

BIBLIOGRAPHY

- Abraham, S., Chaikoff, I.L. and Hassid, W.Z. (1952).
J. Biol. Chem. 195, 567.
- Alexander, D.P., Britton, H.G. and Nixon, D.A. (1966).
J. Physiol., Lond. 185, 382.
- Annison, E.F. (1954). Biochem. J. 57, 400.
- Annison, E.F. (1960). Aust. J. Agric. Sci. 11, 58.
- Annison, E.F. (1965). In 'Physiology of Digestion in the Ruminant' p. 185 [R.W. Dougherty, editor]. Washington, D.C. : Butterworths.
- Annison, E.F., Brown, R.E., Leng, R.A., Lindsay, D.B. and West, C.E. (1967). Biochem. J. 104, 135.
- Annison, E.F., Hill, K.J. and Lewis, D. (1957). Biochem. J. 66, 592.
- Annison, E.F., Leng, R.A., Lindsay, D.B. and White, R.R. (1963a). Biochem. J. 88, 248.
- Annison, E.F. and Lindsay, D.B. (1961). Biochem. J. 78, 777.
- Annison, E.F., Lindsay, D.B. and White, R.R. (1963b). Biochem. J. 88, 243.
- Annison, E.F. and Linzell, J.L. (1964). J. Physiol., Lond. 175, 372.
- Annison, E.F., Linzell, J.L. and West, C.E. (1968). J. Physiol., Lond. 197, 445.
- Annison, E.F. and Pennington, R.J. (1954). Biochem. J. 57, 685.
- Annison, E.F., Scott, T.W. and Waites, G.M.H. (1963). Biochem. J. 88, 482.
- Annison, E.F. and White, R.R. (1961). Biochem. J. 80, 162.
- Annison, E.F. and White, R.R. (1962). Biochem. J. 84, 546.
- Armstrong, D.G. and Beever, D.E. (1969). Proc. Nutr. Soc. 28, 121.
- Ashmore, J., Stricker, F., Lové, W.C. and Kilsheimer, G. (1961). Endocrinology 68, 599.

- Ash, R.W., Pennington, R.J. and Reid, R.S. (1964).
Biochem. J. 90, 353.
- Badawy, A.M., Campbell, R.M., Cuthbertson, D.P. and MacKie, W.S. (1958). Br. J. Nutr. 12, 384.
- Baile, C.A. and Mayer, J. (1970). In 'Physiology of Digestion and Metabolism in the Ruminant' p. 254 [A.T. Phillipson, editor]. Newcastle-upon-Tyne: Oriel Press Ltd.
- Baile, C.A., Mayer, J., Mahoney, A.W. and McLaughlin, C. (1969). J. Dairy Sci. 52, 101.
- Baird, G.C. and Heitzman, R.J. (1970). Biochem. J. 116, 865.
- Baird, G.D., Hibbitt, K.G., Hunter, G.D., Lund, P., Stubbs, M. and Krebs, H.A. (1968). Biochem. J. 107, 683.
- Baker, N. (1969). J. Lipid Res. 10, 1.
- Baker, N. and Huebotter, R. (1964). Am. J. Physiol. 207, 1155.
- Baker, N., Huebotter, R. and Schotz, M.C. (1965). Analyt. Biochem. 10, 227.
- Baker, N. and Rostami, H. (1969). J. Lipid Res. 10, 83.
- Baker, N., Shipley, R.A., Clark, R.E. and Incefy, G.E. (1959). Am. J. Physiol. 196, 245.
- Balch, D.A. and Rowland, S.J. (1967). Br. J. Nutr. 11, 288.
- Baldwin, R.L. and Ronning, M. (1966). J. Dairy Sci. 49, 688.
- Baldwin, R.L., Ronning, M., Radanovics, C. and Plange, G. (1966). J. Nutr. 90, 47.
- Balch, C.C. and Campling, R.C. (1962). Nutr. Abstr. Rev. 32, 669.
- Ballard, F.J. (1965). Comp. Biochem. Physiol. 14, 437.
- Ballard, F.J., Filsell, O.H. and Jarrett, I.G. (1972). Biochem. J. 126, 193.

- Ballard, F.J., Hanson, R.W. and Kronfeld, D.S. (1969).
Fed. Proc. Amer. Soc. Exp. Biol. 28, 218.
- Ballard, F.J., Hanson, R.W., Kronfeld, D.S. and Raggi, F. (1968).
J. Nutr. 95, 160.
- Ballard, F.J. and Oliver, I.T. (1964). Biochem. J. 92, 131.
- Barker, J.N. and Britton, H.G. (1957).
J. Physiol., Lond. 138, 3P.
- Bartley, J.C. and Black, A.L. (1966). J. Nutr. 89, 317.
- Bartley, J.C., Freedland, R.A. and Black, A.L. (1966).
Am. J. Vet. Res. 27, 1243.
- Bartos, S., Skarda, J. and Base, J. (1970).
Endocrinol. Exper. 4, 151.
- Bassett, J.M. (1971). Aust. J. Biol. Sci. 24, 311.
- Bassett, J.M. and Hinks, N.T. (1969). J. Endocrinol. 44, 387.
- Bassett, J.M., Mills, S.C. and Reid, R.L. (1966).
Metabolism 15, 922.
- Bassett, J.M. and Wallace, A.L.C. (1966). Metabolism 15, 933.
- Bassett, J.M., Weston, R.H. and Hogan, J.P. (1971).
Aust. J. Biol. Sci. 24, 321.
- Bath, I.H. and Hill, K.J. (1967). J. Agric. Sci. Camb. 18, 139.
- Bauman, D.E., Davis, C.L. and Bucholtz, H.F. (1971).
J. Dairy Sci. 54, 1282.
- Baxter, C.F., Kleiber, M. and Black, A.L. (1955).
Biochem. Biophys. Acta 17, 354.
- Beever, D.E., Coehlo Da Silva, J.F. and Armstrong, D.G. (1970).
Proc. Nutr. Soc. 29, 43A.

- Bell, E.L. and Garcia, R. (1965). Publication No. SAM-TR-65-59
U.S.A.F. School of Aerospace Medicine, Aerospace
Medical Division, Brooks Air Force Base, Texas,
U.S.A.
- Ben Abdeljlil, A. and Desnuelle, P. (1964).
Biochim. Biophys. Acta 81, 136.
- Bensadoun, A., Paladines, O.L. and Reid, J.T. (1962).
J. Dairy Sci. 45, 1203.
- Bergen, W.G., Purser, D.B. and Cline, J.H. (1968).
J. Anim. Sci. 27, 1497.
- Bergman, E.N. (1963). Am. J. Physiol. 204, 147.
- Bergman, E.N. (1964). Nature, Lond. 202, 1333.
- Bergman, E.N. (1968). Am. J. Physiol. 215, 865.
- Bergman, E.N. and Hogue, D.E. (1967).
Am. J. Physiol. 213, 1378.
- Bergman, E.N., Katz, M. and Kaufman, C.F. (1970).
Am. J. Physiol. 219, 785.
- Bergman, E.N., Reid, R.S., Murray, M.G., Brockway, J.M. and
Whitelaw, F.G. (1965). Biochem. J. 97, 53.
- Bergman, E.N., Roe, W.E. and Kon, K. (1966).
Am. J. Physiol. 211, 793.
- Bergman, E.N., Starr, D.J. and Reulein, S.S. (1968).
Am. J. Physiol. 215, 874.
- Bergman, E.N. and Wolff, J.E. (1971). Am. J. Physiol. 221, 586.
- Berman, M. (1963). Ann. N.Y. Acad. Sci. 108, 182.
- Berman, M. and Schoenfeld, R. (1956). J. Appl. Physiol. 27, 1361.
- Bittar, E.E. (1964). 'Cell pH.' Washington: Butterworths.

- Black, A.L. (1970). In 'Physiology of Digestion and Metabolism in the Ruminant' p. 452 [A.T. Phillipson, editor] Newcastle upon Tyne: Oriel Press Ltd.
- Black, A.L. and Anand, R.S. (1966). Fed. Proc. Fed. Am. Soc. Exp. Biol. 25, 543.
- Black, A.L., Baker, N.F., Bartley, J.C., Chapman, T.E. and Phillips, R.W. (1964). Science 144, 876.
- Black, A.L., Egan, A.R., Anand, R.S. and Chapman, T.E. (1968). 'Isotope Studies on the Nitrogen Chain' p. 247. Vienna: I.A.E.A.
- Black, A.L. and Kleiber, M. (1958). J. Biol. Chem. 232, 203.
- Black, A.L., Kleiber, M. and Brown, A.M. (1961). J. Biol. Chem. 236, 2399.
- Black, A.L., Luick, J., Moller, F. and Anand, R.S. (1966). J. Biol. Chem. 241, 5233.
- Blaxter, K.L. and Martin, A.K. (1962). Br. J. Nutr. 16, 397.
- Bloom, B. (1962). Analyt. Biochem. 3, 85.
- Bloom, B. and Foster, D.W. (1964). J. Biol. Chem. 239, 967.
- Boda, J.M. (1964). Am. J. Physiol. 206, 419.
- Bray, G.A. (1960). Analyt. Biochem. 1, 279.
- Bremer, J. (1969). Eur. J. Biochem. 8, 535.
- Briggs, P.K., Hogan, J.P. and Reid, R.L. (1957). Aust. J. Agric. Res. 8, 674.
- Brownell, G.L., Berman, M. and Robertson, J.S. (1968). Intern. J. Appl. Radiation Isotopes 19, 249.
- Bucko, A., Kopec, Z. and Babala, J. (1969). Nutr. Dieta 11, 127.
- Bush, E. (1963). Analyt. Chem. 35, 1024.

- Butler, T.M. and Elliot, J.M. (1970). J. Dairy Sci. 53, 1727.
- Cahill, G.F., Ashmore, J., Renold, A.E. and Hasting, A.B. (1959). Am. J. Med. 26, 264.
- Cahill, G.F. and Owen, O.E. (1967). In 'Carbohydrate Metabolism and its Disorders' p. 497 [F. Dickens, P.J. Randle and W.J. Whelan, editors]. New York: Academic Press.
- Carr, S.B. and Jacobson, D.R. (1969). J. Dairy Sci. 51, 721.
- Clare, N.T. and Stevenson, A.E. (1964). N.Z. J. Agric. Res. 1, 198.
- Clark, R. and Quin, J.I. (1947-9). Onderstepoort J. Vet. Sci. 22, 345.
- Clarke, E.M., Ellinger, G.M. and Phillipson, A.T. (1966). Proc. R. Soc. B. 166, 63.
- Clary, J.J., Mitchell, G.E. Jr, Little, C.O. and Bradley, N. (1969). Can. J. Physiol. Pharmacol. 47, 161.
- Cocimano, M.R. and Leng, R.A. (1967). Br. J. Nutr. 21, 353.
- Cook, R.M., Liu, S.C. and Quraishi, S. (1969). Biochemistry 8, 2966.
- Cook, R.M. and Miller, L.D. (1965). J. Dairy Sci. 48, 1339.
- Cooper, T.G., Tchen, T.T., Wood, H.G. and Benedict, C.R. (1968). J. Biol. Chem. 243, 3857.
- Corbett, J.L., Farrell, D.J., Leng, R.A., McClymont, G.L. and Young, B.A. (1971). Br. J. Nutr. 26, 277.
- Cori, C.F. and Cori, G.T. (1928). J. Biol. Chem. 79, 309.
- Cowan, J.S., Vranic, M. and Wrenshall, G.A. (1969). Metabolism 18, 319.
- Crockford, P.N., Porte, D., Wood, F.C. and Williams, R.H. (1966). Metabolism 15, 114.

