an apprenticeship as an engineer with Messrs. Murray of Chester-le-street, remaining with the firm until 1832, when he sailed for Sydney in the barque "Mountaineer," arriving in September of that year after a sea passage of nearly nine months. He was first in the employ of Thomas Barker, but after seven years he started, on his own account, a flour mill in Sussex-street. In 1840 he purchased a large block of land abutting on Darling Harbour—known for many years as Struth's Wharf—now the site of W. Howard Smith & Sons' southern wharf, and afterwards until the year 1855 he carried on large engine works there for fifteen years. On his retirement, the business was continued by the Messrs. Napier. As far back as 1836 the *Sydney Gazette* records the boring out of the "Sophia Jane's" 40 in. cylinder at Mr. Struth's establishment. The thirty horse power engine of the steamer "Kangaroo" was made at his works in 1840, and during the same year he fitted the engines of eighty horse power in the colonial steamer "Victoria," built on the Hunter River by Mr. J. Korff. He contracted to keep several of the colonial steamers in repair, and also had contracts with the Municipal Council for water pipes. He cut in two and lengthened a steamer and initiated the North Shore Steam Ferry. Mr. Struth amassed a competency and gave with a liberal hand; among other sums £1,000 to the Presbyterian Church Sustentation, £1,000 to Prince Alfred Hospital, £1,000 to St. Andrew's College, and to found a University Scholarship £1,000; he died in Phillip-street on January 12th, 1886, aged 82 years; his family motto was "*Ero quod eram.*"

William Orr commenced business in 1840, he made land and marine engines at his shop in Sussex-street, and in December 1846 he moved to Grose's Wharf at the foot of Bathurst-street which he had purchased. Messrs. Young and Mather appear to have succeeded him at these works, but his patterns apparently went to P. N. Russell—as the author who had charge of the pattern store in the fifties—well remembers Orr's brand on flour mill patterns at Russell's. Mr. George Coke's engineering establishment in 1840 was also in Bathurst-street.

The Russell family of engineers—of whom Mr. Peter Nicol Russell, founder of the P. N. Russell School of Engineering at the Sydney University, was the most distinguished member—came from Kirkcaldy, in Fifeshire, Scotland, and with their father Robert Russell the elder, first settled in Hobart Town in 1836; but a few years later they came on to Sydney and had an engineering shop in Queen's Place. After the death of his father, Mr. Peter Nicol Russell, the second son, commenced business on his own account in 1842 by purchasing the foundry, situated on the south side of the Royal Hotel, from the executors of Mr. James Blanch. Here Peter Nicol Russell established the Sydney Foundry and Engineering Works, while Robert, his elder brother went to Manilla to erect some machinery, and died in 1849. John the third son, was for some time employed at Dawson's works in lower George-street, and afterwards for a few years traded to the islands in the "Coquette" and "Sarah Ann." Peter Nicol Russell's business so increased in George-street, that he established a branch works for engineering and boilermaking at Day's wharf in Sussex-street, with his younger brother George Russell as manager. By 1854 the business had extended to such a degree that on January 1st, 1855, the firm of P. N. Russell & Co. was launched with establishments at the Sydney Foundry and the Sussex-street Engine Works, as iron and brass founders, engineers, boilermakers, and blacksmiths. Mr. P. N. Russell's partners were his brothers John and George, and Mr. James Wilkie Dunlop, a Scotch engineer from Leith. The senior partner, Mr. P. N. Russell left for England shortly after the new firm was launched, in order to recruit his health, and to make arrangements for shipping the supplies required for the ever increasing business, and Mr. Dunlop (a nephew of Wilkie the painter) was thenceforward and until his retirement in 1863, the engineering head of this famous firm.

The author was articled to Mr. Peter Nicol Russell and his three partners in January 1855, and after serving an apprenticeship to practical work in the pattern, millwright, fitting, turning, and erecting shops, was afterwards most of his time in the drawing office, where he became chief draughtsman before the expiry of his articles, and continued with the firm for five years afterwards until Mr. Dunlop retired. While there he prepared plans for numbers of flour mills, and for the first ice-making machines, designing machinery for the multifarious requirements of colonial industries, many of which (such as sheep-washing and boiling down) no longer exist on the old lines The business of this firm increased so rapidly and was so prosperous, that in 1859 they purchased Brodie and Craig's wharf in Barker-street off Bathurst-street, (since and until lately in the possession of the Adelaide Steam Ship Company). Mr. Peter Nicol Russell returned to Sydney in 1859, when the Bathurst-street works were projected and finally retired from the firm in 1860 to reside in London. The plans for these new works, and also for the wharf, were made by the author; and afterwards the laying out, and superintendence during their construction and erection, was committed to his charge. A quarter of a century afterwards, when the establishment was broken up, these very plans with other interesting mementos of the firm's career, came into his possession. The subsequent enterprise of P. N. Russell & Co. in the construction of dredges, in the erection of another factory (now a fruit market) on the eastern side of Barker-street, for the building of rolling stock for the railways, and in undertaking other important engineering works, until the great lockout of their employees, which took place in 1875, is comparatively modern history.

Reminiscences of colonial engineering during the term of the author's connection with this firm, would alone afford material for a lengthy paper, but would hardly be in place here. Mr. Dunlop retired from the firm in 1863, and the author left at the same time to join him. Before this, Mr. G. A. Murray had joined Messrs. John and George Russell, and thenceforward managed the financial department. George Russell retired in 1874, and thenceforward until the historic lockout of 1875, John Russell and Mr. Murray carried on the business. Mr. John Russell died in 1879. The other members are still alive.

As there is at the present time a great boom in dredge building for mining purposes, and as the Russells' were so much to the front in the construction of the early dredges, a short reference to these works should be interesting now. The operations of dredging, for deeping our harbours and rivers, has become such an important part of the work carried on by the Government, that the Works Department now controls, including those on the bucket, sand-pump, and grab systems, forty-five dredges of all kinds. This is a great contrast to the time which some of us remember, when the "old Hercules" was the only dredge in Australia.

The hull of the "Hercules" was built in the colony at Russell's shipyard (not P. N. Russell), and the machinery was imported. She had a beam-engine, which, I understand from Mr. A. B. Portus, is working still, and originally there was a lot of brick-work about the setting of her old fashioned boiler.

In the year 1857 the Government required a new dredge for Newcastle, and it was one of the first works taken in hand on the establishment of a department of Harbours and Rivers. The hull was built at Rowntree's Dock, Waterview Bay, by Captain Rowntree; Mr. Anderson, (afterwards the district engineer at the Wollongong and Kiama harbour works) being the foreman shipwright responsible for her construction. An imported side-lever engine with its boiler, by Wingate of Glasgow, was purchased from its importers, and on the 19th February 1858, Messrs. P. N. Russell & Co., booked the contract for the rest of the machinery. The finished drawing of this dredge the "Hunter," made by the author over forty years ago, was exhibited at our last annual meeting. With the modifications due to over forty years work, the old craft is still rendering her services to the State.

The next dredge constructed in Sydney had also a wooden hull, it was built at Cuthbert's Wharf, Miller's Point, and had a well; it was intended for the Brisbane River, and was named the "Lytton." Russell's obtained the contract for the machinery, which included a notable oscillating engine, on the 2nd November, 1860. The whole of the working drawings for this machine were also made by the author.

In 1861 the Government called for tenders for a new dredge after a plan had been prepared under the direction of the late Mr. E. O. Moriarty, for a machine which had the buckets around the periphery of a large wheel, but this proposal was not adopted. Mr. Dunlop then instructed the author to make a design for a small dredge, with an iron hull and centre ladder well, of about the same nominal capacity. In this there were several novelties introduced, and among them, the ladder was lifted by hydraulic power instead of by a chain from a winch, the water pressure being about 30 cwt. to the square inch. This design was submitted to the Government, and offered at a price which was approved, and Messrs. Russell booked the order on the 19th February, 1862. This dredge was named the "Pluto," and although at the time it was a success and answered its purpose very well, it was a small affair as compared with some of the magnificent dredges now possessed by the Government of the State. The day of the official trial however was a proud one for the author, because during the course of the little festivities which followed the formal approval and official acceptance, Mr. Dunlop pointedly remarked that "as she was all right, the credit must be given to his boy in the drawing office."

Gold Dredging.—If there is not much poetry to be got out of harbour mud, however modern or scientific the machinery of the dredge which is employed to raise it may be, there is evidence of a different sentiment when it comes to gold dredging. This later industry at least fascinates and charms, if it does not occasionally mesmerise its votaries. Else why this marvellous boom which is now influencing the mining world of Australia and other countries making our engineering shops busy constructing machinery for dredging gold bearing wash-dirt?

This industry appears to have originated in New Zealand, not earlier than twenty years ago. The appliances then used were the old "spoon and bag," worked from a pontoon, and as much as thirty ounces of gold per week has been won with this primitive appliance, having only one man at the pole, and one at the windless. In 1876 current wheel dredges were introduced; these had a large paddle or undershot wheel, moved by the current which worked the dredge buckets; it also raised the water for sluicing. Some of these machines are still at work.

The first steam dredge for gold seeking was built in 1881, the dimensions of the hull being 75 ft. by 18 ft. by 3 ft. 6 in., the capacity of the buckets $1\frac{3}{4}$ cubic ft. each. The largest gold dredge at present in existence, is said to be 120 ft. by 10 ft., with buckets each of 7 cubic feet capacity, and capable of lifting 180 cubic yards per hour. The average cost of this dredging is about 4d. per cubic yard, but it can be done for 1d. in favourable ground. The greatest depth at present worked is 45 ft. under water, the greatest height delivered 25 ft. above water, or 70 ft. in all. But depths have been worked to 60 ft., and tailings have been lifted to 40 ft. Seven men will attend to the largest dredge working continuously, that is, a general manager, and two men for each of the three shifts, every necessary operation being performed by the machinery. These dredges are now being worked in nine different countries by men from New Zealand; probably because New Zealand was the first to start dredging for gold. In New South Wales, Mr. Garland was the first to introduce a dredge on the Macquarie River. Up to the presnt time over 32,000 acres have been applied for in the State under dredging leases, by 460 applicants. An average size gold dredge costs about £6,000, and the largest and most perfect ones double the amount.

This industry has led to an entirely new branch of engineering being established in Sydney, and I am indebted to Mr. C. E. Richardson, of the firm of Richardson and Blair, who are specialists in gold dredge engineering, for some of the particulars quoted. It is pretty well known I think, that several of our engineering works are busy not only on bucket dredges for gold winning, but that they also have in hand modifications of the centrifugal pump dredge, for raising auriferous wash dirt. In these pumps special provision is made to allow very heavy boulders to go through without injury to the revolving vanes of the pumps, and numbers of improvements in their details are suggested and introduced. With the ladder dredges on the other hand, apart from the gold saving appliances, the plant proper is often far behind the government dredges of forty years ago.

Compressed Air.—It does not appear that the use of compressed air, to give motion to machinery, can be traced back earlier than the year 1840, therefore it could have played no part in our first settlers struggles with nature. As the motive power for rock drilling however, and also in connection with coal mining, compressed air has for a long time had an extensive application; and now, not only is its general use extending for all kinds of power transmission, but in two special directions it has recently advanced by such phenomenal strides as to command our particular attention.

Without losing sight for one minute of the fact, that the electrical transmission of power possesses many advantages which do not appertain to other systems, very strong opinions are held by practical engineers, that compressed air has been neglected a good deal, because there is not about it that glamour of mystery and intangibility which surrounds electricity. This halo of mystery, combined with much popular ignorance and delusion with regard to the mechanical power required for the generation of electric energy, (the average man on the street believing it is obtained from nothing and produces itself) has enabled the capital required for enormous electrical enterprises and experiments to be easily raised. The President of the Electrical Association in his opening address last month, expressed himself as very much of the same opinion. Compressed air has certainly in some instances, failed to fulfil what was promised for it (as in the Sturgeon System Power Company of Birmingham), and this no doubt checked the extension of experiments in its application for a long time; now, however, we find the exigencies of the present day have brought forward two remarkable developments. The first has been forced forward by the strong objection which exists in New York and other American cities to the trolley system of electrical street railways, where trolley wires will not be sanctioned at all, and their much greater cost is an objection to conduit lines for the same purpose. This has brought forth fruit in the domain of compressed air for tramway propulsion, and we find as a consequence, that compressed air auto-cars are at present running side by side with the electrical tramway systems in New York, on the Twenty-eighth and Twenty-ninth street lines of the Metropolitan Railway Company. The motor cars of this company are entirely self contained, the air being stored in cylinders under the seats, at a pressure of 2,500 ℔s. to the inch. The air is warmed before use by means of coils in hot water cylinders.

After a year's trial the system has been found so successful that a large power house is now being installed with compressing engines of 1,000 horse power, made by the E. P. Allis Company of Milwaukee. It has been found that with a "thirty foot car," the consumption of air is from 30 to 40 ℔s. per car mile; and the cars will run from 15 to 17 miles without recharging. This system of tramway requires no capital to be sunk on the street, either underground or overhead, except for the ordinary permanent way; there is thus no interest on the first cost and maintenance of conductors to be provided, and the total expense of propulsion is said to be a fraction under three halfpence per car mile. For the transmission of energy through long distances the insulated metallic conductors of an electrical system are simple devices when compared with the tubular mains which are required to convey the equivalent power of compressed air; and still greater is the contrast with regard to the facility with which the electric current can be delivered from the main or conductor to the motor of the car, while the car is in motion. In the now obsolete system of atmospheric railways, there was a direct transmission of power to the car, which was effected by exhausting the main in front of the travelling piston on the car, but such a direct and continuous transmission of power from the main to the travelling motor, has not however yet been accomplished by means of compressed air.

As a set off to this specially advantageous feature of power transmission by electricity, that medium is at a great disadvantage when power has to be stored on an automotor, and the time lost in charging is compared. It would appear that where secondary batteries would take, say six hours to charge from their electric generator, a given number of foot pounds of energy, compressed air reservoirs would only require two minutes for an equivalent transference. To meet this difficulty, some electric cars working with storage batteries remove the whole run-down battery, and replace it with another set ready charged after every exhaustion. This is manifestly a complicated proceeding as compared with the instantaneous connection of an air main coupling. With coal as cheap as it is in Sydney, and the greater relative cost of labour in its effect on the installation and maintenance of an electrical system there appears to be very solid grounds to justify the pneumatic system being tested in New South Wales. It must be remembered that cars carrying their own charge of power can run on the ordinary street as well as on a railway, and the use of such automotors is rapidly on the increase in Europe. The cost of running per car mile on our electric tramways has not yet been published, but it is to be hoped that we may have a paper on this interesting subject during the current session.

The other recent development to be noted in connection with compressed air, is in its application to hand hammers, and small rotary machines to be applied by hand, numbers of which are now on the market catalogued under the general term of pneumatic tools. So rapidly have these tools come into use, and increased in number, value, and importance, that the Institution of Mechanical Engineers, England, recently devoted two whole meetings to their consideration. These tools, unlike the ordinary power hammer, are intended to be held in the workman's hands, while connected by flexible tubes to a supply of compressed air at from 60 to 100 lbs. pressure. In the case of hammers they are able to make from 8,000 to 10,000 strokes a minute, for such purposes as chipping, caulking, dressing, planishing, beading, and scaling; and they will enable one man to do the work that six or eight men could do by hand. The pneumatic piston drills—also held by the workman's hands—for small sizes, will weigh from 28 to 40 lbs., and will do such work as drilling, tapping, expanding tubes, beading, and reaming, at least four times as quickly as the work can be done by hand. For rivetting, instead of the ponderous machines required for hydraulic pressure, very light and portable pneumatic rivetters may be substituted. The popularity of these machines in the iron trades may be judged by the fact that one firm alone had recently been making them at the rate of 800 per month. By the courtesy of Mr. Franki, Manager of Mort's Dock Company, and Mr. Thow, Chief Locomotive Engineer of New South Wales Railways, a number of these appliances are exhibited.

