

CHAPTER 7

GENERAL DISCUSSION

The studies described in the experimental Chapters of this thesis, focus primarily upon the improvement, by genetic means, of the reproduction rate of the Merino breed in Australia. This industry is characterised by low lambing rates when compared to sheep breeding industries in many other countries. Bindon and Piper (1976) have identified the major limiting factors which restrict improvement in reproduction rate in Merino flocks in Australia, and among the most important of these are the inherent low prolificacy of the Merino breed and the high emphasis, in selection programmes, which is placed on the maintenance and improvement of production of wool free from contamination by pigmented fibres. The great majority of the prolific breeds found throughout the world are characterised by either coarse or pigmented fibres, and this factor has largely ruled out improvement of the prolificacy of Merino flocks by crossbreeding with exotic breeds.

The other major factor which hinders the improvement of reproduction rate in Merino flocks is the environment. The majority of the breeding flocks in Australia are found in the relatively low rainfall areas where control of nutrition of the breeding flock is often achieved through manipulation of stocking rate rather than by supplementary feeding. Not only does the climate limit the expression of "potential" ovulation rate, and hence prolificacy, but also limits the opportunities for exerting adequate selection pressure on the female.

With these factors in mind, the concept advanced by Land (1973), that selection for prolificacy in sheep populations may be enhanced by utilising male "marker" traits which are genetically correlated with female reproductive performance, has particular relevance to genetic improvement of reproduction rate in the Australian Merino industry.

The studies described in Chapters 3, 4 and 5 have aimed at quantifying, in a large random breeding Merino flock, the genetic parameters required to accurately assess whether the use of male reproductive traits as indirect selection criteria for female reproductive performance would be more efficient than the methods currently in use.

Given our lack of knowledge of the factors influencing variation in male reproductive traits in Merino flocks maintained under pastoral conditions, it was considered important to first identify and quantify these sources for the male traits under study. Testicular diameter was chosen as the primary trait to be investigated because of its clear genetic association with female reproductive traits in laboratory animals and also because of its ease of measurement.

The results of the study of testicular diameter in the Trangie D flock, reinforce the conclusions from other studies that the trait is moderately to highly heritable. In addition, the genetic correlations estimated from the repeated monthly measurement data, suggest that during the period from 5 to 12 months of age, the expression of testicular diameter is controlled largely by the same set of genes. Allowing for the fact that the heritability of the trait appeared to be lower at 5 months of age, which was thought to be due to masking by maternal influences, the results suggest that ram selection on

testicular size could be successfully practiced from 6-7 months of age. However, it was not until the rams were aged 9-10 months that the penalty of being born as a twin or triplet became non-significant. Therefore ram selection indices for flocks maintained under similar nutritional conditions to those pertaining to this study and which include testicular diameter as a criterion, should ideally utilise a measure taken between 10 and 12 months of age.

The phenotypic and genetic relationships between liveweight and testicular diameter were positive at all ages in the study. However, liveweight at weaning age was not closely correlated, phenotypically and genetically, with testicular size at later ages. Evidence was also found from the examination of testicular diameter at specific liveweights, that at a liveweight typical of an immediate pre-weaning stage of development (17kg), testicular diameter was lowly and sometimes negatively correlated with testicular diameter at higher liveweights. These findings suggest, again, that selection decisions using testicular diameter as a criterion may be better delayed until at least 10 months of age.

The study of serving capacity in the 20-month old rams of the Trangie D flock was highlighted by the absence of additive genetic variation in the measures of sexual performance studied. The relative instability of sexual performance, at both ends of the scale, suggests that the provision of 2 introductory tests of 20 minutes duration was insufficient to allow the establishment of stable behavioural patterns. Further studies of the effect of heterosexual experience prior to testing of young rams for serving capacity, are required to establish the effect of such treatment on both the incidence of sexual

inhibition and on adult levels of serving performance. There also remains the necessity for further investigations of the relationship between pen- and yard-test performance and paddock-mating performance of young rams. Such studies, however, may have to await the further development of remote electronic sensing technology for more labour-efficient monitoring of paddock mating activity.

Genetic relationships between male and female reproductive traits were the subject of the study reported in Chapter 5. Estimates of genetic correlations between testicular diameter and ovulation rate at various ages were derived using dam-son and paternal half-sib covariance methods. In the former case, the method required the use of genetic variances which were not derived from exactly the same population as were the covariance estimates. However, by regarding the correlation estimate, at each age, as a small sample estimate, and pooling across ages, where appropriate, more precise estimates were obtained. Likewise, with the paternal half-sib REML method, starting values of genetic variances and covariances for this iterative procedure, were derived from closely related but not identical populations. It was possible, however, by a pooling procedure to arrive at one overall estimate of the half-sib genetic correlation between testicular diameter at 5-12 months of age and ovulation rate at 18-54 months of age.