- Davis, C.L. (1967). J. Dairy Sci. 50, 1621.
- Davis, C.L., Brown, R.E. and Staubus, J.R. (1960). J. Dairy Sci. 43, 1783.
- De Freitas, A.S.W. and Depocas, F. (1970). Can. J. Physiol. Pharmacol. 48, 561.
- Depocas, F. (1964). Am. J. Physiol. 206, 113.
- Depocas, F. and De Freitas, A.S.W. (1970). Can. J. Physiol. Pharmacol. 48, 557.
- Depocas, F., Minaire, Y. and Chatonnet, J. (1969). Can. J. Physiol. Pharmacol. 47, 603.
- Doetsch, R.N., Robinson, R.G., Brown, R.E. and Shaw, J.C. (1953). J. Dairy Sci. 36, 825.
- Dougherty, R.W. (1955). Cornell Vet. 45, 331.
- Downes, A.M. and McDonald, I.W. (1964). Br. J. Nutr. 18, 153.
- Duncan, D.B. (1955). Biometrics 11, 1.
- Dunn, A., Chenoweth, M. and Hemington, J.G. (1971). Biochem. Biophys. Acta 237, 192.
- Dunn, A., Chenoweth, M. and Schaeffer, L.D. (1967). Biochemistry 6, 6.
- Dunn, A., Chenoweth, M. and Schaeffer, L.D. (1968). Biochem. Biophys. Acta 165, 170.
- Dunn, A., Chenoweth, M. and Schaeffer, L.D. (1969). Biochim. Biophys. Acta 177, 11.
- Dunn, T.G., Hopwood, M.L., House, W.A. and Faulkner, L.C. (1972). Am. J. Physiol. 222, 468.
- Dunn, A. and Strahs, S. (1965). Nature, Lond. 205, 705.
- Egan, A.R. and Black, A.L. (1968). J. Nutr. 96, 450.

- Egan, A.R., Moller, F. and Black, A.L. (1970).
J. Nutr. 100, 419.
- Elsden, S.R., Gilchrist, F.M.C., Lewis, D. and Volcani, B.E.
(1951). Biochem. J. 49, IXIX.
- El-Shazly, K. (1952a). Biochem. J. 51, 640.
- El-Shazly, K. (1952b). Biochem. J. 51, 647.
- El-Shazly, K. and Hungate, R.E. (1965). Appl. Microbiol. 13, 62.
- Engelhardt, W.V. (1970). In 'Physiology of Digestion and Metabolism in the Ruminant' p. 132 [A.T. Phillipson, editor]. England : Oriel Press Ltd.
- Esdale, W.J., Broderick, G.A. and Satter, L.D. (1968).
J. Dairy Sci. 51, 1823.
- Exton, J.H., Corbin, J.D. and Park, C.R. (1969).
J. Biol. Chem. 244, 4095.
- Exton, J.H., Mallette, L.E., Jefferson, L.S., Wong, E.H.A., Friedmann, N., Miller, T.B. and Park, C.R. (1970). Recent Progr. Hormone Res. 26, 411.
- Exton, J.H. and Park, C.R. (1967). J. Biol. Chem. 242, 2622.
- Exton, J.H. and Park, C.R. (1968). J. Biol. Chem. 243, 4189.
- Faichney, G.J. (1969). Aust. J. Agric. Res. 20, 491.
- Farrell, D.J., Corbett, J.L. and Leng, R.A. (1970).
Res. Vet. Sci. 11, 217.
- Felig, P., Marliss, E., Pozefsky, T. and Cahill, G.F. (1970).
Am. J. Clin. Nutr. 23, 7.
- Felig, P., Pozefsky, T., Marliss, E. and Cahill, G.F. Jr (1970).
Science 167, 1003.
- Felts, J.M. and Mayes, P.A. (1967). Biochem. J. 105, 735.

- Filsell, O.H., Jarrett, I.G., Taylor, P.H. and Keech, D.B. (1969). *Biochim. Biophys. Acta* 184, 54.
- Forbath, N. and Hetenyi, G. Jr (1970).
Can. J. Physiol. Pharmacol. 48, 115.
- Ford, E.J.H. (1962). *J. Agric. Sci., Camb.* 59, 67.
- Ford, E.J.H. (1963). *Biochem. J.* 88, 427.
- Ford, E.J.H. (1965). *J. Agric. Sci., Camb.* 65, 41.
- Ford, E.J.H. and Reilly, P.E.B. (1969). *Res. Vet. Sci.* 10, 409.
- Ford, E.J.H. and Reilly, P.E.B. (1970). *Res. Vet. Sci.* 11, 575.
- Forsyth, G. and Hirst, E.L. (1953). *J. Chem. Soc.* 2132.
- Fowle, A.S.E., Matthews, C.M.E. and Campbell, E.J.M. (1964).
Clin. Sci. 27, 51.
- Friedmann, B., Goodman, E.H. and Weinhouse, S. (1970).
Endocrinology 86, 1264.
- Garland, P.B. and Randle, P.J. (1964). *Biochem. J.* 91, 6C.
- Garner, R.J. and Singleton, A.G. (1953).
J. Comp. Pathol. Therap. 63, 300.
- Ghorban, K.Z., Knox, K.L. and Ward, G.M. (1966).
J. Dairy Sci. 49, 1515.
- Govaerts, J. and Lambrechts, L. (1946). *Nature, Lond.* 157, 301.
- Gray, F., Jones, G.B. and Pilgrim, A.F. (1960).
Aust. J. Agric. Res. 11, 383.
- Gray, F.V., Pilgrim, A.F., Rodda, H.J. and Weller, R.A. (1951).
J. Exp. Biol. 29, 57.
- Gray, F.V., Weller, R.A., Pilgrim, A.F. and Jones, G.B. (1966).
Aust. J. agric. Res. 17, 69.

- Gray, F.V., Weller, R.A., Pilgrim, A.F. and Jones, G.B. (1967).
Aust. J. agric. Res. 18, 625.
- Gurpide, E., Mann, J. and Lieberman, S. (1963).
J. Clin. Endocrinol. Metab. 23, 1155.
- Halfpenny, A.F., Rook, J.A.F. and Smith, G.H. (1969).
Br. J. Nutr. 23, 547.
- Hann, R.M. and Hudson, C.S. (1944). J. Am. Chem. Soc. 66, 735.
- Hanson, R.W. and Ballard, F.J. (1967). Biochem. J. 105, 529.
- Hardwick, D.C. (1966). Biochem. J. 99, 228.
- Hardwick, D.C., Linzell, J.L. and Mepham, T. (1963).
Biochem. J. 88, 213.
- Hardwick, D.C., Linzell, J.L. and Price, S.M. (1961).
Biochem. J. 80, 37.
- Head, H.H., Connolly, J.D. and Williams, W.F. (1965).
J. Dairy Sci. 47, 1371.
- Heald, P.J. (1951). Br. J. Nutr. 5, 84.
- Hecker, J.F. (1969). Aust. Vet. J. 45, 293.
- Herrera, M.G., Kamm, D., Ruderman, N. and Cahill, G.F. (1966).
Advan. Enzym. Regul. 4, 225.
- Hertelendy, F., Machlin, L. and Kipnis, D.M. (1969).
Endocrinol. 84, 192.
- Hertelendy, F., Machlin, L.J., Takahashi, Y. and Kipnis, D.M.
(1968). J. Endocrinol. 41, 605.
- Hetenyi, G. Jr and Mak, D. (1970).
Can. J. Physiol. Pharmacol. 48, 732.
- Hetenyi, G. Jr, Ninomiya, R. and Wrenshall, G.A. (1966).
J. Nucl. Med. 7, 454.
- Hetenyi, G. Jr, Rappaport, A.M. and Wrenshall, G.A. (1961).
Can. J. Biochem. Physiol. 39, 225.

- Hetenyi, G. Jr and Wrenshall, G.A. (1968). Can. J. Physiol. Pharmacol. 46, 391.
- Hoberman, H.D. and D'Adamo, A.F. (1960). J. Biol. Chem. 235, 1599.
- Hobson, P.N. (1965). J. Gen. Microbiol. 38, 167.
- Hobson, P.N. and Summers, R. (1967). J. Gen. Microbiol. 47, 53.
- Hogan, J.P. and Weston, R.H. (1967). Aust. J. Agric. Res. 18, 803.
- Hogan, J.P. and Weston, R.H. (1969). Aust. J. Agric. Res. 20, 347.
- Hogan, J.P. and Weston, R.H. (1970). In 'Physiology of Digestion and Metabolism in the Ruminant' p. 474 [A.T. Phillipson, editor]. Newcastle upon Tyne: Oriel Press Ltd.
- Holmes, E.M. and English, P.B. (1969). Res. Vet. Sci. 10, 73.
- Hoogenraad, N.J., Hird, F.J.R., White, R.G. and Leng, R.A. (1970). Br. J. Nutr. 24, 129.
- Hopgood, M.F. and Walker, D.J. (1967). Aust. J. Biol. Sci. 20, 165.
- Horino, M., Machlin, L.J., Hertelendy, F. and Kipnis, D.M. (1968). Endocrinology 83, 118.
- Houpt, T.R. (1959). Am. J. Physiol. 197, 115.
- Huber, J.T., Jacobson, N.L., McGilliard, A.D. and Allen, R.S. (1961). J. Dairy Sci. 44, 321.
- Huggett, A. St G. and Nixon, D.A. (1957). Biochem. J. 66, 12P.
- Hungate, R.E. (1963). J. Bact. Res. 86, 848.
- Hungate, R.E. (1966). In 'The Rumen and its Microbes'. New York: Academic Press.
- Hungate, R.E. (1968). In 'Handbook of Physiology' p. 2725.

- Hunter, G.D. and Millson, G.C. (1964). Res. Vet. Sci. 5, 1.
- Hutchinson, K.J. (1958). Aust. J. Agric. Res. 9, 508.
- Ishaque, M., Thomas, P.C. and Rook, J.A.F. (1971). Nature, Lond. 231, 253.
- Ishiwata, K., Hetenyi, G. Jr and Vranic, M. (1969). Diabetes 18, 820.
- Issekutz, B. Jr, Allen, M. and Borkow, I. (1972). Am. J. Physiol. 222, 710.
- Jarrett, I.G. (1948). J. Coun. Scient. Indus. Res. Aust. 21, 311.
- Jarrett, I.G. (1968). Intern. Congress Endocr. 3, 176,
- Jarrett, I.G., Jones, G.B. and Potter, B.J. (1964). Biochem. J. 90, 189.
- Jarrett, I.G., Potter, B.J. and Filsell, O.H. (1952). Aust. J. Exp. Biol. Med. Sci. 30, 197.
- Jefferson, L.S., Exton, J.H., Butcher, R.W., Sutherland, E.W. and Park, C.R. (1968). J. Biol. Chem. 243, 1031.
- Jones, G.B. (1965). Analyt. Biochem. 12, 249.
- Karam, J.H., Grasso, S.G., Wegienka, L.C., Grodsky, G.M. and Forsham, P.H. (1966). Diabetes 15, 571.
- Karr, M.R., Little, C.O. and Mitchell, G.E. Jr (1966). J. Anim. Sci. 25, 652.
- Katz, M.L. and Bergman, E.N. (1969). Am. J. Physiol. 216, 946.
- Katz, J. and Dunn, A. (1967). Biochemistry 6, 1.
- Katz, J., Rognstad, R. and Kemp, R.G. (1965). J. Biol. Chem. 240, PC1484.
- Katz, J. and Rognstad, R. (1966). J. Biol. Chem. 241, 3600.
- Katz, J. and Rognstad, R. (1969). J. Biol. Chem. 244, 99.