Artificial Light.—The first reference that has been found to this subject in connection with the early history of New South Wales, is in George Barrington's work. Candles are there mentioned as being a great luxury with the first settlers, and shark's oil is said to have been sold at one shilling a quart for illuminating purposes. A few years later when the flocks and herds of the colony had so increased, that fresh meat took the place of imported salt junk, there was, with the inauguration of the butcher, surplus animal fat to hand, which could be rendered into tallow, and candles were popularised. Many persons are still living among us who remember the days when the tin candle mould was an important part of the equipment of every colonial household. With tallow on the market, the business of the soap and candle maker naturally followed, and oil and tallow chandler's shops were common in Sydney. Candles were then produced in a very primitive way, but with the assistance of chemistry and engineering, candle-making now involves a series of highly scientific processes. One Sydney company alone has at present over £30,000 worth of plant engaged in candle making, with copper stills for separating the oleic and stearic acids, and nickel plated stills and filter presses, for the production of glycerine from the bye products The whaling industry, which was initiated at a very early stage of the colony's career, put sperm and black oil on the market, and oil lamps had their day. Mr. White, an engineer already referred to, had several contracts to light the Sydney streets with his improved oil lamps before the advent of gas.

Up to the year 1841, Sydney was lighted either by candles or oil lamps, but on the 24th of May of that year, the Australian Gas Light Company first supplied their customers with gas, in honour of Her Majestys's birthday. The question of establishing gas works had been under consideration for some years before that date, and Mr. Alexander Kinghorne, a civil engineer, had prepared a report on the subject. The Gas Company's charter dates from 7th September, 1837, and the first engineer of the company, Mr. James Bryan, arrived in the colony by the "Ann," with the first consignment of machinery, on the 15th May, 1839. The private lights in use during the first month numbered 181, and in the production of the gas single ended retorts were used. Thirty years later an entirely new plant with double ended fireclay retorts, arrived from England to supersede the original one, and the author was engaged to take charge of its erection, Mr. J. N. Wark at the time being manager, and while with the Gas Company he designed and carried out the conspicuous chimney stack, together with the meter and governor houses which are still in existence at the head station. He terminated his connection with the Gas Company to accept the position of chief engineer and draughtsman to Mort's Dock Company in 1869, in order to design the machinery of the s.s. "Governor Blackall." Since that time the immense gas-works at Mortlake have been carried out, under the direction of the present engineer of the company Mr. T. J. Bush. If electricity is not so supreme in the domain of power transmission as some would have us believe, it has certainly met with unexpected rivalry of late where it was supposed to have permanently outrun all competitors, that is for supplying artificial light under almost every practical set of conditions.

Recent experiments serve to show that, with the most recently improved incandescent burners, the illuminating power of a given volume of gas is multiplied at least ten times over that given when burnt in an old fish-tail or bats-wing burner. Gas engineers have been moving under the stimulus of electric light competition, and now it is evident that the production of a gas for purely heating purposes and use with the incandescent burner, is not the same thing as making gas for direct illumination. Water gas well adapted for use in the gas engine, has been produced cheaply from inferior fuel for a long time, but such gas has poor illuminating power, being practically non luminous, and consists theoretically of hydrogen and carbonic oxide in equal volumes. Under the most modern improvements for the production of illuminating water gas, the coke of gas works is utilised for combustion in a generator, and steam is driven through the incandescent fuel and decomposed; hydrogen is thus liberated, as the oxygen combines with the carbon of the fuel, to form carbonic oxide. This compound gas is then carburetted by the gasification of an enriching oil; and simply by regulating the supply of this oil, the gas can be made at will from sixteen to forty candle power. Very great importance attaches to the manufacture of this carburetted water gas, and it appears to be in more common use in America than ordinary coal gas. In England and Scotland it has lately made great headway, and the Australian Gas Light Company are now introducing it to their Sydney works. It would prolong this address unduly to attempt to describe the process in detail, but the Section may hope to have a paper on the subject from Mr. Bush in due course. I am indebted to that gentleman for the outline particulars so far given.

It would not be fair to leave the subject of light production without a reference to acetylene gas, and to the production of calcium carbide, which has of late made such giant strides, that the output of the world's factories is now estimated at 200,000 tons per annum. Germany is probably ahead of the rest of the world in the use of acetylene gas, as there are twenty seven towns in that country reported as being lit entirely with it. The most notable installation attempted in Australia so far, has been the lighting of the Sydney Cricket Ground, where acetylene gas has supplanted the electric light. By its introduction in connection with the lighting of trains on the Prussian State railway lines, it is estimated that eight thousand tons of carbide will be required per annum for that purpose alone.

As the author designed the whole of the original plant for compressing the gas, as well as for storing and expanding it again, in order to light the carriages on the New South Wales railways, in the year 1878 when Mr. Castner was the contractor, he may perhaps attach undue importance to the question of train lighting. It may, however, be pointed out that recent experiments seem to prove that although pure acetylene is explosive when compressed, and that it has already been the cause of several accidents, it is not explosive when it is combined with three times its volume of oil gas. From the results already attained on the Prussian State railways, it is claimed that the illuminating power of a mixture of 25 per cent. of acetylene gas, with 75 per cent. of ordinary oil gas, is, as compared with oil gas alone, as 325 is to 152, or more than double the efficiency. Such being the case it is evident the carriage reservoirs now in use would either be able to run the present light for double the number of hours, or otherwise they could supply double the light for the same period. The electric lighting of our New South Wales trains is still in the experimental stage, and it cannot be said that success has been attained so far.

Wool and Presses.—After the lost cattle of our first settlers and their progeny were discovered in the district around Camden, since called the Cow Pastures, the flocks and herds of the young colony increased rapidly, and the early production of fine merino wool is a matter of common history. Up to the middle of the century, our staple product wool was brought from the station to Sydney by bullock drays, the trip often took three or four months, and the bales were dumped at the Circular Quay in screw presses. These presses had capstan heads generally worked by four men; at least half an hour was occupied in each operation. Forging the heads to these wool screws was a big job for a blacksmith's shop before the abvent of the steam hammer, and my mind reverts to the consternation that once occurred when on handling one of these big screws in the forge the head tumbled off through the iron being burned.

It was not until the sixties that the introduction of hydraulic power enabled the operation of pressing to be performed in from eight to ten minutes, instead of in thirty. With the continually increased production of wool, a stage was reached about twenty years ago which induced the author to submit a proposal to the late Mr. Alfred Lamb to introduce an entirely new and more rapid system of woolpressing under which water at two or more different pressures should be laid on to the various presses, so that the attendants had only to open and shut valves to perform the operation. The proposal was approved by that enterprising gentleman, a patent taken out, and the plant was manufactured by the Atlas Engineering Company. The low pressure water was under a head of 700 lbs. to the inch, which enabled an ordinary bale to be reduced to at least half of its original bulk. The high pressure water which could be utilised up to 8,000 lbs. to the inch had then only to be turned on, when the operation was completed. Such a success attended this innovation that dumping was reduced to about one-fourth of the time before required, or to say two and a half minutes. Other large firms subsequently adopted this system, and the original plant with the combination valves is still in operation at the Central Wharf, where it has often dumped over 1,200 bales a day. Later on, with increasing competition in the wool business, still more rapidity was demanded and studs took the place of rivets to save some of the time lost in closing the hoop iron bands. In order to enable the secondary or higher pressure to be obtained from one normal supply, the

"Intensifier" was introduced, and made an adjunct of the hydraulic press in many wool pressing establishments. With a water supply at 700 lbs. to the inch, an intensifier having a ratio of 5 to 1, and a press with an eight inch ram, a bale of wool now can be put in off the floor and be first set up with a pressure of about sixteen tons to get it straight and fair, then it can have a heavier squeeze up to about eighty tons, after that have four hoop iron bands secured around it, and lastly when the pressure is released be turned out to make way for its successor, and all in one minute. With men working their best, sixty bales an hour can now be turned out from a press, which is actually a comparatively insignificant looking machine if compared with the monster quadruple presses which were in favour twenty years ago. As regards the amount of manual labour required, one man is now sufficient where thirty would have been required in the middle of the century.

Naval Architecture and Marine Engineering.—The first vessel built in Australia was in Governor Phillip's time to make the journey to Parramatta. She was officially named "The Rose Hill Packet," but the men who had to work the sweeps called her "The Lump." Shipbuilding was early developed here, and home-built sailing craft were very soon familiar on the coast. It was not however until the year 1830 that the keel of the first steamer was laid in Neutral Bay by Messrs. Smith Brothers. She was launched in March 29th, 1831, and christened the "Surprise." The machinery was imported, and on the first of June following the vessel made her first trip to Parramatta. In the year 1832 there was a Parramatta boat built called the "Experiment," which was worked by horses for a short time. The Hon. George Thornton told the author some years ago, that when he was a boy, he had often gone with the boat from the Sydney wharf, and helped to whack up the horses until off Balmain, when he had jumped overboard and swam to Miller's Point. The "Experiment" was not a success with horse power, and was afterwards fitted as a steam vessel and ran as such to Parramatta until the year 1841. The "Surprise" was not regarded as a success either, and was sent to

Hobart Town. At the same time as she was in hand, the building of the old "William the Fourth" was commenced on the Williams River, for Mr. Grose of Parramatta. She was launched in October 1831, and was about 80 ft. long by 20 ft. The engines were from the old firm of Fawcett and Preston of Liverpool, and were put in by Mr. Patterson the engineer of George-street. This vessel ran from the Phœnix Wharf up to well within my memory and until Mr. John E. Manning took her to China. It was on the 15th February, 1832 that this vessel (colloquially known as the "Billy the Fourth," or the "Old Billy"), started on her first journey to Newcastle and Morpeth.

During the time these two first steamers were being got ready, and on the 16th May, 1831, the first steamer from England arrived in Australia. This was the "Sophia Jane" of 153 tons register, which was brought out by Lieutenant Biddulph, R.N., with Mr. Bourne as engineer. This vessel was 126 ft. by 20 ft., and 50 horse power, and was for a long time in the Newcastle trade.

Skipping twenty years we come to the discovery of gold in Australia in 1851, which led to the establishment of the first steam line from England already referred to. The pioneer mail boat was the P. and O. Company's steamer "Chusan." This line included also the "Argo" and the "Crœsus," besides these the "Lady Jocelyn" and other prominent vessels came from over the sea. Locally built vessels had been improving all this time, and ferry services with steamers built and engined in Sydney, had been established, both to Balmain and the North Shore. The late Mr. Henry Perdriau pioneering at Balmain with the "Waterman," and the Gerards and Waterhouse Brothers with the "Agenoria" and the horse ferry from Pottinger-street to Blue's Point with "The Brothers."

With the advance of constructive ability in the colony steam boat building got the benefit of it, and in later days iron instead of wooden vessels were turned out. Of these the most notable perhaps were the "Leichhardt," built at the old A.S.N. Co's. works, and engined on Rowan's system; and the "Thetis" and "Governor

Blackall," built at Mort's Dock. As some indication of the increased importance of this branch of engineering, it may be mentioned that although the author has been for some years engaged in other branches of engineering, yet he has personally been responsible for the design of the hull or machinery or both, of over fifty steam vessels of different sizes. Of these the most notable no doubt, as marking eras in steam navigation, were the double ended screw ferry boat "Wallaby," awarded the first premium in a competition, and the torpedo vessels "Acheron" and "Avernus." The Parliament of New South Wales voted £8,000 in the year 1877 for the construction of two torpedo launches, and the matter was placed in the author's hands with practically only one condition, which was that he was to make the best design possible to fit the money available, and so carefully was this done that the contract price paid to the Atlas Company was £4,125 each, or three per cent. over amount proposed. These boats floated to the calculated draft within a quarter of an inch, and they attained a speed of fifteen knots which was thought a great triumph at the time, however insignficant it may appear now, and yet both the marine and railway shops of the colony had to be searched for materials before they could be built. As a matter of fact, Mort's Dock Company can produce a mail boat, and the Eveleigh Railway Works can construct a locomotive of the highest class, under the elaborate systems and special appliances now existing, without taxing their resources as much as was required for most simple engineering operations, at the time the author commenced his career with Messrs. P. N. Russell and Company.

The reference to locomotives reminds us that our first railway was opened in 1855, when bullock teams were common in George-street, and the leading hotels had great drinking troughs, hollowed out of tree trunks. The first locomotives imported were landed at Moore's Wharf, and hauled by winches up to the top of Miller's Road. Many engines have now been made in the colony, and Messrs. Vale & Co., who have constructed between sixty and seventy locomotives, startled the Sydney people a few years ago by taking a locomotive up Druitt-street and along George-street to the railway under steam. As our machine shops increase their appliances and enlarge their powers year by year, we are enabled to do work which, by comparison with that of earlier epochs, seems wonderful and perfect.

Take for instance, the first Australian bridge, or a culvert as we should now call it, which Mr. Alt set over the tank stream at Bridge-street. No doubt all his energies were taxed to obtain a satisfactory job with the ignorant men and rude tools which then were alone available. Contrast this with the proposed bridge to the North Shore, for which designs are now being invited by the Government. If that bridge is to be worthy of Sydney it will involve the use of nearly thirty thousand tons of steel, and yet there are plenty of firms who will undertake the whole responsibility of supply and erection, and the preliminary work necessary in the drawing office and factory will be carried on with simplicity, precision and regularity. How different to the days when a toothed wheel had to be built up out of wood, then have its rim mortised, afterwards being cogged, and lastly be pitched and have the teeth formed by hand. Before the middle of the century, mechanical engineering had so far advanced, that there were cast iron mortise wheels for the mills instead of wooden ones, and lathes for turning them up. The very first job the author had when he was apprenticed was to get out iron bark cogs in the rough, for the mortise wheels of flour mills; but fifty years before that there could be no accurate or high class work in the field of mechanical engineering here at all, because the necessary tools were not then in existence, and skilled men were 16,000 miles away.

It is interesting to compare the degree of precision to which the mechanic then worked, with that of present standards, this shows it to have been a very low one. The larger mill shafts were often of timber, with cast iron winged gudgeons secured by means of iron hoops shrunk on; these gudgeons had to be turned by hand with a heel tool, as there were no slide rests. Wooden bearings often sufficed to carry the shafts, and there was necessarily some latitude in measurements and the proportion of parts. We have all heard of the "shilling fit" and the "penny fit" used by the workmen in Smeaton's time to designate the closeness with which the pistons of the early steam engines approached the walls of their cylinders. In those days strips of old beaver hats are said to have been a favourite packing for pistons. There was a standing joke in the fifties against a millwright who had been employed in the Flour Company's mill in Sussex-street, it being said that he was one day proceeding steadily along the street to the shop, with his thumb and forefinger curved into the form of the letter C, and that on being hailed by an acquaintance, he said "Don't stop me, I've got the size of the counter shaft." If only a joke, it still shows the primitive ideas of the day, because such a joke would be impossible now that we work to the thousandth part of an inch with Whitworth and other standard gauges; and have measuring machines which show the expansion of a gauge due to the warmth of the fingers which pick it up.

Up to the middle of the century the steam engine in general use for land purposes was either of the "Beam" or "Table" type, and a considerable number of them were made in Sydney by Orr, Bourne, Blanche, Russell, Young and Mather, and Struth, who were then the principal manufacturing engineers in the colony. With the advent of the fifties the horizontal engine began to supplant all other kinds of steam engines on shore, and by the end of that decade Messrs. P. N. Russell & Co. had complete sets of working drawings for horizontal engines of all the sizes in general use made by the author to a standard design. From these plans scores of engines were built by the firm before the final winding up of their business. Some years afterwards a more advanced type of horizontal engine was formulated by the author for Mort's Dock Company which it is believed is not yet out of date. By a singular coincidence two engines were recently inspected by the author for intending purchasers, and they proved to be two of these old friends, one nearly forty, and the other twenty-five years old; both of them had many years of useful life, especially that from Mort's. It is only fair to pay a tribute to the faithful work of our local firms when deserved, as it is often discounted by the glitter and paint of imported machinery.

Although the first Balmain steam ferry boat "Waterman," had an horizontal engine carried over the top of her boiler to drive the paddle wheels, most of the early ferry steamers in Port Jackson had side lever engines; one of these was called the "Pet," and was merely an open boat about thirty feet long with a speed of perhaps three to four miles an hour. Fifty years ago this vessel took passengers over to Balmain from the Gas Works to the Jubilee Dock Bay, in a twenty minutes trip. Other boats including the horse boat "Brothers," which ran from Pottinger-street to North Shore, had steeple engines. All these early ferry steamers had internal flue boilers, and as salt water was used a comparatively low pressure was carried, and regular blowing off was necessary. About forty years ago the arrival of three steamers named the "Nautilus," "Pearl," and "Peri," from Messrs. Randolph Elder & Co., for a rival Balmain ferry, threatened to revolutionise colonial ideas and inaugurate a new era in ferry steamers; they had iron hulls, double oscillating engines, and tubular boilers. The engines had a treadle for each foot to put the "gabs" out of gear, an injection lever for the driver's knees, a throttle valve lever for his elbows, and starting bars for each hand. This gave an air of importance to the men who went through the complicated performance of starting and stopping these boats, but it was too complicated for colonial ideas. Imported ferry boats have never succeeded in displacing the Sydney built ones, and the present most successful Port Jackson Ferry steamers are purely local productions—the result of a gradual development tempered by environment. The Balmain New Ferry Company and their naval architect have made the boldest experiments and widest departures from orthodox practice with great success. Some ferry boats even now have imported engines, although their hulls are locally built, but they certainly do not give less trouble than the colonial made engines. Compared with the gigantic ferry steamers of some American cities, our Sydney vessels are perhaps small, but for speed, comfort, and special adaption to the requirements of the people who use them, they can fairly claim to be equal to any in the world.