The overall pooled values of 0.35 ± 0.08 and 0.16 ± 0.11 estimated by the dam-son and paternal half-sib covariance methods, respectively, differ substantially in their practical impact when used in simple selection response equations. When considering the implications of these 2 estimates, it is relevant to note that in comparison to the

half-sib estimate, that calculated from the dam-son covariances includes a larger contribution due to possible epistatic effects. In selection schemes, where the sire-daughter covariation will be the medium through which selection will act, epistasis of similar magnitude could be expected.

From a practical viewpoint, the results of the studies described in Chapters 3 and 5 provide only the starting points for a detailed evaluation of the use of testicular size as a criterion in ram selection indices. The genetic parameters estimated in these studies will, however, allow a far more rational evaluation of the use of testicular size as a selection criterion for Merino flocks maintained under pastoral conditions than has been the case to date. Further studies of the economic benefits of increasing testicular size, from the viewpoint of "current flock" fertility are required.

Chapter 6 described investigations of the expression of the Booroola Merino F gene in the male phenotype. Whereas the other Experimental Chapters in this Thesis have described studies of traits under the control of many genes of small effect, in Chapter 6 we were concerned with the expression of a gene which has been shown to have a major effect on the female. In retrospect, the expectation that the expression of the F gene should be evidenced in both sexes as a deregulation of gamete release by the gonad, ignores fundamental differences in the endocrine characteristics of the two sexes. Given the differences between the sexes in the plasma concentrations of both gonadotrophins and steroids, it could be expected that there would exist substantial differences between the sexes in the threshold levels of hormones which are required to trigger germ and somatic cell

differentiation and growth. Such differences could easily mask the effect of a gene in one sex, no matter how dramatic its effect in the other. In the extreme case, the differential effect of a gene in the two sexes could produce quite dissimilar endocrine profiles in peripheral plasma of male and female F gene carriers, when comparisons with non-carriers are made. Therefore the explanation for the differences between F gene carriers and non-carriers found in the study of LH profiles at 10 weeks of age, should not be argued from the basic knowledge we have from similar studies with females. Rather, this finding demands more detailed studies of males of equivalent genotypes around this critical age (and liveweight), with a view to fully characterising gonadotrophin and steroid profiles. Such investigations would also serve as a replicate of the study described in Chapter 6, thereby increasing the power of the comparisons between the genotypes.

REFERENCES

- Ahmed, S. I. (1955). The effect of testosterone and pregnant mare serum on semen production of rams of low libido. J. Agric. Sci. Camb. **46**: 168-172.
- Alberio, R. and Colas, G. (1976). Influence of photoperiodism on the sexual development of the young Ile-de-France ram. 8th Inter. Congr. Anim. Reprod. Artif. Insem. Krakow. **3**: 26-29.
- Allison, A. J. (1978). Flock mating in sheep. IV Effect of number of ewes per ram on ejaculate characteristics and libido during the mating period. NZ. Jl. Agric. Res. **21**: 187-195
- Amann, R. P. (1970). Sperm production rates. In "The Testis", 1st Ed. Eds. Johnson, A. D., Gomes, W. R. and Van Demark, N. L., Academic Press, New York, Vol. 1, pp. 443-483.
- Amann, R.P. and Almquist, J.O. (1961). Reproductive capacity of dairy bulls. 1. Technique for direct measurement of gonadal and extra-gonadal sperm reserves. J. Dairy Sci. **44**: 1437-1543.
- Amir, D. and Volcani, R. (1965). Seasonal fluctuation in the sexual activity of Awassi, German Mutton Merino, Corriedale, Border Leicester, and Dorset Horn rams. II. Seasonal changes in semen characteristics. J. Agric. Sci. **64**: 121-125.
- Atkins, K. D. (1980). Selection for skin folds and fertility. Proc. Aust Soc. Anim. Prod. **13**: 174-176.
- Banks, E. M. (1964). Some aspects of domestic behaviour in domestic sheep, Ovis aries. Behaviour **23**: 249-278.
- Baker, R.L., and Morris, C.A. (1982). Selection for early puberty and increased fertility at first mating. 2nd Wld. Congr. Genet. Appld. Livest. Prod. Ed. Garsi. Madrid, Spain **V**: 282-293.
- Barrel, G. K. and Lapwood, K. R. (1978). Seasonality of semen production and plasma LH, testosterone and prolactin levels in Romney, Merino and polled Dorset rams. Anim. Reprod. Sci. **1**: 213-228.
- Barrel, G. K. and Lapwood, K. R. (1979). Effects of various lighting regimes and pinealectomy on semen production in Romney rams. J. Reprod. Fert., **57**: 273-279.
- Benoff, F.H. and Siegel, P.B. (1977). Crowing and mating behaviour in lines of chickens selected for mating frequency. Appl. Anim. Ethol. **3**: 247-254.
- Biddiscombe, E. F., Cuthbertson, E.G. and Hutchings, R.J. (1954). Autecology of some natural pasture species at Trangie, NSW. Aust. J. Botany, **2**(1): 68-98.
- Bindon, B. M. (1973). Genetic differences in plasma luteinising hormone of pre-pubertal lambs. J. Reprod. Fert. **32**: 347-348.
- Bindon, B. M. (1984). Reproductive biology of the Booroola Merino sheep. Aust. J. Biol. Sci. **37**: 163-189.
- Bindon, B.M., Findlay, J.K. and Piper, L.R. (1985). Plasma FSH and LH in prepubertal Booroola ewe lambs. Aust. J. Biol. Sci. **38**: 215-220.