- Kaufman, C.F. and Bergman, E.N. (1971). Am. J. Physiol. 221, 967.
- Kaziro, Y. and Ochoa, S. (1964). Advan. Enzymol. 26, 283.
- Keech, D.B. and Utter, M.F. (1963). J. Biol. Chem. 238, 2609.
- Kerr, R.W. (1950). In 'Chemistry and Industry of Starch' p. 99 [R.W. Kerr, editor]. New York: Academic Press.
- Khachadurian, A.K., Kamelian, M. and Adrouni, B. (1967). Am. J. Physiol. 213, 1385.
- Kleiber, M. (1952). Proc. 4th ann. Oak Ridge Summer Symp. p. 253.
- Knox, K.L., Black, A.L. and Kleiber, M. (1967). J. Dairy Sci. 50, 1716.
- Kondos, A.C. (1967). Aust. Vet. J. 43, 149.
- Krebs, H.A. (1964a). Proc. R. Soc. B 159, 545.
- Krebs, H.A. (1964b). In 'Mammalian Protein Metabolism' p. 125 [H.N. Munro and J.B. Allison, editors]. New York: Academic Press.
- Krebs, H.A. (1969). Advan. Enzyme Regul. 8, 52.
- Krebs, H.A., Hems, A.R., Weidemann, M.J. and Speake, R.N. (1966). Biochem. J. 101, 242.
- Krebs, H.A. and Lund, P. (1966). Biochem. J. 98, 210.
- Krebs, H.A. and Yoshida, T. (1963). Biochem. J. 89, 398.
- Kronfeld, D.S. (1958). Cornell Vet. 48, 394.
- Kronfeld, D.S. and Raggi, F. (1964). Am. J. Physiol. 206, 109.
- Kronfeld, D.S., Ramberg, C.F. and Shames, D.M. (1971). Am. J. Physiol. 220, 886.
- Kronfeld, D.S. and Simesen, M.G. (1961a). Am. J. Physiol. 201, 639.
- Kronfeld, D.S. and Simesen, M.G. (1961b). Cornell Vet. 51, 478.

- Kronfeld, D.S., Tombropoulos, E.G. and Kleiber, M. (1959).
J. Appl. Physiol. 14, 1026.
- Leng, R.A. (1964). Ph.D. Thesis, University of New England,
Armidale, N.S.W.
- Leng, R.A. (1970a). Adv. Vet. Sci. 14, 209.
- Leng, R.A. (1970b). In 'Physiology of Digestion and Metabolism
in the Ruminant' p. 406 [A.T. Phillipson, editor].
Newcastle upon Tyne: Oriel Press Ltd.
- Leng, R.A. and Annison, E.F. (1962). Aust. J. Agric. Res. 13, 31.
- Leng, R.A. and Annison, E.F. (1963). Biochem. J. 86, 319.
- Leng, R.A. and Brett, D.J. (1966). Br. J. Nutr. 20, 541.
- Leng, R.A., Corbett, J.L. and Brett, D.J. (1968).
Br. J. Nutr. 22, 57.
- Leng, R.A. and Leonard, G.J. (1965a). Br. J. Nutr. 19, 469.
- Leng, R.A. and Leonard, G.J. (1965b). Nature, Lond. 207, 760.
- Leng, R.A., Steel, J.W. and Lück, J.R. (1967).
Biochem. J. 103, 785.
- Lindsay, D.B. (1959). Vet. Revs. Annot. 5, 103.
- Lindsay, D.B. (1970). In 'Physiology of Digestion and
Metabolism in the Ruminant' p. 438
[A.T. Phillipson, editor]. Newcastle upon Tyne:
Oriel Press Ltd.
- Lindsay, D.B. (1971). Proc. Nutr. Soc. 30, 272.
- Lindsay, D.B. and Williams, R.L. (1971). Proc. Nutr. Soc. 30, 35A.
- Little, C.O., Mitchell, G.E. and Reitnour, C.M. (1968).
J. Anim. Sci. 27, 790.
- Luick, J.R. and Kleiber, M. (1961). Am. J. Physiol. 200, 1327.

- McClymont, G.L. and Setchell, B.P. (1956). Aust. J. Biol. Sci. 9, 184.
- McDonald, I.W. and Hall, R.J. (1957). Biochem. J. 67, 400.
- McNeill, J.W., Potter, G.D. and Riggs, J.K. (1971). J. Anim. Sci. 33, 1371.
- MacRae, J.C. and Armstrong, D.G. (1966). Proc. Nutr. Soc. 25, 33.
- MacRae, J.C. and Armstrong, D.G. (1969). Br. J. Nutr. 23, 377.
- Mahler, H.R. and Cordes, E.H. (1966). 'Biological Chemistry'. New York: Harper and Row.
- Mallette, L.E., Exton, J.H. and Park, C.R. (1969). J. Biol. Chem. 244, 5724.
- Manchester, K.L. and Young, F.G. (1958). Biochem. J. 70, 353.
- Manns, J.G. (1969). Fedn Proc. Fedn Am. Soc. Exp. Biol. 28, 491.
- Manns, J.G. and Boda, J.M. (1965). Endocrinology 76, 1109.
- Manns, J.G. and Boda, J.M. (1967). Am. J. Physiol. 212, 747.
- Manns, J.G., Boda, J.M. and Willes, R.F. (1967). Am. J. Physiol. 212, 756.
- Mathias, M.M. and Elliot, J.M. (1967). J. Dairy Sci. 50, 1.
- Meier, P. and Zierler, K.L. (1954). J. Appl. Physiol. 6, 731.
- Melander, L. (1960). 'Isotope Effects on Reaction Rates'. New York: Ronald.
- Menahan, L.A. and Wieland, O. (1969). Eur. J. Biochem. 9, 55.
- Minson, D.J. and Cowper, J.L. (1966). Br. J. Nutr. 20, 757.
- Moir, R.J. and Somers, M. (1956). Nature, Lond. 178, 1472.

- Moodie, E.W., Walker, A.I.T. and Hutton, P.H. (1963).
Quart. J. exp. Physiol. 48, 379.
- Morrison, F.B. (1957). 'Feeds and Feeding'. New York:
Morrison Publishing Company.
- Moss, G. (1964). Diabetes 13, 585.
- Munck, A. (1971). Persp. Biol. Med. 14, 265.
- Myers, L.L., Jackson, H.D. and Packett, L.V. (1967).
J. Anim. Sci. 26, 1450.
- Newsholme, E.A. and Gevers, W. (1967). Vitams. Horm. 25, 1.
- Nolan, J.V. and Leng, R.A. (1968). Proc. Aust. Soc. Anim.
Prod. 7, 348.
- Ohneda, A., Aguilar-Parada, E., Eisentraut, A.M. and
Unger, R.H. (1969). Diabetes 18, 1.
- Ohneda, A., Parada, E., Eisentraut, A.M. and Unger, R.H. (1968).
J. Clin. Invest. 47, 2305.
- Ørskov, E.R. (1969). Rev. Cubana Cienc. Agr. 3, 1.
- Ørskov, E.R., Fraser, C. and Kay, R.N.B. (1969).
Br. J. Nutr. 23, 217.
- Ørskov, E.R., Fraser, C. and McDonald, I. (1971a).
Br. J. Nutr. 25, 225.
- Ørskov, E.R., Fraser, C. and McDonald, I. (1971b).
Br. J. Nutr. 26, 477.
- Ørskov, E.R., Fraser, C., Mason, V.C. and Mann, S.O. (1970).
Br. J. Nutr. 24, 671.
- Owen, O.E., Felig, P., Morgan, A.P., Wahren, J. and Cahill, G.F. Jr
(1969). J. Clin. Invest. 48, 574.
- Patterson, M.S. and Green, R.C. (1965). Analyt. Chem. 37, 854.

- Pennington, R.J. (1957). Biochem. J. 65, 534.
- Pennington, R.J. and Appleton, J.M. (1958). Biochem. J. 69, 119.
- Pennington, R.J. and Sutherland, T.M. (1956). Biochem. J. 63, 618.
- Phillips, R.W. and Black, A.L. (1966). J. Comp. Biochem. Physiol. 18, 527.
- Phillips, R.W., Black, A.L. and Moller, F. (1965). Life Sciences 4, 521.
- Phillips, R.W., House, W.A., Miller, R.A., Mott, J.L. and Sooby, D.L. (1969). Am. J. Physiol. 217, 1265.
- Phillipson, A.T. and McAnally, R.A. (1942). J. Exp. Biol. 19, 199.
- Porter, P. and Singleton, A.G. (1971). Br. J. Nutr. 26, 75.
- Potter, E.L., Purser, D.B. and Cline, J.H. (1968). J. Nutr. 95, 655.
- Prentice, T.C., Siri, W., Berlin, N.I., Hyde, G.M., Parsons, R.J., Joiner, E.E. and Lawrence, J.H. (1952). J. Clin. Invest. 31, 412.
- Pritchard, G.I. and Tove, S.B. (1960). Biochim. Biophys. Acta 41, 130.
- Putnam, P.A., Gutierrez, J. and Davis, R.E. (1961). J. Dairy Sci. 44, 1364.
- Radloff, H.D. and Schultz, L.H. (1966). J. Dairy Sci. 49, 971.
- Raggi, F., Hansson, E., Simesen, M.G., Kronfeld, D.S. and Luick, J.R. (1961). Res. Vet. Sci. 2, 180.
- Reichard, G.A., Moury, N.F., Hochella, N.J., Patterson, A.L. and Weinhouse, S. (1963). J. Biol. Chem. 238, 495.
- Reid, R.L. (1958). Aust. J. Agric. Res. 9, 788.