In glaring contrast to the primitive machinery we have been considering we have now in Sydney two Government power houses. In one of these the machinery, of local design and construction, has been most successful, while the steam engines in the other one from an outside firm of commercial engine builders, has given a vast amount of trouble and led to a Commission of Enquiry. As these latter engines have now been running for some time, it would be very interesting to have a comparison of their efficiencies in regular work with those at Rushcutter's Bay.

Looking around at the general progress now being made in the production of mechanical energy on land, we are struck with two things; one is the enormous horse power of some of the steam power plants that have lately been installed, and the other is the startling proposals recently made in connection with gas engines. For a long time the size of marine engine units kept well ahead of those on land, and when steamers reached ten thousand horse power something like finality with its aggregation in one vessel seemed to have been reached. We have now a New York Power House being fitted out to develop one hundred thousand horse power for the Third Avenue railway, and no one can forecast what another ten years may bring forth.

With gas engines it was different, for as long as the Otto patents lasted, the principal sizes made ranged perhaps from a half horse up to twenty or thirty, and occasionally up to sixty horse power. Five or six years ago a flour mill was fitted up in England entirely with gas engines, and only recently at Danbury, Connecticut one hundred horse power gas units were considered of exceptional size. With the expiry of the Otto patents, the extended use of producer gas, and a better comprehension of the thermodynamic superiority of the gas engine over the steam engine as a heat machine, their use has rapidly extended, and the sizes of units have gone up and up, until now the Westinghouse Electric Works at Pittsburg, Pa., are run by a gas engine of 650 H.P., with a 25 in. cylinder and 3 ft. 6 in. stroke. Gas engines of as much as 1,500 H.P. are said to be contemplated. Many tests have been made with recent gas engines shewing a consumption as low as from 12 to 15 ft. of gas per horse power per hour, and it is claimed to have been reduced to 10 cubic feet.

Finally, the Destruction of City Refuse.—Mr. Westinghouse, the American engineer, has recently forwarded a contribution to a New York newspaper, in which he foreshadows an entirely new industrial situation in connection with producer gas. Most engineers know that continual efforts are being made where destructors are employed to get rid of town refuse, to utilise the waste heat for generating steam; fanciful pictures have been drawn of cities that not only incinerate their garbage, but illuminate themselves brilliantly through the utilization of the generated heat. No doubt in a few towns, and under favourable conditions, a certain amount of success has been obtained, but in most cases the proportion of heat generated which is necessary to evaporate the water from the refuse, leaves very little to spare for the steam boiler.

Under the proposals of Mr. Westinghouse, which are on entirely different lines, it is suggested that even with refuse carrying as much as eighty per cent. of water, it will be possible by mixing it with a due proportion of cheap carbon, to convert it economically into fuel gas of great value. This conversion is to be carried out without any offensive odour, and the gas to be produced is to be utilised to drive gas engines, which in turn may drive electric generators or any other machinery. From the daily press it is gathered that the Municipal Council of Sydney contemplates the erection of destructors for incinerating the city refuse, but no description of the apparatus for which tenders have been invited has so far been made public, nor has any statement been made about an intention to utilise the heat.

Sydney has not the reputation of being a model city. It is now believed that Government is about to take the control of the city in its teeth, and that the present holders of the reins will soon be supplanted. Every well wisher of Sydney, who sees and understands what magnificent latent possibilities there are before her must hope that she will for all time be the Queen City of the Southern Hemisphere; and that the new century will open finding old ways departed from, and a new and glorious era of progress, prosperity, morality and cleanliness installed in our midst. When that day arrives, we shall look back with curiosity and wonder at the continued blindness and negligence from which our city—so highly gifted by nature—had suffered so long.

CURVED CONCRETE WALLS FOR STORAGE RESERVOIRS.

By C. W. DARLEY, M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, December 19, 1900.*]

IN carrying out water supplies for small country towns it is necessary to cut down the expenditure in every way possible, so as to keep the total cost within the means of the municipality to pay the interest and provide a sinking fund.

In a great many cases pumping schemes are available and would be much cheaper as regards first cost, but the working expenses are necessarily much higher than for a gravitation scheme, besides experience has proved that country municipal authorities will rarely employ competent skilled labour for looking after the engines, and in consequence many valuable pumping plants may now be seen in the State in a shockingly neglected condition, and complaints are made that the machinery is unsatisfactory and will not work, the sole reason being invariably due to dirt and wilful neglect.

Of late years, partly owing no doubt to the unfavourable reputation thus given to pumping plants, country municipalities have been urging the adoption of gravitation schemes. In only a few instances have these been available, providing an abundant supply within easy reach; while in others, good schemes have been provided by going some miles away, but several towns have had to be content with schemes having a very limited catchment area, and are thus dependent upon occasional thunderstorms and heavy showers to replenish the reservoir, and in some instances this somewhat doubtful supply has been preferred to a pumping scheme within easy reach

When carrying out gravitation schemes for some of the large towns such as Orange, Armidale, and Junee, concrete reservoir walls were erected with gravity sections. The section of wall adopted closely follows that recommended by Professor Rankin in his report on the Tansa Dam for the Bombay Water Works. This wall has a slightly battered inner or water face, the profile of the outer face being a logarithmic curve; this section has of late years been adopted for almost all large reservoir walls. Such a wall resists the pressure of water against it wholly by its own weight, and is consequently termed a gravity wall. Its principle as laid down by Professor Rankine is such that the centre of resistance of any horizontal plane ought not to deviate from the middle of the thickness by more than about one sixth of the thickness—inwards when the reservoir is empty, outwards when it is full—in order that there may be no appreciable tension at the outer edge of the given plane when the reservoir is empty, nor at the inner edge when it is full.

This is about the most economical section to which a dam can be constructed to resist the pressure by gravity alone; but in the case of many small towns the cost of such a dam would be prohibitive; the Department therefore had to resort to a more economical section of dam, and this could only be done by building it in a curved form and treating it as an arch, thus putting the concrete wholly in compression. Several large dams have been successfully constructed on this system in America, but it is only within the last few years that they have been introduced into this State.

A short description of some that have been erected may be interesting. Curved or arched dams can only be constructed when the valley is comparatively narrow and where sound rock can be obtained the whole way across and up each slope, to form good abutments. In some cases where the configuration of the country did not admit of a curve being fitted in from end to end, a short piece of gravity dam had to be constructed at one end from which to spring the arch. This was done at Tamworth and answered the purpose well; and a similar arrangement is about to be carried out in a dam across the Cataract River for the Wollongong Water Supply.

Theoretically it would seem of little importance how the thickening of the dam was arranged; whether both sides should have a batter, thus keeping the centre of gravity of all sections in a vertical line in the centre of the dam, or whether the batter should be on the inner or water face, thus obtaining some help from the downward thrust of water on the batter which some engineers have contended to be of service, or to keep the inner or water face vertical and outer side battered. As a matter of fact we have examples of each form in the State. The Parkes Dam having a double batter, and the Tamworth Dam being battered on the inner face, but the standard practice now adopted, and one found in many respects most convenient in construction, is to keep the inner face vertical and the outer face battered. This arrangement suits the outlet works more conveniently, as the swivel offtake pipe can be brought close up to the face of the dam for cleaning without falling back too much.

Principles upon which the curved dams have been designed.—A curved dam with solid rock abutments being subject to the same stresses as a hollow empty vertical cylinder of the same radius, and surrounded on the outside by water of the same depth as that impounded by the dam, the formula for resistance of cylinders to a crushing pressure, viz.: $P = \frac{2sT}{D}$ or $\frac{sT}{R}$ has been used for calculating the thickness of the seven curved concrete dams or weirs constructed in connection with the Country Towns Water Works to date with radii varying from 100 feet to 300 feet.

The value of s (safe crushing strength of material per square foot) for a dam with granite or basalt abutments, the same stone being used for the concrete, has been taken at 20 tons, and for dams having sandstone abutments, as at Lithgow and Picton, at 10 tons to 12 tons per square foot according to local conditions.

T = Thickness at any point in feet.

R = Radius in feet.

D = Depth of water to be impounded which should be calculated from the maximum estimated highest overflow or flood level.

P = Water pressure in tons per square foot.

$$P = \frac{D \times 62{\cdot}5}{2240} = D \times {\cdot}027902$$

$$T = \frac{RP}{s}$$

$$\therefore T = RD \times {\cdot}0014 \text{ when } s = 20 \text{ tons}$$

$$T = RD \times {\cdot}0023 \text{ when } s = 12 \text{ tons}$$

The thickness of any curved dam at any depth may thus be graphically determined by a simple diagram the top thickness being increased to 3 ft. or 3 ft. 6 in. up to 5 ft., or more, where floating timber is expected to be carried over during floods. The area of the triangle forming the theoretically safe cross section × s = the total thrust on each abutment.

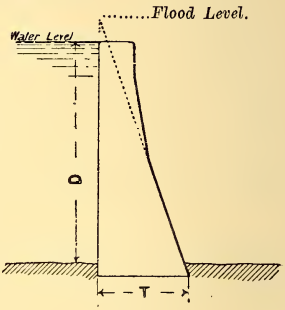


Fig. 1.

There would be no saving of material in constructing a concrete dam, having a limit of resistance of 20 tons per square foot to a greater radius than 500 feet or with a limit of resistance of 12 tons per square foot to a greater radius than 300 feet, because the required thickness would, in both cases, be about equal to that necessary for a dam of gravity section having a line of resistance within the middle third. A slight curve in all long dams is, however, advisable, to allow of more freedom of movement under changes of temperature, and to obviate as far as possible, transverse cracks due to the contraction of the concrete in setting.

The average crushing strength of a large number of specimens of concrete made with the usual proportions of dry materials, viz. 1 cement, $2\frac{3}{4}$ sand, $2\frac{1}{2}$ shivers, and 3 hard metal $1\frac{1}{2}$ in. gauge, six months old, has been ascertained by testing to vary from about 70 tons to 145 tons per square foot—80 tons may be taken as a safe average. Taking the concrete in place at one and a half times stronger than the unsupported test cubes gives an average crushing strength of 120 tons per square foot at least six months old, the factor of safety of the work at that age would therefore be 6 for a limit of resistance of 20 tons, and 8 for a resistance of 15 tons. Mr. Bruce in his paper on the strength of concrete (Proc. Inst. C.E., Vol. CXIII.) considers that the modulus of rupture, found experimentally, may be adopted as the working load in compression. The average modulus of rupture of 14 transverse tests of sandstone, and whinstone concrete made by him = 16 tons per square foot.

A limit of resistance so high as 20 tons per square foot should be used only for curved dams in cases where the foundation, abutments, and metal for concrete consist of sound, hard, igneous rock.

To provide against the green concrete being subjected to a greater head of water than it can safely bear during construction, the work is carried up in nearly level courses not more than 3 ft. in height, the depth of water being controlled by the scour and outlet valves. Should a flood occur during construction the walls may be submerged without much risk. This has happened in one or two cases, but no injury was done as the lower portion of dam is so much thicker in proportion. There would be more risk of course from flood waters crossing the top of a newly completed wall, but in all probability the extra thickness provided in the upper portion would make the work quite safe. In all calculations the weight of the wall has been disregarded although it must materially assist in its strength.

Details of construction of curved concrete dams.—It has been found advisable to construct all our concrete dams by labourers employed directly under the officers of the department without the intervention of a contractor. The reasons for this course are as follows :—Information as to the nature of the foundations can only be obtained from trial shafts, and this is often unreliable. The depths as shewn on the section for a contractor's guidance have to be exceeded in many instances to get down to strata sufficiently solid to make a safe foundation, thus opening the way for contractors to set up claims which are difficult to dispute or adjust. Also, by employing a staff who are moved from one work to another and thus trained to the class of work, a more uniform standard of construction is obtained, and equally as cheap as if done by contract.

English, German and Colonial cements have been in use, but an effort is always made to have each dam carried out in one brand. Of late, the Rock brand cement, manufactured near Sydney by Messrs. Goodlet and Smith, has been almost exclusively used. It is packed in bags and is thus cheaply handled or carted. It is delivered as required from the store at Granville into railway trucks, and thus the expense of erecting large storage sheds on the site of the works is saved. The bags are found very useful for covering green concrete and other purposes.

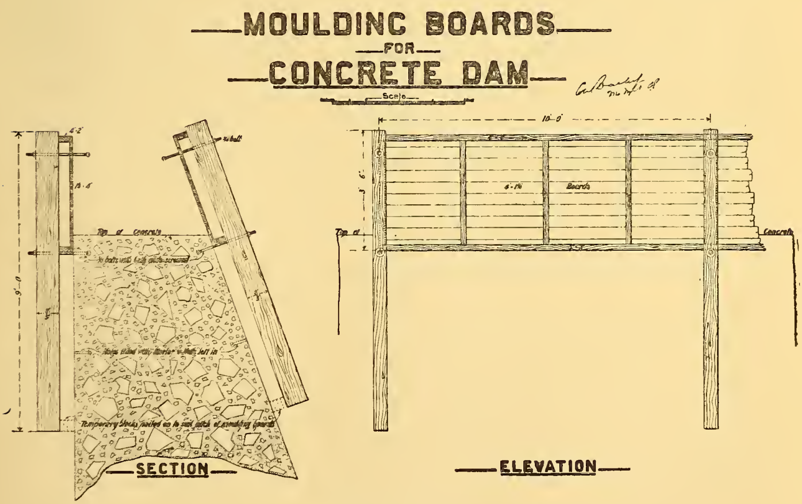
All the sand used for making up the concrete is washed, the usual apparatus employed being the ordinary "Long Tom" of the gold-digger. A horizontal screen is placed at the head of the trough, this not only removes coarse stuff and vegetable matter, but also assists greatly in distributing the water through the mass, thus freeing the particles from dirt. The dust from the stone-crusher, if granite is being broken, mixed with the washed sand is found to add to the strength of the concrete.

Stone is broken up into ballast and shivers by the ordinary types of stone-crushers and passed through a revolving screen to separate the various sizes. The "Little Giant" type of crusher has been generally used, as the pin-plates provided with this machine best stand the wear of breaking to the small gauge of $1\frac{1}{2}$ inch. The pins are of $\frac{3}{4}$ inch tool steel set in a cast-iron backing. Manganese steel plates have been tried, but sufficient experience has not yet been gained to enable me to express an opinion as to their wearing qualities.

As a rule, the rock foundations when laid bare are sufficiently rough to give a grip to the concrete, and it is not necessary to cut skewbacks to take the thrust of the arch. This also applies to the joint under the base, very little artificial roughening being required to make it water-tight.

In preparing the foundation care is taken to remove all soft, loose or shaken rock, and to roughen or step all smooth and inclined surfaces. The rock is then well washed with a jet of water under a pressure of about 20 lbs. per square inch, and all joints, fissures, etc., raked out and carefully grouted, or stopped with cement mortar. A half inch layer of mortar is then spread over the rock surface and worked into all corners and recesses, and upon this while fresh, the concrete is deposited.

The wall is brought up in 3 feet courses, each course consisting of three 12 in. layers carried along, one slightly ahead of the other. The course is held between mould-boards 10 ft. long by 3 ft. 6 in. high, framed of 4 in. by 2 in. hardwood, sheathed with 4 in. by $1\frac{1}{4}$ in. tongued and grooved pine.—(See diagram). Sufficient of these should be made to carry a course the full length of the dam. The mould-boards overlap the preceding lower course 6 in., and are held in position by 8 in. by 4 in. hardwood profiles attached



Drawing 2.

to the inner and outer faces of the wall below. The attachment is by $\frac{3}{4}$ in. bolts screwed at both ends, a bolt and nut is built 6 in. into the concrete at intervals of 10 feet horizontal and 3 ft. vertical. When a course is completed, the mould-boards and profiles are lifted 3 ft.; unscrewing the bolts leaves the nuts in the wall, and the bolt-holes are then filled with mortar. The mould-boards are curved to the mean radius of the face of the wall. On the downstream or concave face the radius increases as the work is carried up, and the mould-boards gradually separate. Filling pieces have to be inserted between the mould-boards; on the upstream or vertical face this does not occur.