- Reid, R.L. (1968). Adv. Vet. Sci. 12, 163.
- Reilly, P.E.B. and Ford, E.J.H. (1971a). Br. J. Nutr. 26, 249.
- Reilly, P.E.B. and Ford, E.J.H. (1971b). J. Endocr. 49, 19.
- Reis, P.J. and Schinckel, P.G. (1961). Aust. J. Agric. Res. 12, 335.
- Rescigno, A. and Segre, G. (1966). 'Drug and Tracer Kinetics.' Boston, Massachusetts: Ginn (Blaisdell).
- Roe, W.E., Bergman, E.N. and Kon, K. (1966). Am. J. Vet. Res. 27, 729.
- Rognstad, R. and Katz, J. (1966). Proc. Nat. Acad. Sci. U.S. 55, 1148.
- Rognstad, R., Kemp, R.G. and Katz, J. (1965). Arch. Biochem. Biophys. 109, 372.
- Rook, J.A.F. (1964). Proc. Nutr. Soc. 23, 71.
- Rose, I.A. (1960). J. Biol. Chem. 235, 1170.
- Rose, I.A., Kellermayer, R., Stjernholm, R. and Wood, H.G. (1962). J. Biol. Chem. 237, 3325.
- Rose, I.A. and O'Connell, E.L. (1961). J. Biol. Chem. 236, 3086.
- Rosen, H. (1957). Archs. Biochem. Biophys. 67, 10.
- Ross, B.D., Hems, R., Freedland, R.A. and Krebs, H.A. (1967). Biochem. J. 105, 869.
- Roughton, F.J.W. (1935). Physiol. Rev. 15, 241.
- Rowland, F.S., Turton, C.N. and Wolfgang, R. (1956). J. Am. Chem. Soc. 78, 2354.
- Ruderman, N.B. and Herrera, M.G. (1968). Am. J. Physiol. 214, 1436.

- Samols, E., Marri, G. and Marks, V. (1965). *Lancet* ii, 415.
- Sanders, R.B. and Riggs, T.R. (1967). *Endocrinology* 80, 29.
- Saur, W.K., Crespi, H.L., Halevi, E.A. and Katz, J.J. (1968a). *Biochemistry* 7, 3529.
- Saur, W.K., Peterson, D.T., Halevi, E.A., Crespi, H.L. and Katz, J.J. (1968b). *Biochem.* 7, 3537.
- Scharff, R. and Wool, I.G. (1965). *Biochem. J.* 97, 272.
- Schmidt-Nielsen, B. and Osaki, H. (1958). *Am. J. Physiol.* 193, 657.
- Scrutton, M.C. and Utter, M.F. (1967). *J. Biol. Chem.* 242, 1723.
- Scrutton, M.C. and Utter, M.F. (1968). *A. Rev. Biochem.* 37, 249.
- Searle, G.L., Strisower, E.H. and Chaikoff, I.L. (1954). *Am. J. Physiol.* 176, 190.
- Setchell, B.P. and Hinks, N.T. (1967). *Biochem. J.* 102, 623.
- Sheppard, C.W. (1962). In 'Basic Principles of the Tracer Method'. New York: John Wiley and Sons.
- Sheppard, A.J., Forbes, R.M. and Johnson, B.C. (1959). *Proc. Soc. Exp. Biol. Med.* 101, 715.
- Shipley, R.A., Chudzik, E.B., Gibbons, A.P., Jongedyk, K. and Brummond, D.O. (1967). *Am. J. Physiol.* 213, 1149.
- Shreeve, W.W. (1965). *Ann. N.Y. Acad. Sci.* 131, 464.
- Shreeve, W.W., Lamdin, E., Oji, N. and Slavinski, R.H. (1967). *Biochemistry* 6, 1160.
- Shumway, R.P., Trujillo, T.T., Bennett, J.A., Matthews, D.J. and Asplund, R.O. (1956). *Am. Soc. Anim. Prod. (West Sect.)* 7, 1.
- Simon, H. (1963). *Z. Naturforsch.* 18b, 360.

- Simon, H. and Medina, R. (1966). Z. Naturforsch. 23b, 326.
- Siri, W. and Evers, J. (1962). In 'Tritium in the Physical and Biological Sciences' p. 71. Vienna: I.A.E.A.
- Skarda, J. and Bartos, S. (1969). J. Endocr. 44, 115.
- Skinner, S.M., Clark, R.E., Baker, N. and Shipley, R.A. (1959). Am. J. Physiol. 196, 238.
- Smith, T.E. (1969). U.S. At. Energy Comm. UCRL-50781, p. 5.
- Smith, R.M. and Marston, H.R. (1971). Br. J. Nutr. 26, 41.
- Smith, R.M. and Osborne-White, W.S. (1969). Proc. Aust. Biochem. Soc. 2, 72.
- Smith, P.H., Sweeney, H.C., Rooney, J.R., King, K.W. and Moore, W.E.C. (1956). J. Dairy Sci. 39, 598.
- Solomon, A.K., Vennesland, B., Klemperer, F.W., Buchanan, J.M. and Hasting, A.B. (1941). J. Biol. Chem. 140, 171.
- Somogyi, M. (1945). J. Biol. Chem. 160, 69.
- Springell, P.H. (1968). Aust. J. agric. Res. 19, 129.
- Steel, J.W. and Leng, R.A. (1968). Proc. Aust. Soc. Anim. Prod. 7, 342.
- Steele, R. (1964). Fedn Proc. Fed. Am. Soc. Exp. Biol. 23, 671.
- Steele, R. (1966). Ergeb. Physiol. 57, 91.
- Steele, R., Bernstein, W. and Bjerknes, C. (1957). J. Appl. Physiol. 10, 319.
- Steele, R., Bishop, J.S., Dunn, A., Altszuler, N., Rathgeb, I. and de Bodo, R.C. (1965). Am. J. Physiol. 208, 301.
- Steele, R., Wall, J.S., de Bodo, R.C. and Altszuler, N. (1956). Am. J. Physiol. 187, 15.
- Stern, J.S., Baile, C.A. and Mayer, J. (1970). Am. J. Physiol. 219, 84.

- Sutherland, T.M. (1957). Biochem. J. 66, 31P.
- Sutherland, T.M. (1963). In 'Progress in Nutrition and Allied Sciences' p. 159 [D.P. Cuthbertson, editor]. Edinburgh: Oliver and Boyd Ltd.
- Szabo, A.J., Maier, J.J., Szabo, O. and Camerini-Cavalos, R.A. (1969). Diabetes 18, 232.
- Tait, J.F. (1963). J. Clin. Endocrinol. Metab. 23, 1285.
- Taylor, T.A. and Ramsay, H.A. (1965). J. Dairy Sci. 48, 505.
- Taylor, P.H., Wallace, J.C. and Keech, D.B. (1971). Biochim. Biophys. Acta 237, 179.
- Thomson, D.J., Beever, D., Cochlo, Da Silva, J.P. and Armstrong, D.G. (1969). Proc. Nutr. Soc. 28, 24A.
- Till, A.R. and Downes, A.M. (1962). Aust. J. Agric. Res. 13, 335.
- Till, A.R. and Downes, A.M. (1963). Lab. Pract. 12, 1006.
- Tombropoulos, E.G. and Kleiber, M. (1961). Biochem. J. 80, 414.
- Topper, Y.J. (1957). J. Biol. Chem. 225, 419.
- Topper, Y.J. (1961). In 'The Enzymes' 5, 413. [P.D. Boyer, H. Lardy and K. Myrbäck, editors]. New York: Academic Press.
- Topps, J.H., Kay, R.N.B. and Goodall, E.D. (1968). Br. J. Nutr. 22, 261.
- Topps, J.H., Kay, R.N.B., Goodall, E.D., Whitelaw, F.G. and Reid, R.S. (1968). Br. J. Nutr. 22, 281.
- Tucker, R.E., Mitchell, G.E. Jr and Little, C.O. (1968). J. Anim. Sci. 27, 824.
- Ulyatt, M.J., Whitelaw, F.G. and Watson, F.G. (1970). J. Agric. Sci., Camb. 75, 565.
- Utter, M.F. and Keech, D.B. (1963). J. Biol. Chem. 238, 2603.

- Vrba, R. (1964). Nature, Lond. 202, 247.
- Van Es, A.J.H. (1967). In 'Energy Metabolism of Farm Animals' p. 513 [K.L. Blaxter, J. Kielanowski and G. Thorbek, editors]. Newcastle upon Tyne: Oriel Press Ltd.
- Van Liew, H.D. (1962). Science 138, 682.
- Vaughan, B.E. and Boling, E.A. (1961). J. Lab. Clin. Med. 57, 159.
- Vaughan, M. (1961). J. Lipid Res. 2, 293.
- Von Holt, C., Schmidt, H., Feldman, H. and Hallmann, I. (1961). Biochem. Z. 334, 524.
- Wagle, R. and Ashmore, J. (1963). J. Biol. Chem. 238, 17.
- Walker, D.J. (1965). In 'Physiology of Digestion in the Ruminant' p. 296 [R.W. Dougherty, editor]. Washington D.C.: Butterworths.
- Walker, D.J. and Nader, C.J. (1970). Aust. J. Agric. Res. 21, 747.
- Warner, A.C.I. (1964). Nutr. Abstracts Revs. 34, 339.
- Waterhouse, C. and Keilson, J. (1969). J. Clin. Invest. 48, 2359.
- Weekes, T.E.C. (1971). Res. vet. Sci. 12, 373.
- Weidemann, M.J. and Krebs, H.A. (1969). Biochem. J. 111, 69.
- Weigand, E., Young, J.W. and McGilliard, A.D. (1972). Biochem. J. 126, 201.
- Weinman, E.O., Strisower, E.H. and Chaikoff, I.L. (1957). Physiol. Rev. 37, 252.
- Weller, R.A. and Gray, F.V. (1954). J. Exp. Biol. 31, 40.
- Weller, R.A., Gray, F.V. and Pilgrim, A.F. (1958). Br. J. Nutr. 12, 421.
- Weller, R.A., Gray, F.V., Pilgrim, A.I. and Jones, G.B. (1967). Aust. J. Agric. Res. 18, 107.

- Weller, R.A., Pilgrim, A.F. and Gray, F.V. (1962).
Br. J. Nutr. 16, 83.
- West, C.E. and Annison, E.F. (1964). Biochem. J. 92, 573.
- West, C.E. and Passey, R.F. (1967). Biochem. J. 102, 58.
- Weston, R.H. and Hogan, J.P. (1968a). Aust. J. Agric. Res. 19, 419.
- Weston, R.H. and Hogan, J.P. (1968b). Aust. J. Agric. Res. 19, 567.
- White, R.G., Williams, V.J. and Morris, R.J.H. (1971).
Br. J. Nutr. 25, 57.
- White, R.G., Steel, J.W., Leng, R.A. and Luick, J.R. (1969).
Biochem. J. 114, 203.
- White, R.R. (1963). Ph.D. Thesis, University of New England,
Armidale, N.S.W., Australia.
- Willes, R.F., Mendel, V.E. and Robblee, A.R. (1970).
J. Anim. Sci. 31, 85.
- Williams, V.J. (1965). Aust. J. Agric. Res. 16, 77.
- Williams, W.F., Weissbar, A.G. and Lauterbach, G.E. (1966).
J. Dairy Sci. 49, 106.
- Williamson, J.R. (1967). Advan. Enzyme Regul. 5, 229.
- Williamson, J.R., Browning, E.T., Thurman, R.G. and
Scholz, R. (1969). J. Biol. Chem. 244, 5055.
- Wiltzout, D.W. and Satter, L.D. (1972). J. Dairy Sci. 55, 307.
- Wolff, J.E., Bergmann, E.N. and Williams, H.H. (1971).
Fedn. Proc. Fedn. Am. Soc. Exp. Biol. 30, 404,
Abstr.
- Wood, H.G. and Utter, M.F. (1965). In 'Essays in Biochemistry'
[P.N. Campbell and G.D. Greville, editors].
New York: Academic Press.