The proportions of the ingredients of the concrete used in the body of the wall are—1 cask of cement, $4\frac{1}{3}$ cubic feet; 12 cubic feet of sand; 10 cubic feet of shivers, $\frac{1}{2}$ inch gauge; 13 cubic feet of metal, $1\frac{1}{2}$ inch gauge. A six inch facing is used on the water side of the wall composed of 1 cask of cement, $4\frac{1}{3}$ cubic feet; 10 cubic feet of sand; 10 cubic feet of shivers, $\frac{1}{2}$ inch gauge.

Plumstones to the maximum size that can be handled by two men are built into the body concrete as closely as will allow of proper ramming and packing round them. They can be most efficiently bedded on their thinnest edges, and should have their greatest length radial to the curve of the wall. With careful packing, and selecting stones of square dimensions, it is possible to get 45% of stone into the work, but in dams of small radius and therefore thin walls 33% of plumstones should only be calculated upon. These small stones have been found to be the most economical size to use; as the dams built for the supply of water to country towns are rarely large enough to bear the expense of providing plant for lifting larger weights the economy of the use of plumstones is obvious.

The practice has been to use the richer concrete on the waterface to make a water-tight wall. Experience has shewn the impermeability of the structure depends almost wholly on the skin worked up on both faces of the concrete. This skin consists of a thin layer of neat cement, which is obtained by working a spade or suitable tool between the concrete and the mould-board. It is best obtained by placing the concrete in position in a fairly wet condition. But wet concrete contracts by the gradual escape of excess moisture and vertical cracks would appear in the wall, and therefore to guard against this it becomes necessary to use the concrete as dry as possible and ram thoroughly. To obtain the impervious skin the concrete face should be floated with neat cement immediately the mould-boards are removed and while it is in a green and moist condition.

The whole of the concrete is run in on a tramway of a gauge narrow enough for the skips to pass between the mould-boards on the thinnest part of the wall. If the site is suitable, the stone-crusher, mixing boards, etc., are placed so that the material gravitates through all the processes to the work. Where the pipes pass through the dam they are carefully cleaned, washed over with cement grout and bedded in, and surrounded by one to one cement mortar.

Outlet Works.—The outlet works generally consist of a large cast-iron scour pipe, usually 24 inch diameter, controlled on the outside by an ordinary double faced stop valve operated from the top of the dam. At the inner end of the pipe a bell mouth is formed in the concrete to facilitate the insertion of a wooden ball should the necessity arise to remove or repair the stop valve. A cast iron offtake pipe about twice the capacity of the proposed main is built into the wall at a somewhat higher level than the scour pipe and fitted on the outside with a stop valve, and on the inside with a trunnion joint and moveable wrought iron galvanised pipe with a galvanised wire netting screen at the end. By means of an ordinary crab winch fixed to a platform on the top of the dam, the offtake pipe can be lowered or raised as required, so as to draw off near the surface, it can also be hauled up to the vertical position and the screen cleaned when necessary. In small reservoirs where there is little wave action, the moveable pipe is buoyed by a float. The crest of the dam forms the waste weir, which is made as long as possible where the catchment is large.

As far as possible it is desirable to avoid constructing concrete dams, certainly the upper or thin portions during very hot weather. It has been found by experience that walls so constructed are far more liable to crack during succeeding cold weather, especially in the case of reservoirs that have not been filled for some time after completion, thus allowing them to thoroughly dry out and contract. However, although the cracks, which in some cases may extend almost the whole way down the wall, are very unsightly and alarming to the uninitiated, they need really cause no anxiety to the engineer, for soon after the dam fills with water, thus moistening and expanding the concrete, and partly no doubt pressing home the arch, the cracks close up and fine particles of matter in the water render them water-tight.

In the case of the Tamworth dam, the top portion of which was built during warm weather and remained dry till after the very cold winter had set in, some apparently large cracks appeared, but they all closed soon after the reservoir was filled, so much so that it is now quite impossible to detect where they were, likewise in the Mudgee dam constructed under similar circumstances as regards heat, etc., which also remained unfilled for over a year, several large cracks appeared, some open as much as $\frac{1}{8}$ in. on top, but they all closed up soon after the first filling. In this respect curved dams have a decided advantage over straight gravity dams, for when the latter form of wall cracks, which all long walls of concrete are liable to do when subjected to change of temperature and stand dry for any length of time, they do not so readily close up again.

Cost of curved concrete dams.—The cost of material of course varies at each site, according to length of rail carriage distance, for carting from railway, distance from suitable stone or sand, and cost of labour vary with adaptability of site for economical working. The actual cost is best illustrated by taking a fair average case in practice and giving the cost in detail. In the case referred to, the distance of rail carriage was 253 miles, and road carriage six miles. Sand was obtained from a dry creek three miles from the works; and stone from a diorite quarry about 200 yards from the dam, but in this case the quarry being below the level of the dam all the material had to be lifted.

Cost for one cubic yard of each ingredient used in concrete:—

	s.	d.
Sand—Getting and washing	3	7
Carting	1	11
Cost of sand per cubic yard...	5	6
Rubble stone—Quarrying	3	8
Explosives, etc.	0	7
Cartage	0	7
Cost of rubble stone per cubic yard ...	4	10
1½ inch metal and ½ inch shivers—Quarrying ...	4	0
Explosives	0	7
Crushing and cartage	4	0
Cost per cubic yard	8	7
Cement—Cost price of cement per cask ...	9	9
Freight, 253 miles rail	5	9
Cartage, 6 miles	0	8
Cement per cask	16	2

Cost of one cubic yard of aggregate in wall on a total of 2,763 cubic yards:—

	Quantity.	Per unit. s.	Per unit. d.	£	s.	d.
Cement, cask	.581	16	2		9	4·71
Grout, cask	·0119	16	2			2·31
Sand, cubic yard	·243	5	6		1	4·04
Metal and shivers, cubic yard ...	·435	8	7		3	8·8
Rubble stone cubic yard ...	·482	4	10		2	3·93
Timber in casing						3·62
Labour fixing timber						6·8
Labour, mixing and placing, including tools gear, etc.					4	0·5
Carting material and mixing boards						6
Erection of plant, building and temporary dam for water supply						10·8
Cost of plant charged to works						5·77
Freight and cartage on plant					1	0·7
Taking down plant and clearing up						2·22
Total cost per cubic yard of dam				1	5	0·20

In this instance about 45% of plum stone was worked in with the concrete.

Attached is a statement of eight curved dams designed, seven of which are complete, the eighth, namely that for the Wollongong Water Supply, is just about to be constructed. The leading dimension and capacity are given in each case as well as the nature, specific gravity, and weight per cubic foot of the stone used in the concrete.

The following table gives particulars of the curved dams constructed to date, also the weight of stone used in the concrete, and capacity of reservoir.

Name.	Greatest Height. Ft. In.	Length in feet.	Radius in feet.	Nature of rock.	Specific gravity.	Weight in pounds per cubic foot.	Calculated limit of pressure in tons.	Capacity in million gallons.
Lithgow ...	35 0	178	100	sandstone ...	2·34	146	10	15
Parkes ...	33 0	540	300	granite ...	2·75	171½	24	115
Cootamundra	45 6	500	250	diorite ...	{ 2·69 2·66	168 166 }	20	136·5
Tamworth ...	61 5	443	250	granite ...	2·71	169	20	50
Picton ..	*28 0	112	120	sandstone ...	2·36	147	12	14
Wellington...	48 0	350	150	conglomerate	2·67	166½	20	30
Mudgee ...	50 0	498	253	altered slate	2·69	168	20	42
Wollongong	42 0	528	200	basalt	..	...	20	168

* Designed to be raised a further 15 ft. hereafter if necessary, making 43 ft. in all.

Drawing No. 1 shews the plan of a curved dam and three sections of dams constructed, section No. 3 being the type now mostly adopted and recommended.

Drawing No. 2 illustrates the method of timbering as described in the paper.

Drawing No. 3 shews a section of the Bear Valley Dam erected in California, U.S.A. This is a somewhat remarkable section, having an apparently very heavy foundation and an almost parallel wall on top—in this case the lower portion of the dam must be subjected to a compression of about 43 tons per square foot. I have drawn on in dotted lines the section of dam adopted in the State for sake of comparison.

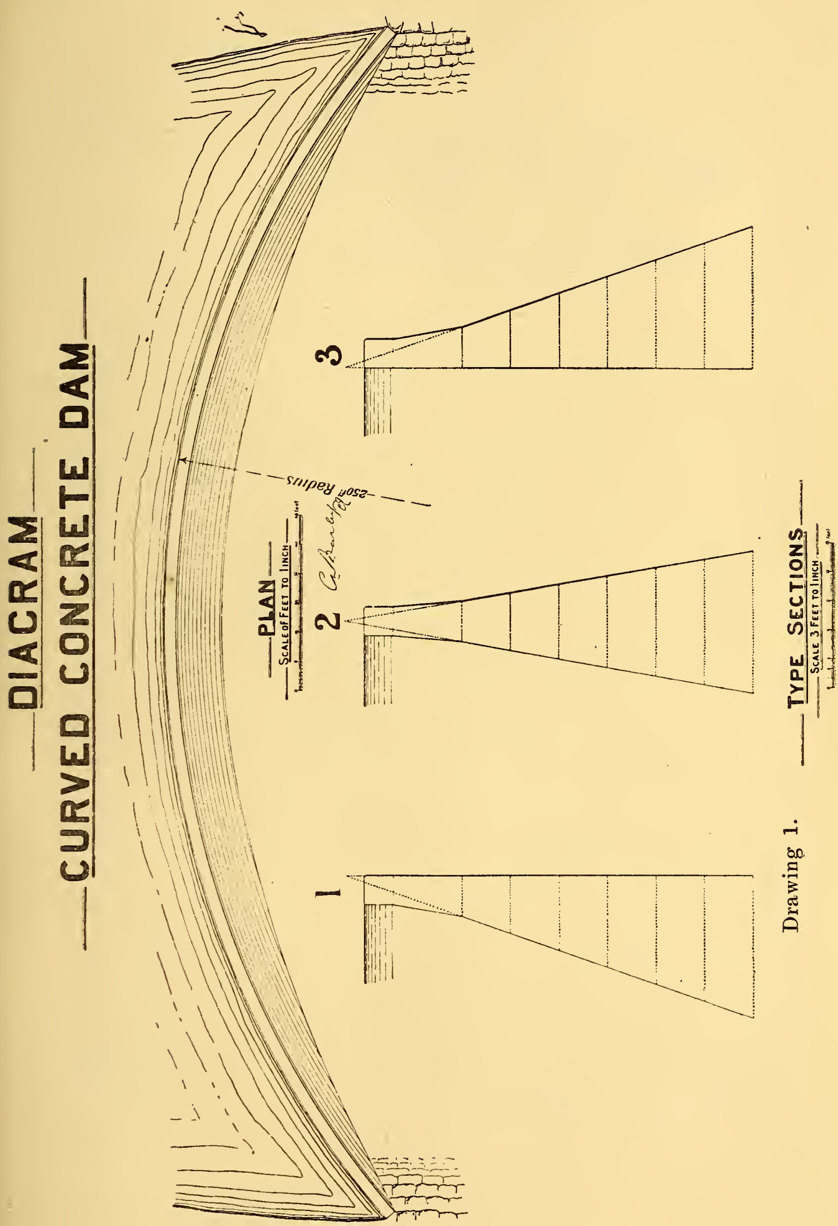
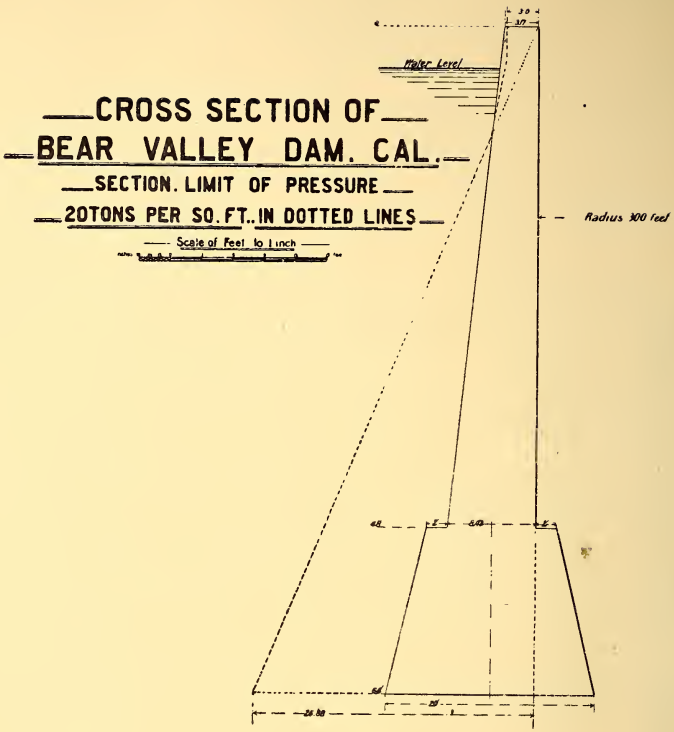


DIAGRAM
CURVED CONCRETE DAM
PLAN
SCALE of FEET TO 1 INCH
250ft Radius
1
2
3
TYPE SECTIONS
SCALE 3 FEET TO 1 INCH

Drawing 1.



Drawing 3.

The Tamworth and Picton concrete reservoir walls were carried out by Mr. S. H. Weedon, as Resident Engineer; the Parkes and Mudgee concrete walls by Mr. H. Fleming, Resident Engineer; and the Cootamunda and Wellington concrete walls by Mr. J. Symonds, Resident Engineer. In each case these officers had charge of the pipe laying and all other works in connection with the water supply as well. Mr. L. A. B. Wade, M. Inst. C.E., Supervising Engineer, had the general direction and supervision of all the works above referred to.

EXPERIMENTAL INVESTIGATION ON THE STRENGTH OF BRICKWORK WHEN SUBJECTED TO COMPRESSIVE AND TRANSVERSE STRESSES.

By Prof. W. H. Warren, M. Inst. C.E., M. Am. Soc. C.E., and
S. H. Barraclough, B.E., M.M.E., Assoc. M. Inst. C.E.

[*Read before the Engineering Section of the Royal Society of N. S. Wales, December 19, 1900.*]

1. The following investigation comprises tests of brick columns and of brick beams built both in cement and in lime mortars, together with tests of the materials used in building the columns and beams. A special effort was made to keep the conditions as uniform as possible. The bricks used were all of one quality; the sand in the mortar was Neapean River sand sifted through 400 and caught on 900 meshes per square inch. The Portland cement was Hemmoor brand, obtained from one shipment; the lime was ordinary stone lime of uniform quality. The proportions of sand, of cement or lime, and of water used in making the mortar were accurately measured and the materials were mixed in a uniform manner. The same bricklayer was employed to build all the columns and beams; and the joints were maintained the same thickness throughout.

2. *Compression Tests.*—The columns were about 56 inches long and 9 inches by 9 inches or 14 inches by 9 inches in section, (Figs. 1 and 2). They were built on planed cast iron face plates specially constructed for the purpose, and were finished accurately on their upper ends to plane surfaces. In lifting them into the machine the columns were held between the upper and lower face plates under a slight initial compression of about half a ton by means of bolts passing through lugs on the face plates; the bottom plate was allowed to rest upon a ball bearing, and the top plate was removed before testing so that the top of the column was brought

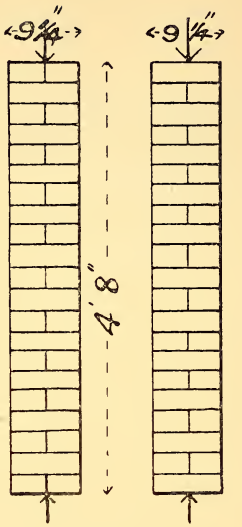


Fig. 1.

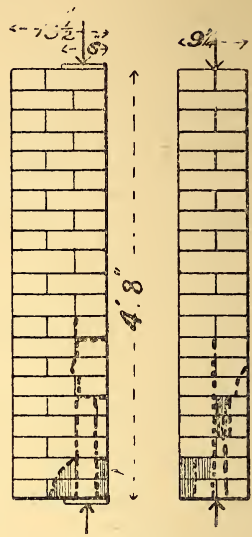


Fig. 2.

into contact with the compression plate of the vertical testing machine. The columns were thus placed in the machine without injury. The compressions produced by the loads applied were measured for each two tons increment by means of dial extensometers arranged on opposite sides of the column as shown in Fig. 3. These dials record the compressions between two fixed points in the column, and are independent of the movement of the machine. The readings were observed to ·01 mm., and a sample[1] of the results obtained is shown in Table I. The curves in figs. 5 and 6 show the relation between the loads and the compressions produced. A short column of brickwork 12 inches long and 9 inches by 9 inches in section was tested with a double set of Marten's mirror apparatus arranged on two opposite sides, the reflected images of the four scales being observed with four telescopes in the customary manner (see Fig. 4 and Table II.). It was also retested immedi-

[1] It was not considered necessary to reproduce the whole of the observations taken, as this would have greatly increased the bulk of the paper without any corresponding advantage. The plotted curves show the kind of result obtained with sufficient accuracy.

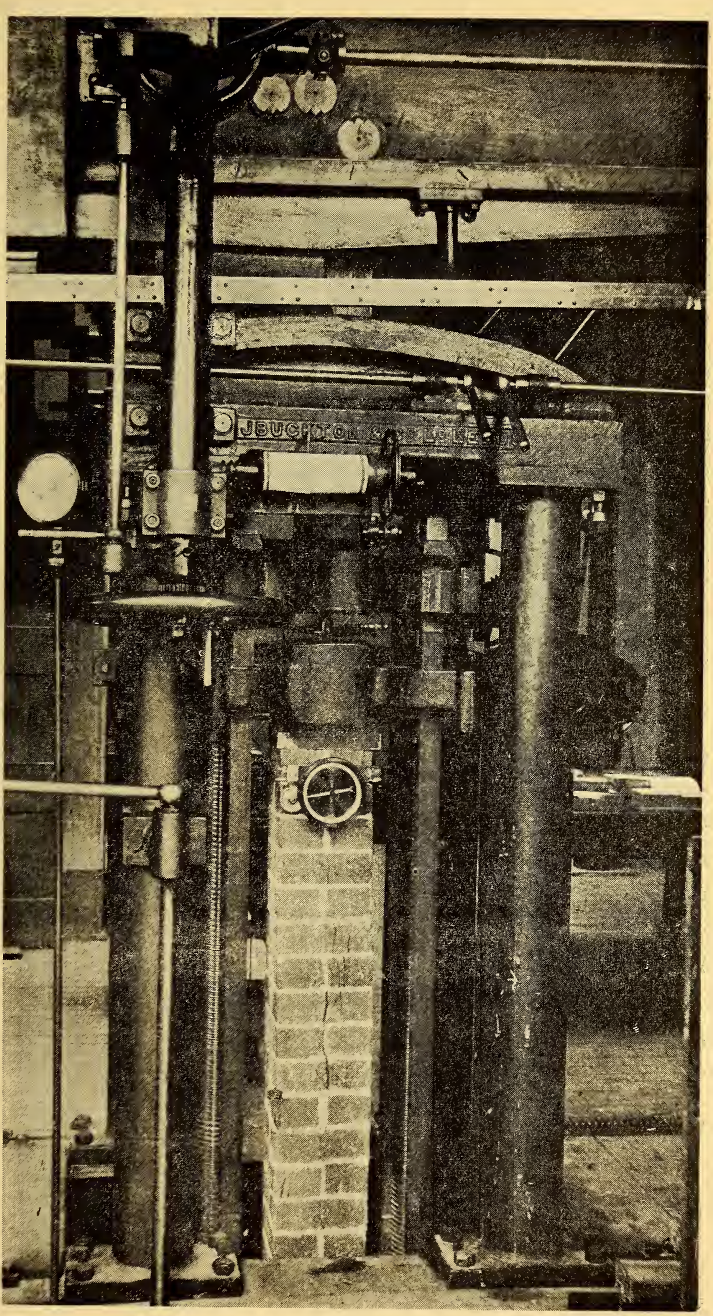


Fig. 3.

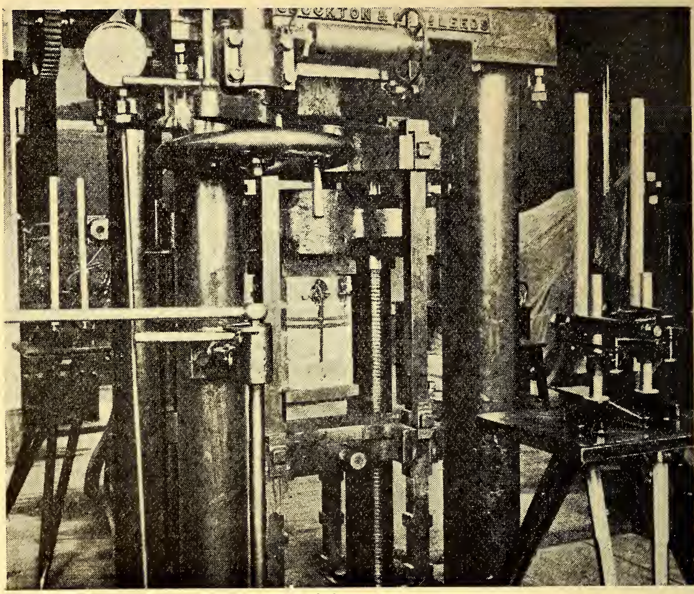


Fig. 4.

ately and after an interval of several months (Table II.). A short column of cement mortar 12 inches long and 6 inches by 6 inches in section was tested in a similar manner (Table III.). A summary of results is given in Tables IV. and V.[1] For purposes of comparison and to supply further information on the crushing strength of brickwork, the results of testing brick columns at the Watertown Arsenal, U.S.A., and also by the Institution of British Architects are summarised in Tables VI. to IX.

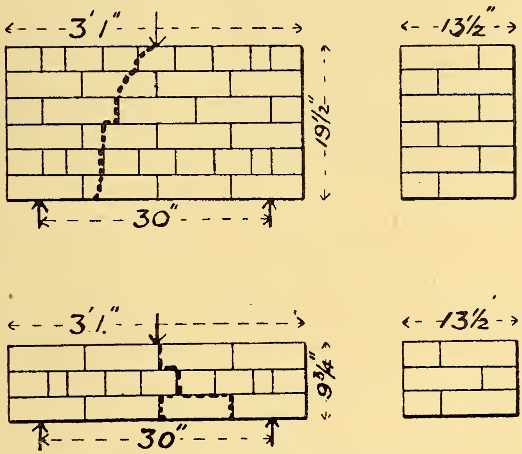
3. *Transverse Tests.*—The transverse tests of brick beams in cement and in lime mortar were made in the same testing machine,

[1] May 8, 1901.—The following additional results have been obtained since the paper was written :—

No.	Age days.	Dimensions. Inches.	Mortar.	Crushing load. Tons.
X_1	33	51·4 × 9 × 9	1 cement + 2 sand + 15% water	69
X_2	35	13·3 ditto	ditto ditto	over 100
X_3	34	52 ditto	1 cement + 4 sand + 15% water	65

X_2 cracked at 40 tons, but carried 100 tons without breaking although all four corners were cracked considerably.

and the deflections under the various loads applied were measured by means of verniers reading to ·001 inch, and also with the same dial extensometers which were used in testing the compressions of the brick piers. Eight beams were tested, each 3 feet long by one and a half bricks (approximately 13½ inches) wide, and three and six bricks deep respectively (Figs. 5 and 6). Four



Figs. 5 and 6.

of the beams were built in lime mortar, two of one to two and two of one to four, and four in cement mortar of the same proportions respectively. Two smaller beams were also built in cement mortar 14 inches long by one and a half bricks wide and three bricks deep. The beams were faced with mortar to true planes where they rested on the end supports, and on the central knife edge through which the loads were applied. The general results are recorded in Table X., and the deflections in Table XI., and the corresponding curves are plotted in Fig. 7.

4. *Tests of the materials used in building the piers and beams.*—The tests made on the materials used in building the columns and beams consisted of transverse and compressive tests of the bricks and of the various mortars, and also tensile tests of the mortars. The compressive tests of the mortar were made on prisms or slabs, each 6 inches by 6 inches in area, but varying in height or thickness

BRICK BEAMS.

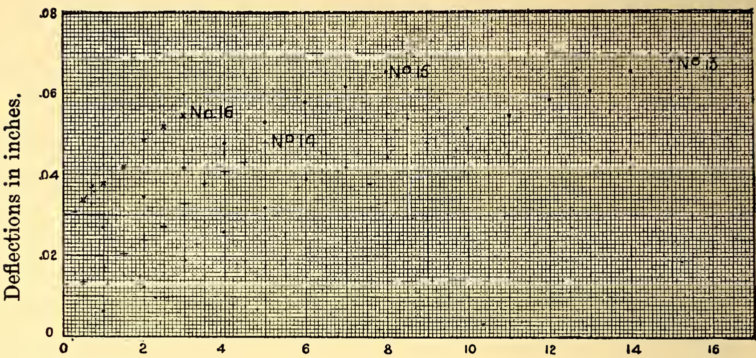


Fig. 7.

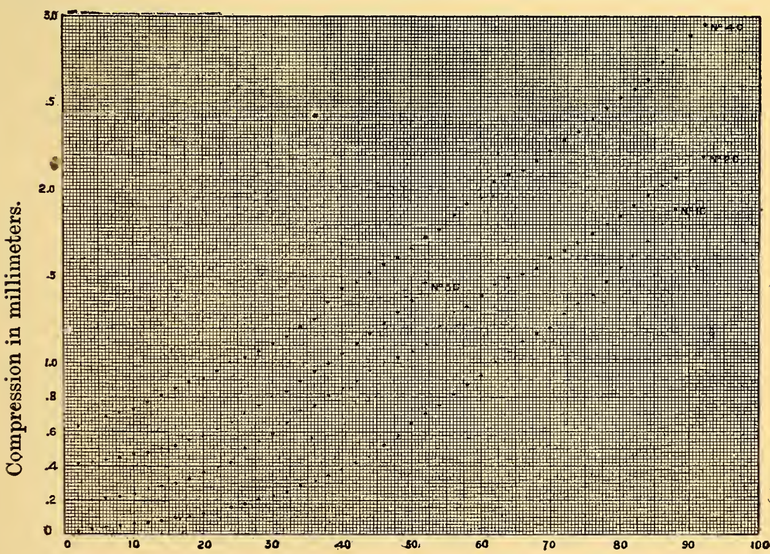
from 12 inches to $\frac{1}{2}$ inch. The results are recorded in detail in Table XIII. Cross breaking tests of the mortar were made on prisms 2 inches by 2 inches in section, supported at each end and loaded in the centre of a span of 10 inches; the results are recorded in Table XII. Shearing adhesion tests of the mortar were made in which one brick was made to slide relatively to another, to which it was connected by a mortar joint in single shear, or between two others in double shear as shown in Figs. 10 and 11 (Table XV.).

Tests were also made to determine the direct adhesion of discs of brick inserted in the centre of moulds for making mortar briquettes, the adhesion being measured by the tensile stress necessary to separate the mortar from the disc of brick (Table XVI.). Table XVII. gives the results obtained some years ago in regard to the shearing resistance of a particular brand of pressed brick united (as shown in Figs. 10 and 11) with cement mortar of various kinds, and is reproduced here for purposes of comparison.

5. *Conclusion in regard to the compressive tests of brick piers.*—The experiments on the strength of brick piers subjected to a compressive load were made in order to ascertain both the crushing strength, and the deformations under equal increments of

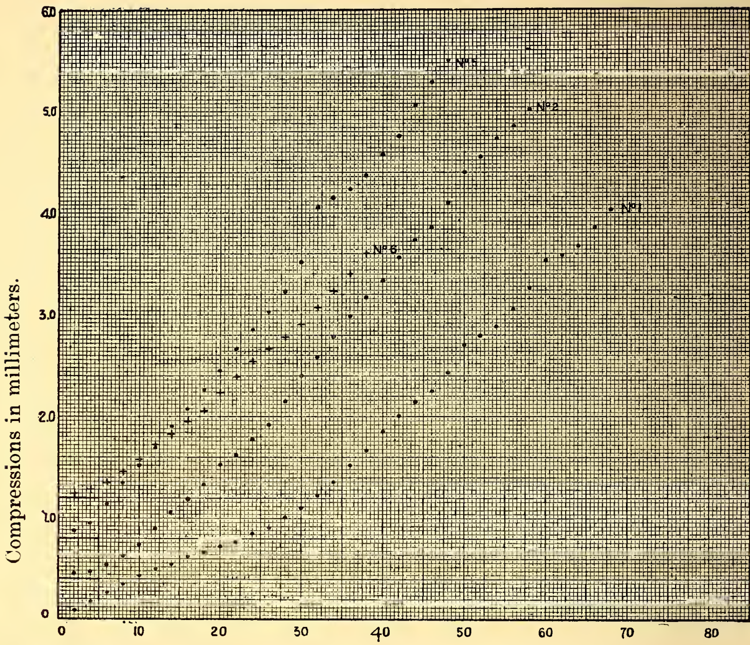
loading. Thus the load applied was increased by equal increments of two tons which on the section of 9 inches by 9 inches was equivalent to about 3·6 tons per square foot, but in spite of the care taken in building the column, the uniformity of the mortar joints, the placing of the column in the machine and the accuracy with which the compressions produced by the load were observed the results obtained were very irregular, and it would appear to be impossible to establish a modulus of elasticity, even for a given brick and mortar. The authors are lead to doubt the possibility of obtaining exact information on this point owing to the impossibility of maintaining the conditions sufficiently uniform in building the piers of brickwork or in the bricks themselves. The curves (Figs. 8 and 9) show the loads applied and the compressions produced by them in the long columns. The results for the short columns were more uniform as they were nearly a year old and there were fewer mortar joints, and these had attained a greater strength than those in the longer piers which were generally only four

BRICK COLUMNS IN CEMENT MORTAR.



Load in tons. Fig. 8.

BRICK COLUMNS IN LIME MORTAR.



Load in tons. Fig. 9.

months old. On the whole, however, the inconsistencies in the results are considerable and difficult to explain.

The crushing strengths obtained were more satisfactory, and may be taken as showing the load necessary to produce the first indications of failure, which always appeared as a fine crack or cracks, visible under a large magnifying glass. Sometimes these cracks would appear on one side only, but more frequently on all four sides at about the same time. The loads were applied slowly, giving just time to observe and book the readings of the extensometers, and in some cases the loads which might be expected to produce fracture were maintained for times varying from five minutes to fourteen days. When fracture occurred nearly all the bricks were broken. Taking the average of the five tests made on cement mortar piers, the load producing cracks is 172 tons per square foot for mortar comprised of one part of Portland cement to two parts of the coarse river sand, and of the four tests made with mortar of the same materials, but in the proportion of one to four the load was 149 tons per square foot. Brickwork in cement is generally built with mortar comprised of one part of cement to three parts of sand, but the materials of the mortar and the workmanship are not generally as good as in the test piers. The bricks, however, are generally as good as these used, and occasionally better. Taking all these circumstances into consideration it appears that the crushing strength of ordinary good brickwork in cement mortar is about 150 tons per square foot, and the safe load may be taken at least from 15 to 20 tons per square foot.

In lime mortar brickwork the average of three tests of the same bricks with mortar comprised of one part of stone lime to two parts of the same sand was 85 tons per square foot; and with mortar comprised of one part of lime to four parts of sand was 46·5 tons per square foot, from which it appears that the safe working loads may be taken as at least 5 and 9 tons respectively.

6. *Conclusion in regard to transverse strength of brickwork.*—It will be observed that the lime mortar beams were tested after nearly a year, but that they all failed by horizontal shearing of the mortar, the bricks remaining uninjured, so that the modulus of rupture calculated in the ordinary way has not the usual meaning. Comparing the intensities of horizontal shearing stress developed in testing the beams with the average results obtained by testing the shearing resistance (Figs. 10 and 11), and with the results of testing briquettes of the mortar, in which small square discs of the brick had been inserted when moulding the briquettes, thereby developing the direct adhesive strength of the mortar to the brick, it is difficult to account for the failure of the mortar in the beams at the low stresses indicated. The shearing strengths of the two mortars, as in Figs. 5 and 6 were 21·5 and 20·7 ℔s. per square inch respectively, and the adhesive strengths 13·2 and 9·8 ℔s. per square inch respectively. The deeper beams gave

the better results, but even after twelve months the lime mortar was weaker than the bricks.