Woodman, H.E. and Evans, R.E. (1938). J. Agric. Sci.
Camb. 28, 43.

Wool, I.G. (1964). In 'Actions of Hormones on Molecular Processes'
p. 422 [G. Litwack and D. Kritchevsky, editors].
New York: J. Wiley and Sons.

Wrenshall, G.A. and Hetenyi, G. (1959). Metabolism 8, 531.

Wrenshall, G.A. and Hetenyi, G. Jr (1962). Diabetes 11, 236.

Wrenshall, G.A., Hetenyi, G. and Best, C.H. (1961).
Can. J. Biochem. Physiol. 39, 267.

Young, J.W., Thorp, S.L. and De Lumen, H.Z. (1969).
Biochem. J. 114, 83.

APPENDIX : SECTION 3

Table A3-1. Analysis of variance for data of Part A

Table lists measured variables tested. Lines delineate non-significant differences ($P > 0.05$) using Duncan's multiple-range test (Duncan, 1955). The values for each ration are the means for three or four experiments.

Source	Analysis of variance			Ration		
	Degress of freedom	Mean square	F Value	A	B	C
1. Irreversible loss of plasma glucose (mg/min)						
Ration	2	107	0.90			
Ration x sheep	7	119				
2. Total volatile fatty concentration in ruminal fluid (mmol/l)						
Ration	2	2049	16.9**	66.5	75.8	109.5
Ration x sheep	9	121				
3. Propionate concentration in ruminal fluid (mmol/l)						
Ration	2	75.2	4.70			
Ration x sheep	8	16.0				
4. Production rate of propionate (mmol/min)						
Ration	2	.0112	0.72			
Ration x sheep	9	.0155				
5. Glucose derived from propionate (%)						
Ration	2	372	6.45*	35.5	38.5	53.5
Ration x sheep	9	57.7				
6. Net conversion rate of propionate into glucose (mmol/min)						
Ration	2	.0198	7.92*	.21	.28	.35
Ration x sheep	9	.0025				
7. Propionate converted into glucose (%)						
Ration	2	263	2.55			
Ration x sheep	9	103				

* $P < 0.05$, ** $P < 0.01$.

Table A3-2. Intake and digestibility coefficients for energy and protein of lucerne chaff
and SR and concentration of plasma glucose of sheep given
intravenous infusions of $[U-^{14}C]$ glucose

Sheep no.	Sheep wt (kg)	Ration* (g/day)	Gross energy (kcal/day)	Apparent digestibility (%)	Crude protein** (g/day)	Apparent protein digestibility (%)	Plasma glucose (mg/100 ml)	Plateau SR of glucose (μ Ci/g)
171	25.4	250 (I)	969	60.2	43.1	77.5	55 ± 0.4	29.8 ± .4
174	20.2	250 (I)	969	58.2	43.1	75.9	56 ± 1.0	35.4 ± .4
133	27.2	600 (I)	2326	61.8	103.4	77.8	61 ± 0.7	25.3 ± .1
175	28.8	600 (I)	2326	61.0	103.4	78.2	65 ± 0.5	19.9 ± .2
179	33.7	800 (E)	3123	61.4	67.5	65.8	63 ± 1.4	17.1 ± .4
46	32.0	800 (E)	3123	57.2	67.5	61.9	61 ± 0.7	16.3 ± .1
140	32.7	800 (I)	3151	59.7	141.9	75.3	58 ± 1.0	17.0 ± .1
143	30.2	800 (I)	3151	59.7	141.9	75.3	62 ± 0.8	18.3 ± .1
162	32.2	800 (I)	3244	63.4	132.8	75.5	66 ± .5	16.8 ± .3
114	34.1	800 (I)	3220	60.8	127.3	75.7	57 ± .2	18.8 ± .1
191	40.1	800 (I)	3220	57.5	127.3	69.9	58 ± .8	16.1 ± .1
175	31.1	800 (I)	3220	59.1	127.3	74.6	67 ± .8	16.1 ± .1
81	33.4	800 (I)	3090	57.3	116.5	73.7	62 ± .9	20.1 ± .5
184	35.5	1000 (I)	3877	62.1	172.3	78.6	64 ± 0.7	14.7 ± .1
191	38.8	1000 (I)	3877	60.9	172.3	77.0	61 ± 0.8	13.4 ± .2

* Ration identification given in parentheses (see Table 3-5).

** Nitrogen × 6.25.

/ Mean values with their standard errors for four to eight samples taken at 20 to 35 min. intervals.
Values for sheep 140, 143, 114, 191 and 175 also appear in Table A4-6.

/ Faeces from sheep 140 and 143 were inadvertently mixed and digestibility coefficients are given
as mean values for these two sheep.

APPENDIX : SECTION 4

Table A4-1. Intake and digestibility coefficients for energy and protein of ration B given to sheep

Sheep no.	Gross energy (kcal/day)	Apparent energy digestibility (%)	Crude protein* (g/day)	Apparent protein digestibility (%)
176	1737	84.6	61.8	80.7
187	1752	74.3	61.2	67.0

* Nitrogen x 6.25.

Table A4-2. SR of blood bicarbonate and the SR and concentration of plasma glucose before and during an intravenous infusion of glucose

Each animal received intravenously a 9 or 15 h infusion of $\text{NaH}^{14}\text{CO}_3$. D-glucose was infused during the last 6 h of a 15 h infusion. Mean concentrations and plateau SR values of plasma glucose with their standard errors are given for three to seven samples taken at 20 to 35 min intervals between 6 and 9 h or 9 and 15 h of the infusion. For each sheep, mean values before and during glucose infusion were significantly different ($P < 0.05$) from each other. SR of blood bicarbonate was not altered by glucose infusions and the mean values with their standard errors are given for five to fourteen samples taken at 20 to 40 min intervals from the 6th hour of the infusion of $\text{NaH}^{14}\text{CO}_3$.

Sheep no.	Sheep wt (kg)	Ration	Glucose infusion (mg/min)	Plasma glucose (mg/100 ml)	Plateau SR ($\mu\text{Ci/g C}$) of: Plasma glucose	Blood bicarbonate
175	34.8	Lucerne	-	81 \pm 0.5	0.98 \pm .016	7.16 \pm .17
98	39.8	Lucerne	-	57 \pm 1.5	0.91 \pm .020	6.13 \pm .26
125	30.1	Lucerne	-	63 \pm 0.8	1.08 \pm .012	7.89 \pm .36
			16.4	75 \pm 2.3	0.89 \pm .012	
122	25.8	Lucerne	-	71 \pm 1.2	0.93 \pm .009	6.85 \pm .15
			34.1	77 \pm 1.5	0.68 \pm .030	
			67.9	82 \pm 2.6	0.42 \pm .013	
114	33.6	Lucerne	-	56 \pm 1.4	0.91 \pm .021	6.40 \pm .13
			67.3	81 \pm 1.1	0.33 \pm .004	
162	30.4	Lucerne	-	75 \pm 1.0	0.97 \pm .006	6.82 \pm .24
			94.0	100 \pm 1.1	0.34 \pm .001	
175	32.6	Lucerne	-	67 \pm 0.9	1.20 \pm .025	7.18 \pm .11
			99.3	119 \pm 2.7	0.38 \pm .002	
191	38.6	Lucerne	-	70 \pm 1.7	1.01 \pm .012	7.22 \pm .06
			133.0	128 \pm 0.8	0.28 \pm .006	
191	38.3	Wheat	-	79 \pm 0.8	0.93 \pm .006	7.86 \pm .11
183	36.8	Wheat	-	69 \pm 0.8	1.06 \pm .038	10.0 \pm .7
98	36.3	Wheat	-	68 \pm 0.6	0.80 \pm .008	9.00 \pm .08
			16.8	78 \pm 1.4	0.56 \pm .012	
179	29.8	Wheat	-	45 \pm 0.7	0.91 \pm .013	10.3 \pm .2
			102.3	57 \pm 1.9	0.30 \pm .004	
29	28.8	Wheat	-	67 \pm 0.9	1.18 \pm .009	11.5 \pm .6
			137.0	221 \pm 4.3	0.31 \pm .008	

Table A4-3. SR and concentration of plasma glucose before
and during an intravenous infusion of glucose

Each animal received intravenously a 12 h infusion of [$U-^{14}C$]glucose. D-glucose was infused during the last 6 h. Mean concentrations and plateau SR values of plasma glucose are given with their standard errors for three to seven samples taken at 25 to 35 min intervals immediately before and during the glucose infusion. For each sheep, values with the superscript a or b are not significantly different ($P > 0.05$) from each other.

Sheep no.	Sheep wt (kg)	Ration	Glucose infusion (mg/min)	Plasma glucose (mg/100 ml)	Plateau SR of glucose*: ($\mu\text{Ci/g}$)
191	38.7	Lucerne	- 4.5	60 \pm 0.3 ^a 62 \pm 1.0 ^a	18.3 \pm .28 ^a (17.4 \pm .26 ^b) 18.5 \pm .21 ^a (17.4 \pm .24 ^b)
175	31.2	Lucerne	- 9.3	65 \pm 1.0 ^a 68 \pm 1.1 ^a	19.7 \pm .20 (18.9 \pm .26) 17.8 \pm .23 (17.1 \pm .28)
125	30.1	Lucerne	- 16.4	42 \pm 0.8 50 \pm 0.9	- 18.0 \pm .44
122**	29.4	Lucerne	- 34.2 68.7	75 \pm 1.1 82 \pm 0.4 96 \pm 1.7	23.0 \pm .00 - -
114	33.6	Lucerne	- 67.3	58 \pm 1.5 91 \pm 1.7	14.0 \pm .16 9.08 \pm .113
175	32.6	Lucerne	- 99.3	77 \pm 1.6 120 \pm 1.4	13.2 \pm .16 6.81 \pm .085
191	38.6	Lucerne	- 133.0	71 \pm 1.3 129 \pm 2.6	15.0 \pm .13 5.97 \pm .063
162	31.7	Wheat	- 4.2	62 \pm 1.3 ^a 62 \pm 1.3 ^a	17.0 \pm .35 (16.7 \pm .16) 18.9 \pm .41 (18.9 \pm .31)
179	31.2	Wheat	- 8.4	56 \pm 0.9 62 \pm 0.5	23.3 \pm .30 (22.6 \pm .40 ^a) 21.8 \pm .27 (21.8 \pm .33 ^a)
98	36.3	Wheat	- 16.8	73 \pm 0.9 ^a 74 \pm 0.8 ^a	20.1 \pm .20 16.9 \pm .07
20	32.9	Wheat	- 53.3	63 \pm 0.3 104 \pm 1.0	24.1 \pm .33 13.2 \pm .07
179	29.8	Wheat	- 102.3	60 \pm 1.4 98 \pm 1.3	17.7 \pm .35 6.68 \pm .202
196	30.5	Wheat	- 104.6	80 \pm 0.8 136 \pm 7.7	14.5 \pm .29 7.24 \pm .057
29	28.8	Wheat	- 137.0	66 \pm 0.8 221 \pm 2.1	19.8 \pm .09 6.39 \pm .148

* Values in parentheses were obtained simultaneously with infusions of [$6-^3\text{H}$]glucose.