In testing the beams built in cement mortar after about six months hardening in air, the greater strength of the mortar enabled them to resist the horizontal shearing stresses much better, and with the stronger of the two cement mortars the bricks were the weaker, whereas the weaker mortar appeared to be just about as strong as the bricks. This is seen by the failure by rupture of the bricks and shearing in tests Nos. 15 and 16, as well as the direct tests for shearing and adhesion, giving about the same results as the shearing stress developed in the beams.

The two smaller beams built in cement mortar and tested after about twelve months, gave results showing the mortar to be stronger than the bricks. The modulus of rupture calculated from the results obtained in testing the cement mortar beams has the ordinary meaning, since in all cases failure occurred by rupture of the bricks. The deflections observed with the various loads applied in the cement mortar beams are plotted in Fig. 7, and the curves are more or less parallel up to a total load of two tons, but the coefficient of elasticity is irregular.

It is necessary to know the transverse strength of brickwork in order to determine the load which will be brought to bear upon a beam spanning an opening and carrying a brick wall. The brickwork as it is gradually built over the girder increases in weight directly as the height, but its resistance as a beam increases as the square of the height. The height at which it will just support itself depends upon its transverse strength, thus[1]:—

Let l denote the span of an opening.
,, h the height of brickwork which is self-supporting.
,, t the thickness of the brick wall.
,, w the weight of a cubic foot of brickwork.
,, f the modulus of rupture in pounds per square inch.

The bending moment occurs near the points of support of the beam,

[1] See Baker's *Masonry Construction,* and *Engineering,* Vol. XIV.

and is:—

$$\frac{Wl}{12}$$

but W the total weight of the brickwork over the girder is:—
$whtl$

$$\therefore \frac{Wl}{12} = \frac{whtl^2}{12}$$

The moment of resistance of the brick beam is:—$\frac{1}{6}\,th^2\,(144\,f)$

$$\therefore \frac{whtl^2}{12} = \frac{th^2\,(144\,f)}{6}$$

$$h = \frac{wl^2}{288f}$$

It is sometimes assumed, for convenience, that w equals 144 lbs. per cubic foot (although more frequently about 125) as then:—

$$h = \frac{l^2}{2f}$$

i.e., the height equals the square of the span divided by twice the modulus of rupture.

If the wall, for example, is built over an opening 20 feet wide and the modulus of rupture is 10 lbs. per square inch, (see Table X.) then in order that it should be self-supporting we have:—

$$h = \frac{20 \times 20}{20} = 20 \text{ feet}$$

A height greater than this would be more than self-supporting, and it is seen the height diminishes as the modulus of rupture decreases. For any height less than that at which the brickwork becomes self-supporting the wall would require to be supported and would bring pressure upon the beam. When the bricks are first laid the transverse strength will be much smaller, and the load upon the beam correspondingly greater, but as time goes on the strength will gradually increase, and the actual load upon the beam becomes gradually less and less, and very frequently disappears altogether.

Since the net resistance of the wall increases simply as the height, let h' equal the height which would produce the maximnm load upon the beam, then:—

$\frac{h'}{h}$ = the portion of the entire weight of the wall which is self-supporting, and:—

$$1 - \frac{h'}{h} = \text{the portion which requires support.}$$

The total height to be supported is:—

$$\left(1 - \frac{h'}{h}\right) h'$$

This is a maximum when $h' = \frac{h}{2}$ or the expression

$$\left(1 - \frac{h'}{h}\right) h' = \frac{h}{4}$$

The maximum load in the beam equals the weight of a quarter of the height of a self-supporting wall.

$$\text{Since } h = \frac{l^2}{2f} \text{ and } h' = \frac{h}{2} \therefore h' = \frac{l^2}{4f}$$

This gives the height of the wall producing the maximum load on the girder.

Referring to the example it appears that since 20 feet is the height of a wall which would support itself, assuming that the value of the modulus of rupture is 10 ℔s. per square inch; the height of the wall producing the maximum load upon the beam is 10 feet.

It is clear that the practice of assuming that the whole height of brickwork above the girder over an opening is actually carried by the girder is incorrect; moreover the girder should be designed to carry whatever load is actually brought upon it depending on the transverse strength of the brickwork, not as a beam supported at each end and loaded uniformly along its length, but as a beam fixed at the ends, having its maximum bending moment at the points of support.

Table I.—BRICK COLUMN No. 4 C.

Built in mortar, 1 part Hemmor Cement to 4 parts of Nepean River sand, with 15% water.

Length of column = 56 inches.

Length over which the compressions were observed = 53½ inches.

Cross section = 9 inches by 9 inches = 81 square inches.

Age when tested, 4 months.

Total Load in Tons.	Readings of Dial Extensometers in Millimeters.				Remarks.
	Front.	Back.	Mean.	Difference	
2	0·22	0·20	0·21		
				0·03	
4	0·23	0·25	0·24		
				0·03	
6	0·24	0·29	0·27		
				0·02	
8	0·26	0·32	0·29		
				0·03	
10	0·28	0·35	0·32		
				0·04	compression per ton up to 10 tons 0·0145 mm.
12	0·33	0·38	0·36		
				0·03	
14	0·36	0·42	0·39		
				0·05	
16	0·42	0·45	0·44		
				0·03	
18	0·45	0·49	0·47		
				0·02	
20	0·47	0·51	0·49		compression per ton up to 20 tons 0·0162 mm.
				0·05	
22	0·52	0·55	0·54		
				0·04	
24	0·57	0·59	0·58		
				0·03	
26	0·61	0·61	0·61		
				0·04	
28	0·65	0·64	0·65		
				0·04	
30	0·70	0·68	0·69		
				0·06	
32	0·77	0·72	0·75		
				0·04	
34	0·82	0·75	0·79		
				0·04	
36	0·87	0·79	0·83		slight crack across one corner of fifth course from top.
				0·11	
38	1·03	0·84	0·94		
				0·07	
40	1·14	0·88	1·01		compression per ton up to 40 tons 0·0209 mm.
				0·04	
42	1·18	0·91	1·05		
				0·05	

Table I. (continued)—BRICK COLUMN No 4 C.

Total Load in Tons.	Readings of Dial Extensometers in Millimeters.				Remarks.
	Front.	Back.	Mean.	Difference	
44	1·25	0·95	1·10		
				0·05	
46	1·31	0·99	1·15		
				0·04	
48	1·36	1·02	1·19		
				0·05	
50	1·41	1·07	1·24		
				0·07	
52	1·48	1·13	1·31		
				0·05	
54	1·54	1·17	1·36		
				0·08	
56	1·65	1·22	1·44		
				0·06	
58	1·74	1·26	1·50		
				0·04	
60	1·77	1·30	1·54		
				0·09	
62	1·90	1·35	1·63		
				0·04	
64	1·94	1·40	1·67		
				0·03	
66	1·96	1·43	1·70		
				0·05	
68	2·02	1·47	1·75		
				0·06	
70	2·11	1·50	1·81		
				0·06	
72	2·18	1·55	1·87		
				0·04	
74	2·23	1·59	1·91		
				0·08	
76	2·33	1·64	1·99		
				0·06	
78	2·42	1·68	2·05		
				0·06	
80	2·48	1·74	2·11		
				0·05	
82	2·53	1·78	2·16		
				0·05	
84	2·60	1·82	2·21		
				0·11	
86	2·75	1·88	2·32		
				0·06	
88	2·82	1·94	2·38		column cracked.
				0·09	
90	2·91	2·02	2·47		
				00·6	
92	2·96	2·10	2·53		Dials removed. Broke at 100 tons after carrying weight for 25 min. Nearly every brick fractured.

Table II.

COMPRESSION TEST, BRICK PIER No. 10.

Mortar = 1 cement + 2 sand + 15% water.
Dimensions = 13·25 inches by 9 inches by 9 inches.
Length over which compressions were measured = 200 mm.
Age when tested = 358 days.

Load in Tons.	Readings of Mirrors with distance rods.				Readings of Mirrors without distance rods.				Compn. (A.−B.) per ton ·01 mm.	Remarks
	Front. ·02 mm.	Back. ·02 mm.	Mean ·01 mm.	Diff. A. ·01 mm.	Front. ·02 mm.	Back. ·02 mm.	Mean. ·01 mm.	Diff. B. ·01 mm.		
3·7	10·5	0	10·5		0·50	13·0	13·50			
				0·28				0·0	0·22	
5·0	10·68	0·08	10·78		0·51	12·99	13·50			Average comp. per ton = 0 00139 mm.
				0·28				0·0	0·14	
7·0	10·84	0·22	11·06		0·51	12·99	13·50			
				0·35				−0·01	0·18	
9·0	11·04	0·37	11·41		0·51	12·98	13·49			
				0·33				+0·01	0·16	
11·0	11·22	0·52	11·74		0·55	12·95	13·50			Coefficient of elasticity = 1772 tons per sq. inch
				0·30				0·0	0·15	
13·0	11·34	0·70	12·04		0·58	12·92	13·50			
				0·36				0·0	0·18	
15·0	11·51	0·89	12·40		0·58	12·92	13·50			
				0·30				−0·02	0·16	
17·0	11·69	1·01	12·70		0·58	12·90	13·48			
				0·21				0·0	0·105	
19·0	11·82	1·09	12·91		0·58	12·90	13·48			
				0·27				−0·01	0·14	
21·0	11·98	1·20	13·18		0·58	12·89	13·47			
				0·28				0·0	0·14	
23·0	12·13	1·33	13·46		0·58	12·89	13·47			
				0·32				−0·01	0·17	
25·0	12·29	1·49	13·78		0·58	12·88	13·46			
				0·31				0·00	0·155	
27·0	12·45	1·64	14·09		0·58	12·88	13·46			
				0·34				−0·01	0·18	
29·0	12·61	1·82	14·43		0·58	12·87	13·45			
				0·38				−0·03	0·21	
31·0	12·79	2·02	14·81		0 58	12·84	13·42			
				0·38				−0·01	0·195	
33·0	12·94	2·25	15·19		0·59	12·82	13·41			
				0·40				−0·01	0·205	
35·0	13·11	2·48	15·59		0·58	12·81	13·39			
				0·52				0·00	0·26	
37·0	13·29	2·82	16·11		0·58	12·81	13·39			
				0·33				+0·01	0·16	
39·0	13·43	3·01	16·44		0·60	12·80	13·40			
				0·45				−0·01	0·22	
41·0	13·62	3·27	16·89		0·59	12·80	13·39			
				0·45				−0·01	0·23	
43·0	13·81	3·53	17·34		0·59	12·79	13·38			
				0·40				0·00	0·20	
45·0	13·92	3·82	17·74		0·60	12·78	13·38			
				0·59				0·0	0·295	
47·0	14·22	4·11	18·33		0·60	12·78	13·38			
				0·50				+0·01	0·245	
49·0	14·43	4·40	18·83		0·60	12·77	13·37			

Table II.—COMPRESSION TEST, BRICK PIER No. 10—Test Repeated.

Load in Tons.	Readings of Mirrors with distance rods. Front. ·02 mm.	Back. ·02 mm.	Mean ·01 mm.	Diff. A. ·01 mm.	Readings of Mirrors without distance rods. Front. ·02 mm.	Back. ·02 mm.	Mean. ·01 mm.	Diff. B. ·01 mm.	Compn. (A.−B.) per ton ·01 mm.	Remarks
1·6	0·00	0·00	0·00		0·00	0·00	0·00			Test repeated.
				0·36				0·00	0·106	
4·0	0·26	0·10	0·36		0·02	0·03	0·00			
				0·55				+0·11	0·11	
8·0	0·62	0·29	0·91		0·04	0·07	0·11			Average comp.
				0·72				+0·06	0·17	per ton =
12·0	0·01	0·62	1·63		0·08	0·09	0·17			0·001928 mm
				0·81				0·00	0·202	
16·0	1·44	1·00	2·44		0·07	0·10	0·17			
				0·77				−0·01	0·195	
20·0	1·84	1·37	3·21		0·06	0·10	0·16			Coefficient of
				0·81				+0·02	0·20	Elasticity
24·0	2·21	1·81	4·02		0·07	0·11	0·18			= 1288 tons
				0·83				+0·02	0·202	per sq inch.
28·0	2·60	2·25	4·85		0·08	0·12	0·20			
				0·82				+0·03	0·212	
32·0	2·93	2·74	5·67		0·08	0·15	0·23			
				0·88				+0·02	0·215	
36·0	3·33	3·22	6·55		0·08	0·17	0·25			
				0·92				+0·02	0·225	
40·0	3·68	3·79	7·47		0·09	0·18	0·27			
				1·00				+0·01	0·247	
44·0	4·11	4·36	8·47		0·09	0·19	0·28			
				0·95				−0·01	0·24	
48·0	4·51	4·91	9·42		0·08	0·19	0·27			

COMPRESSION TEST, BRICK PIER No. 10 (Retested).

4	0·00	0·00	0·00		0·00	0·00	0·00			
				0·16				−0·04	0·20	
5	0·09	0·07	0·16		−0·02	−0·02	−0·04			Average comp
				0·89				−0·01	0·18	per ton =
10·0	0·61	0·44	1·05		−0·02	−0·03	−0·05			0·00223 mm.
				1·02				−0·01	0·20	
15·0	1·17	0·90	2·07		−0·02	−0·04	−0·06			
				1·06				−0·04	0·22	
20·0	1·64	1·49	3·13		−0·02	−0·08	−0·10			Coefficient of
				1·05				−0·00	0·21	Elasticity
25·0	2·18	2·00	4·18		−0·02	−0·08	−0·10			= 1105 tons
				1·07				−0·01	0·21	per sq. inch.
30·0	2·65	2·60	5·25		−0·02	−0·09	−0·11			
				1·09				−0·00	0·218	
35·0	3·05	3·29	6·34		−0·00	−0·11	−0·11			
				1·15				−0·01	0·22	
40·0	3·61	3·88	7·49		−0·01	−0·11	−0·12			
				1·21				−0·01	0·24	
45·0	4·11	4·59	8·70		−0·02	−0·13	−0·13			
				1·18				−0·03	0·242	
50·0	4·60	5·28	9·88		−0·02	−0·14	−0·16			
				1·24				−0·02	0·252	
55·0	5·02	6·10	11·12		+0·01	−0·19	−0·18			
				1·31				−0·01	0·26	
60·0	5·56	8·87	12·43		+0·01	−0·18	−0·17			

Table II.—COMPRESSION TEST, BRICK PIER No. 10 (Retested).

Age when tested = 520 days.