** Sheep received two 3 h infusions of D-glucose.

Table A4-4. Analysis of variance for regression equations of Part A

Table lists individual regressions for the two diets, lucerne and wheat, tested for homogeneity.

Source of Variance	Degrees of freedom	Mean square	F value
1. Regression of the percentage of endogenous glucose suppressed on the rate of glucose infusion (mg/min), for sheep given wheat or lucerne.			
Individual regression lines:			
Between slopes	1	2.61	.019
Residual	13	141	
Parallel regression lines:			
Common slope	1	2688	20**
Between lines	1	2.46	.019
Residual	14	132	
2. Regression of the quantitative suppression of the irreversible loss of endogenous glucose (mg/min) on the infusion rate of glucose (mg/min) for sheep given wheat or lucerne.			
Individual regression lines:			
Between slopes	1	24.5	0.59
Residual	13	41.4	
Parallel regression lines:			
Common slope	1	1237	31**
Between lines	1	37.8	0.94
Residual	14	40.1	
3. Regression of the irreversible loss of plasma glucose (mg/min) on plasma glucose concentration (mg/100 ml) for sheep given wheat or lucerne and intravenous infusions of glucose.			
Individual regression lines:			
Between slopes	1	3219	6.6*
Residual	13	490	
Parallel regression lines:			
Common slope	1	18010	26**
Between lines	1	1081	1.6
Residual	14	685	

Table A4-4 (continued)

Source of Variance	Degrees of freedom	Mean square	F value
4. Regression of the increase in plasma glucose concentration (mg/100 ml) on the infusion rate of glucose (mg/min), for sheep given wheat or lucerne.			
Individual regression lines:			
Between slopes	1	2655	4.2
Residual	25	637	
Parallel regression lines:			
Common slope	1	23589	42**
Between lines	1	2310	4.1
Residual	26	563	
5. Regression of the decrease in the irreversible loss of endogenous glucose (mg/min) on the increase in plasma glucose concentration (mg/100 ml), for sheep given wheat or lucerne and intravenous infusions of glucose.			
Individual regression lines:			
Between slopes	1	298	8.1*
Residual	13	36.8	
Parallel regression lines:			
Common slope	1	1022	18**
Between lines	1	132	2.4
Residual	14	55.5	

* P < 0.05, ** P < 0.01

Table A4-5. SR of ruminal propionate and plasma glucose immediately before and during intravenous infusions of glucose (see Table 4-3)

Sheep were given simultaneously, an intravenous infusion of [6-³H]glucose and an intraruminal infusion of [2-¹⁴C]propionate. Mean SR values of plasma glucose with their standard errors are given for three to six samples taken at 20 to 30 min intervals immediately before and during glucose infusion. For each sheep, mean values were significantly different ($P < 0.05$) from each other. Mean SR values for ruminal propionate are given with their standard errors for eight to seventeen samples taken at 20 to 30 min intervals from the 6th hour of the infusion.

Sheep no.	Glucose infusion (mg/min)	Rumen propionate ($\mu\text{Ci/g C}$)	Plateau SR of:		
			Plasma glucose ($\mu\text{Ci/g C}$)	($\mu\text{Ci } ^3\text{H/g}$)	
175	-		21.9 \pm .44	17.5 \pm .21	
	19.2	29.6 \pm 0.7	18.2 \pm .04	16.0 \pm .12	
	38.5		13.7 \pm .13	12.0 \pm .08	
179	-		21.2 \pm .47	17.5 \pm .19	
	30.0	41.5 \pm 0.8	13.7 \pm .48	13.7 \pm .18	
	60.1		7.3 \pm .01	10.0 \pm .08	
46	-	55.1 \pm 4.0	20.1 \pm .41	19.8 \pm .45	
	59.6		7.1 \pm .03	11.9 \pm .14	

Table A4-6. SR of plasma glucose and blood bicarbonate and the concentrations of plasma glucose and lactate before and during infusions of sodium propionate (see Tables 4-5 and 4-7)

Sheep were given intravenously a mixture of [$U-^{14}C$]glucose and [$6-^3H$]glucose for 13 to 15 h. Propionate was infused over the last 5 to 6 h of this infusion. Mean values with their standard errors are given for three to seven samples taken at 20 to 30 min intervals immediately before and during propionate infusion. For each sheep, values with the same superscript a are not significantly different ($P > 0.05$) from each other.

Sheep no.	Sheep wt (kg)	Propionate infusion (mmol/min):		Plasma glucose (mg/100 ml)	Plasma lactate (mg/100 ml)	Plateau SR of:		
		Intraruminal	Intravenous			Plasma glucose ($\mu\text{Ci/g}$): [$6-^3H$]	[$U-^{14}C$]	Blood bicarbonate ($\mu\text{Ci/g C}$)
140	32.7	-	-	58 ± 1.0	4.4 ± .46	16.5 ± .14	17.0 ± .12	5.95 ± .248
		-	0.99	75 ± 1.6	8.7 ± .83	11.9 ± .10	12.1 ± .10	4.56 ± .025
143	30.2	-	-	62 ± 0.8	4.9 ± .22	17.8 ± .11	18.3 ± .14	5.58 ± .056
		-	0.99	77 ± 1.4	7.8 ± .33	12.1 ± .14	12.5 ± .15	4.11 ± .040
191	40.1	-	-	58 ± 0.8	3.4 ± .26a	15.0 ± .27	16.1 ± .13	-
		-	0.35	70 ± 1.3	3.7 ± .31a	12.7 ± .09	14.4 ± .13	-
114	34.1	-	-	57 ± 0.2	3.2 ± .23	17.6 ± .13	18.8 ± .09	-
		-	0.62	65 ± 0.8	5.4 ± .46	15.9 ± .24	16.1 ± .08	-
175	31.1	-	-	67 ± 0.8	3.2 ± .25	14.9 ± .05	16.1 ± .09	-
		-	1.12	82 ± 0.7	5.1 ± .13	11.9 ± .19	13.0 ± .22	-

Table A4-7. SR of plasma glucose and blood bicarbonate and the concentrations of plasma glucose and lactate before and during intravenous infusions of sodium propionate (see Table 4-5)

Sheep were given intravenously a mixture of [6-³H]glucose and NaH¹⁴CO₃ for 13 to 14 h. Propionate was infused over the last 5 to 6 h of this infusion. Mean values with their standard errors are given for three to ten samples usually taken at 20 to 30 min intervals immediately before and during the infusion of propionate. For each sheep, values with the same superscript a or b are not significantly different ($P > 0.05$) from each other. The SR of blood bicarbonate was not altered by infusions of propionate.

Sheep no.	Sheep wt (kg)	Propionate infusion (mmol/min)	Plasma glucose (mg/100 ml)	Plasma lactate (mg/100 ml)	Plateau SR of:		
					[6- ³ H] (μ Ci/g)	[U- ¹⁴ C] (μ Ci/g C)	Blood bicarbonate (μ Ci/g C)
140	32.7	- 0.99	60 ± 0.4 70 ± 0.7	4.6 ± .06 9.0 ± .59	18.6 ± .36 12.1 ± .15	1.06 ± .039 1.22 ± .019	6.72 ± .114
143	30.2	- 0.99	71 ± 1.3 85 ± 0.9	5.5 ± .62 7.4 ± .30	16.8 ± .08 12.3 ± .12	0.93 ± .010 1.17 ± .002	6.98 ± .085
130	32.4	- 1.92	66 ± 1.2 ^a 68 ± 1.0 ^a	6.7 ± .80 10.2 ± .80	11.5 ± .21 8.5 ± .24	1.15 ± .036 1.39 ± .008	-
130	32.4	- 0.99* 1.99*	73 ± 1.2 ^a 70 ± 2.1 ^a 69 ± 0.8 ^a	8.2 ± .52ab 7.1 ± .58ab 6.2 ± .55b	11.6 ± .47 ^a 12.1 ± .47 ^a 12.5 ± .09 ^a	1.27 ± .018 ^a 1.30 ± .010 ^a 1.34 ± .043 ^a	-

* Intravenous infusion of sodium chloride.

Table A4-8. SR of rumen propionate and plasma glucose and the concentrations of plasma glucose and lactate before and during intraruminal infusions of sodium propionate (see Table 4-7)

Sheep received simultaneously, an intravenous infusion of [6-³H]glucose and an intraruminal infusion of [2-¹⁴C]propionate. Mean values with their standard errors are given for two to six samples taken at 20 to 30 min intervals immediately before and during propionate infusion. For each sheep, values with the same superscript a were not significantly different ($P > 0.05$) from each other.

Sheep no.	Sheep wt (kg)	Propionate infusion (mmol/min)	Plateau SR of:			
			Plasma glucose (mg/100 ml)	Plasma lactate (mg/100 ml)	Rumen propionate ($\mu\text{Ci/g C}$)	Plasma glucose [$^{\text{U}-14}\text{C}$] ($\mu\text{Ci/g C}$)
191	40.1	-	60 ± 1.1 ^a	3.5 ± .07 ^a	63.9 ± 1.4	15.9 ± .27
		0.35	59 ± 0.6 ^a	2.9 ± .13 ^a	39.6 ± 2.5	18.4 ± .21
114	34.1	-	58 ± 1.1	3.8 ± .11	31.2 ± 0.4	18.2 ± .02
		0.62	65 ± 0.8	4.5 ± .16	23.2 ± 0.4	17.0 ± .31
175	31.1	-	64 ± 0.6	3.4 ± .19	65.6 ± 4.1	25.1 ± .88
		1.12	70 ± 0.5	4.9 ± .26	23.0 ± 0.3	19.0 ± .33
179	37.4	-	61 ± 0.9	-	61.9 ± 1.6	19.4 ± .10
		0.98	66 ± 0.4	-	25.8 ± 0.3	15.5 ± .41
172	38.0	-	68 ± 0.7	4.4 ± .16	31.9 ± 1.7	17.6 ± .69
		2.12	91 ± 1.5	8.4 ± .33	18.0 ± 0.7	-
		4.23	102 ± 0.9	11.3 ± .25	8.0 ± 0.3	-
57	36.7	-	63 ± 1.1	4.3 ± .17 ^a	51.2 ± 0.8	18.6 ± .20
		3.20	87 ± 3.3	5.9 ± .87 ^a	9.0 ± 0.6	7.8 ± .15
		6.35	73 ± 0.4	8.0 ± .31	4.5 ± 0.5	-
						15.2 ± .21
						10.3 ± .25
						9.4 ± .31

Table A4-9. SR of plasma glucose and blood bicarbonate before and during intra-abomasal infusions of casein (see Table 4-8)

Sheep were given intravenously an infusion of a mixture of [6-³H]glucose and NaH¹⁴CO₃. Mean SR values with their standard errors are given for nineteen (glucose-C), three to five (glucose-H) and eleven (bicarbonate-C) samples. For each sheep, mean values were significantly different ($P < 0.05$) from each other.