Load in Tons.	Readings of Mirrors with distance rods.				Readings of Mirrors without distance rods.				Compn. (A.−B.) per ton ·01 mm.	Remarks
	Front. ·02 mm.	Back. ·02 mm.	Mean ·01 mm.	Diff. A. ·01 mm.	Front. ·02 mm.	Back. ·02 mm.	Mean. ·01 mm.	Diff. B. ·01 mm.		
0	6·90	9·60	16·50		8·00	4·60	12·60			
				1·30				+0·08	0·35	
4	7·09	10·71	17·80		7·86	4·78	12·68			Average comp.
				0·51				−0·05	0·28	per ton =
6	7·22	11·09	18·31		7·86	4·77	12·63			0·00241 mm.
				0·46				+0·05	0·20	
8	7·39	11·38	18·77		7·86	4·78	12·68			
				0·43				−0·04	0·24	
10	7·60	11·60	19·20		7·89	4·75	12·64			Coefficient of
				0·42				−0·03	0·23	Elasticity
12	7·80	11·82	19·62		7·89	4·72	12·61			= 1023 tons
				0·43				0·00	0·22	per sq. inch.
14	7·96	12·09	20·05		7·90	4·71	12·61			
				0·43				−0·01	0·22	
16	8·13	12·35	20·48		7·90	4·70	12·60			
				0·51				−0·01	0·25	
18	8·41	12·58	20·99		7·89	4·70	12·59			
				0·43				−0·01	0·22	
20	8·61	12·81	21·42		7·88	4·70	12·58			
				0·48				0·00	0·24	
22	8·82	13·08	21·90		7·88	4·70	12·58			
				0·45				+0·01	0·22	
24	9·04	13·31	22·35		7·89	4·70	12·59			
				0·45				−0·03	0·24	
26	9·22	13·58	22·80		7·87	4·69	12·56			
				0·44				−0·01	0·22	
28	9·44	13·80	23·24		7·87	4·68	12·55			
				0·48				−0·01	0·24	
30	9·67	14·05	23·72		7·86	4·68	12·54			
				0·44				−0·01	0·22	
32	9·80	14·36	24·16		7·88	4·65	12·53			
				0·49				−0·02	0·25	
34	10·07	14·58	24·65		7·86	4·65	12·51			
				0·44				−0·01	0·22	
36	10·29	14·80	25·09		7·86	4·64	12·50			
				0·49				0·00	0·24	
38	10·49	15·09	25·58		7·86	4·64	12·50			
				0·44				−0·01	0·22	
40	10·69	15·33	26·02		7·87	4·62	12·49			
				0·48				+0·01	0·23	
42	10·92	15·58	26·50		7·88	4·62	12·50			
				0·46				−0·02	0·24	
44	11·14	15·82	26·96		7·87	4·61	12·48			
				0·47				0·00	0·23	
46	11·32	16·11	27·43		7·88	4·60	12·48			
				0·51				0·00	0·26	
48	11·59	16·35	27·94		7·88	4·60	12·48			
				0·51				0·00	0·25	
50	11·83	16·62	28·45		7·89	4·59	12·48			
				3·51				0·00	0·26	
52	12·03	16·93	28·96		7·90	4·58	12·48			
				0·57				−0·01	0·29	
54	12·31	17·22	29·53		7·89	4·58	12·47			
				0·52				−0·02	0·27	
56	12·55	17·50	30·05		7·89	4·56	12·45			
				0·54				−0·01	0·27	
58	12·79	17·80	30·59		7·89	4·55	12·44			
				0·53				0·00	0·27	
60	13·02	18·10	31·12		7·90	4·54	12·44			

Table III.—COMPRESSION TEST CEMENT MORTAR PIER, No. 1.
Mortar = 1 cement + 2 sand + 10% water.
Dimensions = 12 inches by 6 inches by 6 inches.
Length over which compressions ware measured = 200 mm.
Age when tested = 109 days in water.

Load in Tons.	Readings of Mirrors with distance rods.				Readings of Mirrors without distance rods.				Compn. (A – B.) per ton ·01 mm.	Remarks
	Front. ·02 mm.	Back. ·02 mm.	Mean ·01 mm.	Diff. A. ·01 mm.	Front. ·02 mm.	Back. ·02 mm.	Mean. ·01 mm.	Diff. B. ·01 mm.		
0	4·00	3·50	7·50		2·50	4·00	6·50			
				1·16				+0·03	0·565	
2	4·53	4·13	8·66		2·49	4·04	6·53			Average comp. per ton = 0·0067 mm.
				0·56				–0·01	0·57	
3	4·80	4·42	9·22		2·48	4·04	6·52			
				0·53				–0·01	0·5	
4	5·22	4·63	9·85		2·44	4·07	6·51			Coefficient of Elasticity = 832 tons per sq. inch.
				0 61				+0·01	0·60	
5	5·65	4·81	10·46		2·42	4·10	6·52			
				0·62				–0·02	0·64	
6	6·08	5·00	11·08		2·40	4·10	6·50			
				0·79				+0·01	0·73	
7	6·40	5·47	11·87		2·40	4·11	6·51			
				0·59				0·00	0·59	
8	6·81	5·65	12·46		2·40	4·11	6·51			
				0·71				–0·01	0·72	
9	7·28	5·89	13·17		2·39	4·11	6·50			
				0·80				+0·01	0·79	
10	7·52	6·27	13·97		2·40	4·11	6·51			
				1·20				+0·01	0·595	
12	8·25	6·92	15·17		2·40	4·12	6·52			
				1·51				0·00	0·755	
14	9·08	7·60	16·68		2·40	4·12	6·52			
				1·63				–0·01	0·82	
16	0·95	8·36	18·31		2·39	4·12	6·51			
				1·49				+0·06	0·715	
18	11·45	9·35	20·80		2·38	4·19	6·57			
				1·76				– 0·08	0·92	
20	12·45	10·31	22·76		2·31	4·18	6·49			
20	12·70	10·50	23·20							After standing a few minutes
				2·31						
15	11·49	9·40	20·89		2·39	4·16	6·55			
				2·88				+0 01	0·58	
10	10·15	7·86	18·01		2·40	4·16	6·56			
				3·47				– 0·02	0·69	
5	8·22	6·32	14·54		2·40	4·14	6·54			
				4·72				–0·04	0·95	
0	5·20	4·52	9·72		2·40	4·10	6·50			
					(Retested.)					
0	4·50	5·00	9·50		4·00	2·50	6·50			
				1·33				–0·01	0·67	
2	5·13	5·70	10·83		3·99	2·50	6·49			Average comp. per ton = 0·0072 mm.
				1·41				–0·01	0·70	
4	5·67	6·57	12·24		3 97	2·51	6·48			
				1·56				+0·03	0·77	
6	6·10	7·70	13·80		4·00	2·51	6·51			
				1·45				+0·01	0·72	
8	6·65	8·60	15·25		4·02	2·50	6·52			Coefficient of Elasticity = 768 tons per sq. inch.
				1·43				–0·01	0·72	
10	7·36	9·32	16·68		4·01	2·50	6·51			
				1·36				+0·01	0 69	
12	8·04	10·00	18·04		4·02	2·50	6·52			
				1·41				0·00	0·71	
14	8·74	10·71	19·45		4·02	2·50	6·52			
				1·42				+0·01	0·71	
16	9·43	11·44	20·87		4·03	2·50	6·53			
				1·57				0·00	0·79	
18	10·19	12·25	22·44		4·03	2·50	6·53			
				1·54				–0·02	0 78	
20	10·99	12·99	23·98		4 04	2·47	6·51			

Table IV.—BRICK PIERS IN CEMENT MORTAR.

No. of Test,	Description.	Age when tested in months.	Total load pr'ducing cracks in tons.	Total load pr'ducing crushing tons.	Load producing cracks tons sq. ft.	Ultimate crushing load tons per sq. ft.	Ratio of strength of pier to a single brick (295 tons sq. ft.	Remarks.
1 C.	Brick pier, 56½ in. by 9 in by 9 in.; mortar 1 cement + 2 sand + 15% water	4	88	98	156	174	52%	Fine hair-cracks occurred from bottom up to 7 courses in top side and 3 courses in back side. The load was gradually increased up to 98 tons, the cracks gradually opening until fracture occurred. All bricks except the 3 top courses were fractured.
2 C.	Brick pier, 56¼ in. by 9 in. by 9 in.; mortar 1 cement + 2 sand + 15% water	4	92	100	163	178	58%	Fine cracks which gradually extended until 100 tons was supported. After 5 minutes the column broke with a loud report—every brick was fractured.
3 C.	Brick pier, 55·6 in. by 9 in. by 9 in.; mortar 1 cement + 4 sand + 15% water	4	50	71	88	126	30%	Duration of test three-quarters of an hour.
4 C.	Brick pier, 56 in. by 9 in. by 9 in.; mortar 1 cement + 4 sand + 15% water	4	88	100	156	178	52%	Fine cracks occurred which opened out until 100 tons was supported, 25 minutes after which the column broke—every brick being fractured.
3 A.	Brick pier, 56 in. by 9 in. by 9 in.; mortar 1 cement + 2 sand + 15% water	4	100 no result	...	177	...	60%	This column was not affected in any way by 100 tons, which it carried for 14 days.
4 A.	Brick pier, 56 in. by 9 in. by 9 in.; mortar 1 cement + 2 sand + 15% water	4	100	...	177	...	60·0%	ditto
7 A.	Ditto, 1 cement + 4 sand + 15% water	4	100	...	177	...	60·0%	ditto
8 A.	Ditto ditto	16	100	...	177	...	60·0%	This column broke after carrying 100 tons for 1½ hours.
5 A.	14 in. by 9 in. column, 56¼ in. long, 4 in. eccentricity mortar 1 cement + 4 sand + 15% water	5	68	80	121	142	41·0%	Crushing force at most strained edge 248 tons, least 65 tons.
2 A.	14 in. by 9 in. column, 1 cement + 4 sand + 15% water, 4 in. eccentricity	5	70	...	...	...	...	Crushing force at most strained edge 216 tons.

Table V.—BRICK PIERS IN LIME MORTAR.

No. of Test.	Description.	Age when tested, months.	Total load pr'ducing cracks tons.	Total load pr'ducing crushing tons.	Load producing cracks tons sq.ft.	Ultimate crushing load tons per sq. ft.	Ratio of strength of pier to a single brick (295 tons sq.ft.	Remarks.
1 L.	Brick pier, 55 in. by 9 in. by 9 in.; mortar 1 lime + 2 sand + 15% water	4½	48	68	85	121	29%	The hair crack occurred which gradually opened out until 68 tons was reached, when fracture occurred, every brick breaking.
2 L.	Ditto, ditto	4½	42	68·8	75	122	25·4%	Fine cracks occurred and the column split longitudinally on all four sides—every brick fractured.
5 L.	Brick pier, 55·5 in. by 9 in. 9 in.; mortar 1 lime + 4 sand + 15% water	4½	28	50	50	89	16·9%	The column broke at 50 tons.
6 L.	Ditto, ditto	4½	24	40	43	71	14·6%	Column cracked on all four sides at 40 tons, cracks gradually widened till fracture occurred.
3 L.	Brick pier, 55 in. by 9 in. by 14 in.; mortar 1 lime + 2 sand + 15% water	4	68	83·6	96	...	32·5%	Eccentricity 4 inches.

Table VI.—CRUSHING STRENGTH OF BRICK PIERS, WATERTOWN ARSENAL, U.S.A.

BUILT OF COMMON BRICKS.

Composition of Mortar.	Weight per cubic foot, lbs.	Height in inches.	Sectional area square inches.	Ultimate Strength. Total in lbs.	Per square inch in lbs.	Per square foot in tons of 2,000 lbs.	Per cent. of single brick	Remarks.
1 Lime, 3 sand	135·6	16·48	60·80	148,800	2,440	175·6	13·3	
ditto	133·6	80 05	62·40	96,100	1,540	110·8	8·4	
ditto	...	23 90	138 06	296,400	2,150	154·8	11·7	
ditto	...	24·30	119·58	244,600	2,050	147·6	11·2	has hollow centre 4·5 by 4·5 in.
ditto	131·5	117·6	138 06	154,300	1,118	8·5	6·1	
ditto	136·0	120·4	115·50	183,300	1,587	114·3	8·6	
1 Portland cement, 2 sand	131·0	120·0	138 06	276,600	2,003	144·2	10·9	has hollow centre 4·75 by 4·75 in.
ditto	...	31·85	256 00	696,000	2.720	195·8	14·8	
ditto	...	121·00	256 00	483,100	1,887	135·8	10·3	
			BUILT	OF BAY	STATE	BRICKS.		
1 Lime, 3 sand	...	24·10	146·41	201,000	1,370	98·6	12·0	
ditto	...	72·50	144·00	163,200	1,133	81·6	9·9	
ditto	119·7	73·00	144·00	174,300	1,210	87·1	10·6	

Table VII.—CRUSHING STRENGTH OF BRICK PIERS, WATERTOWN ARSENAL, U.S.A.

Built of Face Bricks.

Composition of Mortar.	Weight per cubic foot lbs.	Height in inches.	Sectional area square inches.	Ultimate Strength. Total lbs.	Ultimate Strength. Per square inch lbs.	Ultimate Strength. Per square foot in tons of 2,000 lbs.	Ultimate Strength. Per cent. of single brick.	Remarks.
1 Lime, 3 sand	137·4	16·13	57·00	143,600	2,520	181·4	18·1	
ditto	133·5	80·00	57·76	108,400	1,877	135·1	13·5	
1 Portland cement, 2 sand	136·3	16·24	57·76	218,100	3,766	271·8	27·1	
ditto	133·5	80·00	57·76	129,900	2,249	161·9	16·2	
1 Lime, 3 sand	...	23·05	132·25	257,100	1,940	139·7	13·9	
ditto	...	23·04	113·76	226,100	1,900	143·3	14·3	has hollow centre 4·25 by 4·25 in.
ditto	131·7	119·90	132·25	199,800	1,511	108·9	10·9	
ditto	125·0	119·13	115·44	208,600	1,807	130·1	13·0	has hollow centre 4·1 by 4·1 in.
1 Portland cement, 2 sand	...	23·50	132·25	486,000	3,670	264·2	26·4	
ditto	132·2	119·30	132·25	298,000	2,253	162·2	16·2	
			Built	of Face	Bricks.			
1 Lime, 3 sand	118·2	72·25	144·00	191,600	1,331	95·8	11·1	joints broken every six courses bricks laid on edge
ditto	118·1	73·00	156·25	189,200	1,211	87·2	10·6	
ditto	120·3	90·25	144·00	169,100	1,174	84·6	10·3	
ditto	118·0	119·60	144·00	133,100	924	66·6	8·1	
ditto	107·0	120·75	96·00	90,200	940	67·7	8·2	
ditto	118·7	120·50	192·00	148,500	773	55·7	6·8	
2 lime mortar (1 l. + 3 s.) 1 Rosendale cement	120·6	73·63	144·00	237,000	1,646	118·5	14·4	
1 Rosendale cement, 2 s'nd	123·0	72·13	144·00	284,000	1,972	142·0	17·3	
2 lime mortar (1 l. + 3 s.) 1 Portland cement	120·3	73·38	144·00	203,200	1,411	101·6	12·4	
1 Portland cement, 2 sand	119·7	72·60	144·00	258,000	1,792	129·0	15·7	
Clear Portland cement	126·6	72·00	144·00	342,000	2,375	171·0	20·8	

Table VIII.—RESULTS OF TESTS BY ROYAL INSTITUTE OF BRITISH ARCHITECTS.

Piers 6 feet high by 18 inches square, (approx). Mortar 1 grey lime and 2 sand.

Kind of Brick.	Age when tested weeks.	Total load in tons.	Crushing strength of pier in tons per sq. foot.	Commencement of failure tons per sq. foot.	Compression at or about fracture in 32nds inch.	Compression at commencement of failure in 32nds in.	Crushing strength of brick in tons per sq. foot.	Ratio of strength of pier to brick percent.	Remarks.
London Stocks from Sittingbourne	18·3	23·34	10·41	4·18	...	...	84·27	12·4	The strength of the mortar used in
	$12\frac{6}{7}$	41·99	18·28	7·01	13	2		21·7	piers was not tested, but the lime
	$43\frac{4}{7}$	32 53	14·11	9·14	12	4		16·7	mixed with 2 vols. of standard sand
	$43\frac{4}{7}$	25 56	10·97	5·84	11	5		13·0	obtained from Leighton Buzzard gave at—
Gault bricks from Burnham, Kent	18·3	51·18	21·82	5·00	...	...	182·20	12·0	4 weeks 6·08 tons per square foot.
	18·8	50·25	22·03	6·16	14	...		12·1	12 „ 8·73 „
	$43\frac{4}{7}$	51·95	22·93	8·64	29	16		12·6	24 „ 15·72 „
	$43\frac{4}{7}$	36·02	16·23	9·50	22	11		8·9	34 „ 28·19 „
Leicester Red from Elliston, near Leicester	19·1	68·81	22·93	15·20	18	...	382·10	6·0	Specimens tested were prepared in
	18·6	72·28	31·55	16·11	32	...		8·2	cubes 3 inch sides. The mortar used
	$43\frac{6}{7}$	71·37	31·29	15·79	30	10		8·2	in piers was about half as strong as
	$43\frac{6}{7}$	50·96	22·18	11·34	20	5		5·8	that with standard sand.
Blue Bricks from Rowley Regis, wire cut, no frogs	18·6	157·90	69·22	22·43	42	...	701·10	9·8	
	19·4	181·10	79·39	21·42	32	...		11·3	
	$43\frac{6}{7}$	168·98	75·56	15·86	39	4		11·4	
	$44\frac{3}{7}$	145·58	62·08	18·97	38	10		8.8	

Table IX.—RESULTS OF TESTS BY ROYAL INSTITUTE OF BRITISH ARCHITECTS

Piers 6 feet high by 18 inches square (approximate). Mortar 1 volume Portland cement and 4 volumes sand.