Sheep no.	Casein hydrolysate (mg/min)	Plateau SR of:		
		Plasma glucose ($\mu\text{Ci/g C}$)	$(\mu\text{Ci } ^3\text{H/g})$	Blood bicarbonate ($\mu\text{Ci/g C}$)
256	-		18.6 ± .29	
	57.5	0.95 ± 0.020	16.7 ± .37	6.91 ± .123
	112.2		14.2 ± .03	
722	-		20.1 ± .29	
	77.7	1.02 ± 0.16	17.3 ± .40	7.47 ± .069
	158.6		13.7*	

* Approximate estimate of the plateau SR (see text).

Table A4-10. SR of plasma glucose and rumen propionate before and during intravenous infusions of sodium butyrate (see Table 4-9)

Sheep were given simultaneously, an intravenous infusion of [6-³H]glucose and an intraruminal infusion of [2-¹⁴C]propionate. Mean SR values with their standard errors are given for three to ten (glucose) and seventeen (propionate) samples. For each sheep, values with the superscript a were not significantly different ($P > 0.05$) from each other.

Sheep no.	Butyrate infusion (mmol/min)	Plateau SR of:		
		Rumen propionate ($\mu\text{Ci/g C}$)	Plasma glucose ($\mu\text{Ci/g C}$)	($\mu\text{Ci } ^3\text{H/g}$)
130	-	41.4	17.4 \pm .29 ^a	15.5 \pm .04 ^a
	0.25	\pm 1.9	17.4 \pm .13 ^a	15.5 \pm .04 ^a
	0.50			
183	-	50.3	17.2 \pm .32	16.0 \pm .05 ^a
	0.25	\pm 2.6	16.5 \pm .14	15.8 \pm .13 ^a
	0.50			

Table A5-1. Zero-time intercepts and rate constants of mono- and multiexponential components describing the SR - time curve in plasma glucose of sheep following intravenous injections of mixtures of [$U-^{14}C$] glucose and [$6-^3H$]-, [$3-^3H$]- or [$2-^3H$]glucose

Sheep no.	Glucose injected	Multiexponential analysis							Monoexponential analysis					
		Time interval * (hr)	Zero-time intercepts ($\mu\text{Ci/g}$ of glucose)			Rate constants (min^{-1})			Residual standard deviation	Time interval * (hr)	Zero-time intercept ($\mu\text{Ci/g}$ of glucose)	Rate constant (min^{-1})	Correlation coefficient	Residual standard deviation
			a_1	a_2	a_3	m_1 ($\times 10^1$)	m_2 ($\times 10^2$)	m_3 ($\times 10^3$)						
20	[$U-^{14}C$]	.3-30(35)	98.8	90.1	.273	.214	.780	.35	.059	.3-1.0(10)	188	.139	.987	.0152
	[$3-^3H$]	.3-30(33)	115	51.8	.055	.127	.834	.26	.069	.3-1.0(10)	187	.141	.991	.0127
20	[$U-^{14}C$]	.5-32(32)	132	73.3	.533	.195	.729	.82	.033	.5-1.0(4)	187	.124	.991	.0110
	[$2-^3H$]	.5-32(32)	117	82.9	.020	.206	.876	.14	.357	.5-2.2(8)	181	.128	.999	.0067
196	[$U-^{14}C$]	.4-30(33)	151	20.2	.306	.127	.580	.38	.037	.4-1.0(7)	177	.126	.978	.0160
	[$3-^3H$]	.4-30(33)	152	21.6	.052	.133	.788	.27	.081	.4-1.0(7)	174	.129	.980	.0153
196	[$U-^{14}C$]	.5-31(32)	198	28.0	.402	.172	.717	.72	.051	.5-1.1(4)	241	.169	.994	.0142
	[$2-^3H$]	.5-31(32)	151	112	.071	.284	1.24	.18	.230	.5-1.9(7)	233	.174	.999	.0125
170	[$U-^{14}C$]	.3-31(31)	256	6.36	.364	.154	.435	.66	.115	.3-1.0(5)	249	.133	.956	.0323
	[$6-^3H$]	.3-31(31)	268	4.01	.104	.157	.433	.26	.121	.3-1.0(5)	252	.131	.956	.0320
170	[$U-^{14}C$]	.3-30(36)	225	22.0	.241	.183	.715	.35	.053	.3-1.0(9)	247	.169	.991	.0147
	[$3-^3H$]	.3-30(36)	204	28.2	.061	.191	1.00	.34	.099	.3-1.4(10)	240	.186	.996	.0150
170	[$U-^{14}C$]	.5-24(28)	114	91.2	.445	.148	.790	.34	.033	.5-1.0(4)	215	.120	.993	.0110
	[$2-^3H$]	.5-24(27)	86.9	169	.093	.431	1.08	.27	.253	.5-2.2(8)	205	.124	.999	.0082

* The number of observations is given in parentheses.

Table A5-2. Analysis of variance for parameters of glucose metabolism

Table lists measured variables tested. Variables were measured by multi-exponential (M) or monoexponential (S) analysis of carbon-14 (C) and tritium (H) disappearance curves from plasma glucose of sheep given intravenously, injections of mixtures of [$U-^{14}C$]glucose and [3H]glucose. Lines delineate non-significant differences ($P > 0.05$) using Duncan's multiple range test (Duncan, 1955). Symbols used for irreversible loss and total entry rate of glucose are I and T respectively.

Source	Analysis of Variance			Duncan's Test					
	Degrees of freedom	Mean square	F value	M	S	I	T	SHT	
(1) Single injection of [$U-^{14}C$]glucose with [$6-^3H$]glucose									
(a) Glucose pool									
Sheep	1	.437	7.53						
Method	3	.002	0.03						
Sheep x method	3	.058							
(b) Glucose space									
Sheep	1	3.130	2.14						
Method	3	0.125	0.09						
Sheep x method	3	1.460							
(c) Glucose kinetics									
Sheep	1	356.00	42.10**						
Method	4	5.20	0.61						
Sheep x method	4	8.46							
(2) Single injection of [$U-^{14}C$]glucose with [$3-^3H$]glucose									
(a) Glucose pool									
Sheep	3	2.270	73.2**						
Method	3	.050	1.6						
Sheep x method	9	.031							
(b) Glucose space									
Sheep	3	5.560	9.00**						
Method	3	0.563	0.91						
Sheep x method	9	0.618							
(c) Glucose kinetics									
Sheep	3	41.6	3.50*	MCT	MHI	SCT	MCT	SHT	
Method	4	101.0	8.49**	60.4	68.5	69.4	70.2	74.1	
Sheep x method	12	11.9							
(3) Single injection of [$U-^{14}C$]glucose with [$2-^3H$]glucose									
(a) Glucose pool									
Sheep	3	1.740	35.50**	MH	MC	SC	SH		
Method	3	0.292	5.96*	4.52	4.93	5.00	5.15		
Sheep x method	9	0.049							
(b) Glucose space									
Sheep	3	16.10	15.90**	MH	MC	SC	SH		
Method	3	4.73	4.68*	18.8	20.5	20.8	21.3		
Sheep x method	9	1.01							
(c) Glucose kinetics									
Sheep	3	213.00	62.1**	MCI	SCT	MHI	MCT	SHT	
Method	4	83.30	24.3**	55.2	62.1	62.1	65.1	67.4	
Sheep x method	12	3.43							

* P < 0.05, ** P < 0.01

Table A5-3. Zero-time intercepts and rate constants of multiexponential components describing the SR-time curve of bicarbonate of jugular blood between 0.5 and 31 h after an intravenous injection of [$U-^{14}C$]glucose

Sheep no.	Sheep wt (kg)	Zero-time intercepts ($\mu\text{Ci/g C}$)			Rate constants (min^{-1})			Residual standard deviation
		a_1	a_2	a_3	m_1 ($\times 10^1$)	m_2 ($\times 10^2$)	m_3 ($\times 10^3$)	
196	34.1	-40.4	33.0	.512	.546	.546	.26	.0568
170	30.8	-40.4	41.2	.832	.194	.632	.35	.0795

WATER HYDROGEN MODELIntroduction

Till and Downes (1962) reported that total water and its rate of turnover in sheep can be measured by consideration of the SR-time curve of blood water following intravenous injections of tritiated water. These calculations were based on the assumption that the linear decline in log SR of blood water from about five hour post-injection of tracer reflects the loss of water hydrogen from a single pool. Such interpretation of the disappearance curve of tritium from blood water appears oversimplified since further information can be gained by compartmental analysis (see Steele, 1964; Baker, 1969).

The greater delay in equilibration of tritium in body water in ruminants than apparently for example, in the normal hydrated human (Prentice, Siri, Berlin, Hyde, Parsons, Joiner and Lawrence, 1952; Fowle, Matthews and Campbell, 1964) could be the result of a greater volume of water in the intestinal tract of ruminants, especially the rumen (Shumway, Trujillo, Bennett, Matthews and Asplung, 1956; Till and Downes, 1962). Thus, it is possible that the initial decline in the SR of blood water which precedes the rectilinear phase of the log (SR) - time curve following intravenous injections of tritiated water largely represents the mixing of tritiated water in the rumen.

Results and Theory

The SR-time curves of hydrogen of blood water of sheep 20 and 196 following intravenous injections of tritiated water (see Figure 5-3) were well described by an equation of the form:

$$SR_t = a_1 e^{-m_1 t} + a_2 e^{-m_2 t} \quad \dots A5-1$$

and the a and m values are given in Table A5-2.

Table A5-4. Zero-time intercepts and rate constants of exponential components describing the specific radioactivity-time curve of water hydrogen of jugular blood of sheep given single injections of tritiated water

Sheep no.	Sheep wt (kg)	Zero-time intercepts (nCi/mg H)		Rate constants (min ⁻¹)		Residual standard deviation
		a ₁	a ₂	m ₁ (x10 ¹)	m ₂ (x10 ⁴)	
20	37.3	.212	.360	.358	.9	.0228
196	34.7	.112	.397	.164	.7	.0217

With reference to the proposed two compartmental model shown in Figure A5-1, the pool sizes of water hydrogen in compartments 1 and 2 were calculated using the a values from equation A5-1 as follows:

$$Q_1 (\text{mg}) = \frac{a_1}{a_1 + a_2} \quad \dots A5-2$$

and,

$$Q_2(\text{mg}) = \frac{q_{01}}{a_2} - Q_1 \quad \dots \text{A5-3}$$

where q_{01} is the dose of tritiated water injected (nCi) into compartment 1. The transport rates (R , mg H/min) for the model were determined from the a and m values in equation A5-1 by means of the following algebraic method, which was based in part on the procedure given by Rescigno and Segre (1966).

Boundary Conditions

Figure A5-1 is considered to be in the steady state and rates at which all processes occur are assumed to be constant. Thus the total flow of water hydrogen into each compartment must equal its total out flow. Then,

$$\begin{aligned} R_{10} + k_{12}Q_2 &= (k_{21} + k_{01})Q_1 \\ R_{20} + k_{21}Q_1 &= k_{12}Q_2 \end{aligned} \quad \dots \text{A5-4}$$

where k_{ij} is the fraction of water hydrogen in compartment j entering compartment i per min.

When the tritium (q_{01}) is injected into compartment 1 at time, $t = 0$:

$$q_1 = q_{01}; q_2 = 0$$

where q_i is the quantity of tritium instantaneously present in compartment i .

Formulation of Flow Equations

The equations describing the change in the tritium content in each of the pools with respect to time are:

$$\begin{aligned} \text{pool 1: } \frac{dq_1}{dt} &= - (k_{21} + k_{01})q_1 + k_{12}q_2 & \dots A5-5 \\ \text{pool 2: } \frac{dq_2}{dt} &= k_{21}q_1 - k_{12}q_2 \end{aligned}$$

Solution of Equations

Applying the Laplace transforms Lq_1 and Lq_2 of q_1 and q_2 , equation A5-5 becomes:

$$\begin{aligned} sLq_1 - q_{01} &= - (k_{21} + k_{01})Lq_1 + k_{12}Lq_2 & \dots A5-6 \\ sLq_2 &= k_{21}Lq_1 - k_{12}Lq_2 \end{aligned}$$

where s is the Laplace operator.

It may be shown from equation A5-6 that:

$$\frac{Lq_1}{q_{01}} = \frac{s + k_{12}}{s^2 + s(k_{21} + k_{12} + k_{01}) + k_{01}k_{12}} \quad \dots A5-7$$

The denominator of equation A5-7, $s^2 + s(k_{21} + k_{12} + k_{01}) + k_{01}k_{12}$, may be simplified to $(s + m_1)(s + m_2)$ where m_1 and m_2 are complex constants which serve to replace other constants.

Hence,

$$s^2 + s(k_{21} + k_{12} + k_{01}) + k_{01}k_{12} = s^2 + s(m_1 + m_2) + m_1m_2 \quad \dots A5-8$$

Therefore,

$$m_1 + m_2 = k_{21} + k_{12} + k_{01} \quad \dots A5-9$$

and

$$m_1 m_2 = k_{01} k_{12} \quad \dots A5-10$$

Rewriting equation A5-7 in terms of m_1 and m_2

$$\frac{Lq_1}{q_{01}} = \frac{s + k_{12}}{(s + m_1)(s + m_2)} \quad \dots A5-11$$

The antittransform of equation A5-11 is:

$$\frac{q_1}{q_{01}} = \frac{(k_{12} + m_1)e^{-m_1 t}}{m_2 - m_1} + \frac{(m_2 - k_{12})e^{-m_2 t}}{m_2 - m_1} \quad \dots A5-12$$

It may be shown from equation A5-1 that:

$$SR_t = a_1 + a_2 \left(\frac{a_1}{a_1 + a_2} e^{-m_1 t} + \frac{a_2}{a_1 + a_2} e^{-m_2 t} \right) \quad \dots A5-13$$

From a consideration of equation A5-2, equation A5-11 may be expressed as:

$$SR_t = \frac{q_{01}}{Q_1} \left[\frac{a_1}{a_1 + a_2} e^{-m_1 t} + \frac{a_2}{a_1 + a_2} e^{-m_2 t} \right] \quad \dots A5-14$$

and

$$\frac{q_1}{q_{01}} = \frac{SR_t Q_1}{q_{01}} = \left[\frac{a_1}{a_1 + a_2} \right] e^{-m_1 t} + \left[\frac{a_2}{a_1 + a_2} \right] e^{-m_2 t} \quad \dots A5-15$$

Hence, from equations A5-12 and A5-15,

$$\frac{a_1}{a_1 + a_2} = \frac{k_{12} - m_1}{m_2 - m_1} \quad \dots A5-16$$

$$\frac{a_2}{a_1 + a_2} = \frac{m_2 - k_{12}}{m_2 - m_1}$$

Thus the transport rates given in Figure A5-1 may be calculated by substituting the values for a_i and m_i (see Table A5-4) in equations A5-9, A5-10, A5-16 and A5-5.

Discussion

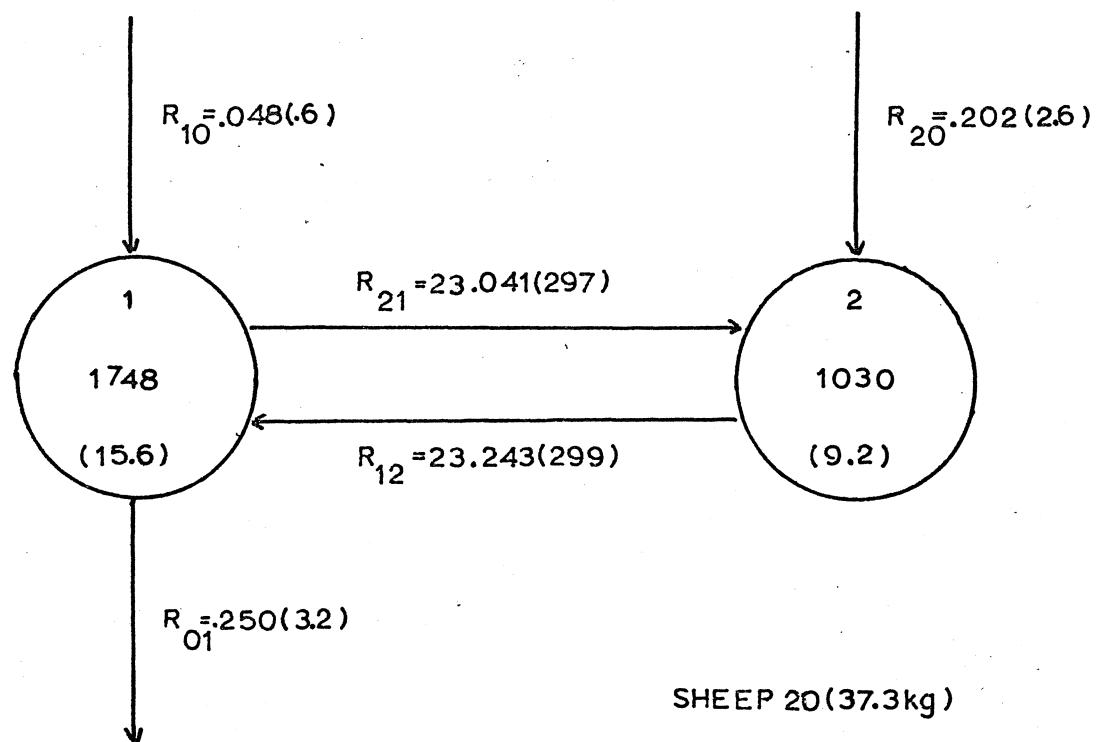
The disappearance curves of tritiated water from blood were curvilinear on semi-logarithmic co-ordinates, indicating that a multi-compartmental system exists for removal of tritium from blood water of sheep. A two-compartmental model was proposed as the minimal model necessary to explain these observed disappearance curves (see Figure A5-1).

The estimates given in Figure A5-1 for the volume of water in the rumen and the rapid transport rates of water across the ruminal wall appear reasonable in view of the large and variable

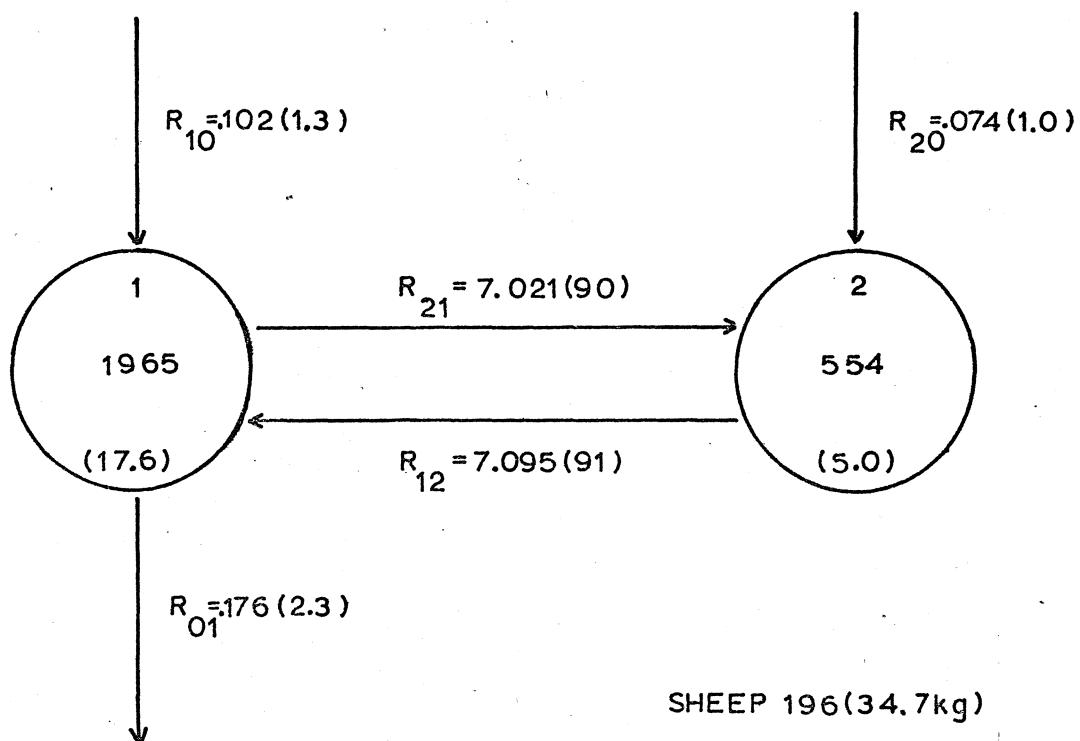
volume of ruminal fluid in sheep (Downes and McDonald, 1964) and from studies of water fluxes across the rumen wall of goats (Engelhardt, 1970) and sheep (Willes, Mendel and Robblee, 1970). The predicted intakes of water by sheep were in accord with values published by Clark and Quin (1947-9) although estimates of metabolic water, which are depicted as entry of water from outside the system into compartment 1 (Figure A6-1) appear excessive for sheep given a ration of 800 g lucerne chaff daily. If it is assumed that carbohydrates were the major constituent of roughage digested (which is equivalent to 1,900 kcal per day for these sheep), metabolic water arising from the oxidation of this carbohydrate would probably not exceed .5 l/day (van Es, 1967). These estimates of water transport rates can only be regarded as approximate since the data were minimal. Pool sizes and transport rates for water may have been over-estimated because of the possible exchange of water hydrogen with protein hydrogen (see Siri and Evers, 1962; Springell, 1968), and the incorporation of water hydrogen into organic molecules such as glucose (Figure A5-3). However, this technique warrants further investigation to assess whether it may be useful for predicting the volume of water in the rumen of intact animals.

Figure A5-1. A two-compartmental model of water hydrogen kinetics in fed sheep compatible with the disappearance curve of tritium from blood water. Compartment 1 was assumed to represent a pool of water hydrogen (g) in the body and alimentary tract except for the water hydrogen (g) in the rumen (compartment 2). R_{ij} denotes the transport rate of hydrogen (g/min) from compartment j to compartment i. R_{01} , production of metabolic water by tissues; R_{02} , entry of water into the rumen from feed and drink; R_{21} , entry of endogenous water into the rumen by absorption and in saliva; R_{12} , loss of water from the rumen by absorption and flow to the lower intestinal tract; and R_{01} , loss of water in urine, faeces, expired air and by any other means of irreversible disposal. Equivalent values in litres of water and litres per day for compartment sizes and transport rates respectively are given in parentheses.

AS



SHEEP 20 (37.3kg)



SHEEP 196 (34.7kg)