Kind of Brick.	Age when tested in weeks.	Total load in tons.	Crushing strength in tons per square foot.	Commencement of failure tons per sq. foot.	Compression of pier at or about fracture in inches.	Compression at commencement of failure in inches.	Mean crushing strength of brick in tons per square foot.	Ratio of strength of pier to strength of brick percent.	Remarks.
London Stocks from Sittingbourne with frogs	21·0	36·33	16·03	7·22	0·25	...	84·27	19·0	The compressive strength of 3 inch cubes of the mortar used in building the piers was 29 tons per square foot at 24 weeks. The cement tested with Leighton Buzzard sand gave at—
	21·0	34·01	13·83	5·72	0·32			16·3	
	45·8	50·96	22·34	5·52	0·40	0·100		26·5	
	45 8	39·50	16·95	8·19	...	0·125		20·0	
Gault bricks from Burnham, Kent, without frogs	12·7	108·23	48·10	10·47	0·43	0·250	182·20	26·4	4 weeks 31·45 tons per square foot
	12·7	115·70	51·05	21·39	0·37	0·180		28·0	13·7 ,, 48·52 ,,
	21·0	42 16	18·07	6 98	0·25	0·070		1·0	24·0 ,, 56·15 ,,
	20·5	40·50	17·51	7·08	0·28	0·100		0·9	36·0 ,, 58·62 ,,
	45·8	60·92	26·23	18 37	0 31	0·150		14·3	
	46·8	78·35	33 64	21·88	0·31	0·218		18·5	
Red bricks from Elliston, Leicester without frogs	12·4	194·38	86·39	25·97	...	0 218	382·1	22 5	
	22·7	157·90	67·36	17·81	0·250	0·060		17·6	
	21·7	116·14	49·54	21·82	0·375	...		13 0	
	45·8	110·72	47·86	26·33	0·310	0·218		12·5	
	45·8	122 17	53·00	17·78	0·470	0·270		14·0	
Blue bricks from Rowley Regis, wire cut, no frogs	12 6	245·18	108·25	32·37	0·400	0 094	701·1	15·4	
	12·8	220·28	97·90	35·92	0·340	0 180		14 0	
	*21·7	106·86	84·47	29·45	0·750	...		12·0	* These piers were built 13½ inches square.
	22·7	134·70	61·14	16 91	0·690	...		8·7	
	*46·8	116·69	91·80	36·56	0·290	0·090		13·0	
	46·8	166·99	73·17	37·16	0·250	0·125		10 5	

Table X.—TRANSVERSE TESTS OF BRICK BEAMS.

Lime Mortar.

No. of Beam.	Dimensions of Beam. Inches. Length.	Breadth.	Depth.	Span Inches	Weight of Beam Pounds. Total.	Per cub. ft	Proport'n of sand to one part lime or cement & 15 percent water.	Age when tested in days.	Total breaking load applied at centre, lbs.	Modulus of rupture. Lbs. per sq. in	Approximate coefficient of elasticity. Lbs. per sq. in	Max. intensity of horizontal shearing stress along the most strained joint. Lbs. per sq. in.	Remarks.
9	37	14	20·1	30	751	124·5	2	347	4,108	31·4	no deflection measured.	10·9	Beams failed by horizontal shearing along the mortar joints.
10	37	14	16·5	30	626	127·7	4	358	1,822	24·3	,,	6·3	
11	36·75	13·75	10	30	368	126	2	350	540	17·7	,,	2·6	
12	36·75	14	9	30	322	121	4	350	347	13·7	,,	1·8	
									Cement	Mortar.			
13	37	14	19·75	30	764·5	129	2	180	33,462	276	23,108	92·0	Beams failed by rupture of bricks on tension side.
14	37·25	14	9·5	30	388	135	2	177	11,357	405	180,000	58·0	
15	37	14	20	30	762	127	4	180	20,470	164	19,285	55·0	Beams failed by horizontal shearing along the mortar joints. The bricks were broken on the tension side of No. 16.
16	37·25	14	9·5	30	379	133	4	174	6,870	244	157,457	35·0	
17	14	13·5	9	12	...	...	2	384	53,760	886	no deflection measured.	289	Beams failed by rupture of bricks on tension side.
18	14	13·5	9	8	...	...	4	384	44,800	492	,,	243	

Table XI.—TRANSVERSE TESTS OF BRICK BEAMS BUILT IN CEMENT MORTAR.

Beam No. 13.

Load applied in centre pounds.	Deflection in inches per 2240 lbs.
2,550	
	0·0060
4,790	
	0·0065
7,030	
	0·0070
9,270	
	0·0060
11,510	
	0·0070
13,750	
	0·0030
15,990	
	0·0025
18,230	
	0·0035
20,470	
	0·0035
22,710	
	0·0030
24,950	
	0·0040
27,190	
	0·0020
29,430	
	0·0050
31,670	
	0·0025
33,462	

Beam No. 15.

Load applied in centre pounds.	Deflection in inches per 2240 lbs.
2,550	
	0·0070
4,790	
	0·0075
7,030	
	0·0065
9,270	
	0·0050
11,510	
	0·0049
13,750	
	0·0040
15,990	
	0·0035
18,230	
20,470	

Beam No. 14.

Load applied in centre pounds.	Deflection in inches per 1120 lbs.
3,517	
	0 0035
4,637	
	0·0035
5,757	
	0·0055
6,877	
	0·0050
7,997	
	0·0030
9,117	
	0·0020
10,237	
	0·0050
11,357	

Beam No. 16.

Load applied in centre pounds.	Deflection in inches per 1120 lbs.
1,270	
	0·0040
2,390	
	0·0040
3,510	
	0·0065
4,630	
	0 0035
4,780	
	0·0025
6.870	

In computing the coefficients of elasticity as shown in the preceding table, the deflections for the smaller loads only were used. The results are of course only roughly approximate.

Table XII.—TRANSVERSE TESTS OF CEMENT AND LIME MORTARS.

Cement Mortar.

No.	Composition of Mortar.	Section in inches.	Span inches.	Load in lbs. mean of 6 tests.	Age in months.
A	1 cement + 2 Nepean River sand + 15% water	2 × 2	10	263	4
B	1 cement + 4 sand + 15% water	2 × 2	10	153	4
	Lime Mortar.				
C	1 stone lime + 2 Nepean River sand + 15% water	2 × 2	10	18·4	4
D	1 lime + 4 sand + 15% water ...	2 × 2	10	12·7	4

TRANSVERSE STRENGTH OF BRICKS.

Bricks 4½ inches wide, 3 inches deep, 7½ inches centres. Mean breaking load 3,462 lbs. Modulus of rupture, 962 lbs. per square inch.

Table XIII.—COMPRESSIVE STRENGTH OF CEMENT AND LIME MORTARS USED IN PIERS.

Cement Mortar.

No.	Composition of Mortar.	Size in inches.	Area exposed to crushing. sq. in.	Final crushing load lbs. mean of 3 tests,	Compressive strength lbs. per sq. in	Age in months.
A	1 cement + 2 Nepean River sand + 15 per cent. water	6×6×9	36	63,516	1,764	4
		6×6×6	36	84,116	2,336	4
	ditto	6×6×4	36	92,400	2,566	4
	ditto	6×6×2	36	*100,000	over 2777	4
	ditto	6×6×1	36	†224,000	6,222	4
	ditto	6×6×½	36	‡224,000	over 6222	4
B	1 cement + 4 Nepean River sand + 15 per cent. water	6×6×9	36	35,866	996	4
		6×6×6	36	57,816	1,606	4
	ditto	6×6×4	36	64,766	1,799	4
	ditto	6×6×2	36	95,066	2,630	4
	ditto	6×6×1	36	181,776	5,049	4
	ditto	6×6×½	36	206,304	5,730	4
	Lime Mortar.			mean, 2 tests		
C	1 stone lime + 2 Nepean River sand + 15 per cent. water	6×6×12	36	1,075	28	4
		6×6×9	36	1,445	40	4
	ditto	6×6×6	36	1,860	61	4
	ditto	6×6×4	36	2,740	76	4
	ditto	6×6×2	36	7,725	214	4
	ditto	6×6×1	36	8,712	242	4
	ditto	6×6×½	36	20,250	562	4
D	1 stone lime + 4 Nepean River sand + 15 per cent. water	6×6×12	36	305	8·4	4
		6×6×9	36	510	14	4
	ditto	6×6×6	36	1,642	47	4
	ditto	6×6×4	36	2,137	59	4
	ditto	6×6×2	36	7,175	199	4
	ditto	6×6×1	36	8,325	231	4
	ditto	6×6×½	36	16,408	455	4

* Without breaking. † Cracked on edges. ‡ Slight cracks on edge.

Table XIV.—TENSILE TESTS OF CEMENT AND LIME MORTARS USED IN PIERS.

Cement Mortar.

No.	Composition of Mortar.	Section in inches.	Area. sq. inches	Load in lbs. mean of 6 tests.	Tensile strength. lbs. per sq. in	Age in months.
A	1 cement + 2 Nepean River sand + 15% water	1·5 × 1·5	2·25	722	320	4
B	1 cement + 4 sand + 15% water	1·5 × 1·5	2·25	409	181	4
	Lime Mortar					
C	1 stone lime + 2 Nepean River sand + 15% water	1 5 × 1·5	2·25	84	37·4	4
D	1 lime + 4 sand + 15% water	1·5 × 1·5	2·25	46	20·4	4

Table XV.—SUMMARY OF SHEARING TESTS OF MORTAR AND BRICKS USED IN THE TESTS OF BRICKS, PIERS, AND BEAMS.

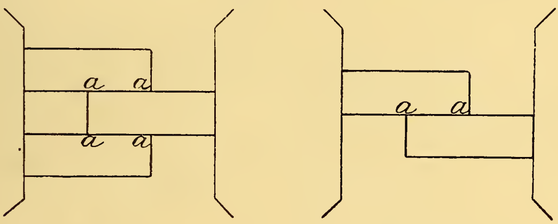


Fig. 10. Fig. 11.

Description of Materials.	Average shearing strength on planes a a Lbs. per square inch.	Age in days.
1 Hemmoor cement 2 Nepean River sand ...	192·2	122
1 ditto 4 ditto ...	58·75	122
1 Stone lime 2 ditto ...	21·46	129
1 ditto 4 ditto ...	20·7	129

Table XVI.—ADHESION TESTS OF BRIQUETTES WITH DISCS OF BRICK IN THE CENTRE.

Description of Materials.	Mean of 2 highest. Lbs. per square inch	Age in days.
1 Cement 2 Nepean River sand 15 per cent. water	49·3	122
1 ditto 4 ditto ditto	40·4	122
1 Stone lime 2 ditto ditto	18·2	122
1 ditto 4 ditto ditto	9·8	122

Table XVII.—SUMMARY OF RESULTS OBTAINED IN 1878 OF SHEARING TESTS WITH PRESSED BRICKS IN CEMENT MORTAR (Castle Brand Cement).

Description of Materials.	Average shearing strength in lbs. per sq. inch after 7 days on planes a.a. (figs. 10, 11)	Average shearing strength in lbs. per sq. inch after 28 days on planes a.a. (figs. 10, 11)
Neat cement	168	213
Crushed sandstone and cement, 1 to 1	117	146
ditto 2 to 1	53	73
ditto 3 to 1	26	48
ditto 4 to 1	16	45
Bluestone dust and cement ...1 to 1	79	136
ditto ...2 to 1	47	84
ditto ...3 to 1	34	45
ditto ...4 to 1	23	41
Nepean River sand and cement, 1 to 1	102	105
ditto 2 to 1	38	45
ditto 3 to 1	20	24
ditto 4 to 1	9	14

INDEX.

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EXCHANGES AND PRESENTATIONS

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344 Annapolis (Md.) *Naval Academy.
345 Baltimore ...*Maryland Geological Survey.
346 ,, ...*Johns Hopkins University.
347 Beloit (Wis.) ...*Chief Geologist.
348 Berkeley ...*University of California.
349 Boston ... ...*American Academy of Arts and Sciences.
350 ,, ...*Boston Society of Natural History.
351 ,, ... State Library of Massachusetts.
352 Brookville (Ind.)*Brookville Society of Natural History.
353 ,, ...*Indiana Academy of Science.
354 Buffalo (Ind.) ...*Buffalo Society of Natural Sciences.
355 Cambridge (Mass.)*Cambridge Entomological Club.
356 ,, ...*Museum of Comparative Zoology at Harvard College.
357 Cheyenne, Wyo...*Experiment Station, Department of Agriculture.
358 Chicago ... ...*Academy of Sciences.
359 ,, ... American Medical Association—The Newberry Library.
360 ,, ...*Field Columbian Museum.
361 ,, ...*University of Chicago Press.
362 ,, ...*Western Society of Engineers.
363 Cincinnati ...*American Association for the Advancement of Science.
364 ,, ...*Cincinnati Society of Natural History.
365 Cleveland, O. ...*Geological Society of America.
366 Coldwater ... Michigan Library Association.
367 Davenport (Iowa)*Academy of Natural Sciences.
368 Denver ... ...*Colorado Scientific Society.
369 Easton, Pa. ...*American Chemical Society.
370 Fort Monroe (Va.)*United States Artillery School.
371 Hoboken (N.J.) ...*Steven's Institute of Technology.
372 Iowa City (Iowa) *Director Iowa Weather Service.
373 Jefferson City...*Geological Survey of Missouri.
374 Madison (Wis.)...*Wisconsin Academy of Sciences, Arts and Letters.
375 Minneapolis ...*Minnesota Academy of Natural Sciences.
376 Newhaven (Conn) *Connecticut Academy of Arts and Sciences.
377 New York ...*American Geographical Society.
378 ,, ...*American Institute of Mining Engineers.
379 ,, ...*American Museum of Natural History.
380 ,, ...*American Society of Civil Engineers.
381 ,, ...*Editor *Journal of Comparative Medicine and Veterinary Archives.*
382 ,, ...*New York Academy of Sciences.
383 ,, ...*New York Microscopical Society.
384 ,, ...*School of Mines, Columbia University.
385 Palo Alto (Cal.)...*Geological Survey of Arkansas.
386 Philadelphia ...*Academy of Natural Science.
387 ,, ...*American Entomological Society.
388 ,, ...*American Philosophical Society.
389 ,, ...*Franklin Institute.
390 ,, ...*Geological Survey of Pennsylvania.
391 ,, ...*Philadelphia Commercial Museum.
392 ,, ...*University of Pennsylvania.
393 ,, ...*Wagner Free Institute of Science.
394 ,, ...*Zoological Society of Philadelphia.
395 Salem (Mass.) ...*Essex Institute.
396 St. Louis ... ...*Academy of Science.
397 ,, ...*Missouri Botanical Garden.

398 San Francisco ...*California Academy of Sciences.
399 ,, ...*California State Mining Bureau.
400 Scranton (Pa.) ...*The Colliery Engineer Co.
401 Urbana ... ...*Illinois State Laboratory of Natural History.
402 Washington ...*Bureau of Education (Department of the Interior).
403 ,, .. *Bureau of Ethnology.
404 ,, ...*Chief of Engineers (War Department).
405 ,, ...*Chief of Ordnance (War Department).
406 ,, ...*Department of Agriculture, Library.
407 ,, ...*Department of Agriculture, Weather Bureau.
408 ,, ...*Director of the Mint (Treasury Department).
409 ,, ...*Library (Navy Department).
410 ,, ...*National Academy of Sciences.
411 ,, ...*Office of Indian Affairs (Department of the Interior).
412 ,, ...*Philosophical Society.
413 ,, ...*Secretary (Department of the Interior).
414 ,, ...*Secretary (Treasury Department).
415 ,, ...*Smithsonian Institution.
416 ,, ...*Surgeon General (U.S. Army).
417 ,, ...*U. S. Coast and Geodetic Survey (Treasury Department).
418 ,, ...*U.S. Geological Survey.
419 ,, ...*U. S. National Museum (Department of the Interior).
420 ,, ... U.S. Patent Office.
421 ,, ...*War Department.

SUMMARY.

Asia, Africa, South America, &c.	13
Australasia	59
Editors of Periodicals	5
Europe (excepting United Kingdom)	162
India, Canada, and other Colonies	17
United Kingdom	87
Unite States of America	78
Total	421

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G. H. KNIBBS }

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CONTENTS.

VOLUME XXXIV.

CONTENTS.