- Bindon, B. M. and Piper, L. R. (1976). Assessment of new and traditional techniques of selection for reproduction rate. In "Sheep Breeding". Proc. Inter. Congr. Muresk, Perth. August, 1976. Eds. Tomes, G.J., Robertson, D.E., and Lightfoot, R.J. WA Inst. Tech., Perth. pp 357-371.
- Bindon, B. M. and Piper, L. R. (1982). Physiological characteristics of high fecundity sheep and cattle. Proc. Wld. Congr. Sheep and Cattle Breed. Eds. Barton, R. A. and Smith, W. C. Dunsmore Press Ltd. Palmerston North, New Zealand. I. pp. 315-331.
- Bindon, B. M., Piper, L. R. and Evans, R. (1982). Reproductive biology of the Booroola Merino. In "The Booroola Merino: Proceedings of a Workshop". Eds. Piper, L. R., Bindon, B. M., Nethery, R. D. CSIRO, Melbourne, Australia. pp. 21-34.
- Bindon, B. M., Piper, L. R. and Thimonier, J. T. (1984). Pre-ovulatory LH characteristics and time of ovulation in the prolific Booroola Merino ewe. J. Reprod. Fert. 71: 519-533.
- Bindon, B. M. and Turner, H. N. (1974). Plasma LH of the pre-pubertal lamb: A possible early indicator of fecundity. J. Reprod. Fert. 39: 85-88.
- Blanc, M.R. and Terqui, M. (1976). Determination of the age of establishment of the inhibin-follicle stimulating hormone feed-back mechanism in the ram lamb. IRCS. Med. Sci. Bull. 4: 17.
- Blockey, M. A. deB. (1976). Serving Capacity - a measure of the serving efficiency of bulls during pasture mating. Theriogenol. 6: 393-401
- Blockey, M. A. deB. (1983). Mating management of rams. Sheep and Wool Officer's Seminar. Vic. Dept. Agric. Melbourne, June, 1983.
- Blockey, M. A. DeB., Straw, W. M. and Jones, L. P. (1981). Heritability of scrotal circumference and serving capacity of bulls. Proc. 2nd Conf. Aust. Assoc. Anim. Breed. Genet. Melbourne, p. 244.
- Bourke, M. E. (1967). A study of mating behaviour of Merino rams. Aust. J. Exp. Agri. Anim. Husb. 7: 203-205.
- Bradford, G. E. (1972). Genetic control of litter size in sheep. J. Reprod. Fert. Suppl., 15: 23-41.
- Bremner, W. J., Cumming, I. A., Williams, D. M., de Kretser, D. M. and Lee, V. W. K. (1981). The effect of intrauterine gonadectomy on fetal and neonatal gonadotrophin secretion in the lamb. J. Reprod. Fert. Suppl. 30: 61-66.
- Brinks, J. S., McInerney, M. J. and Chenoweth, P. J. (1978). Relationship of age at puberty in heifers to reproductive traits in young bulls Proc. West. Sect. Amer. Soc. Anim. Prod. 29: 28-30.
- Burfening, P. J. and Tulley, D. (1982). Effect of selection for high and low prolificacy on libido and scrotal circumference. 2nd Wld. Congr. Genet. Appld. Livest. Prod. Ed. Garsi. Madrid, Spain VII. pp. 536-542.
- Butterfield, R.M., Griffiths, D.A., Thompson, J.M., Zamora, J. and James, J.M. (1983) Changes in body composition relative to weight and maturity in large and small strains of Merino rams. 1. Muscle, bone and fat. Anim. Prod. 36: 29-37.

- Cahill, L. P., Blockey, M. A. deB. and Parr, R. A. (1975). Effects of ram behaviour and ram libido on the fertility of young ewes. Aust. J. Exp. Agric. Anim. Husb. 15: 337-341.
- Cahill, L. P., Saumande, J., Ravault, J. P., Blanc, M., Thimonier, J., Mariana, J. and Mauleon, P. (1981). Hormonal and follicular relationships in ewes of high and low ovulation rates. J. Reprod. Fert. 62: 141-150.
- Carmen, J. L. and Green, W. W. (1952). Histological study of the development of the testis of the ram. J. Anim. Sci. 11: 674-687.
- Carr, W.R. and Land, R.B. (1975). Plasma LH levels and testis diameters of ram lambs of different breeds. J. Reprod. Fert. 42: 325-333.
- Catt, K. J. and Dufau, M. L. (1976). Basic concepts of the mechanism of action of peptide hormones. Biol. Reprod. 14:1-15.
- Clarke, J. N. (1972). Current levels of performance in the Ruakura Fertility flock of Romney sheep. Proc. N.Z. Soc. Anim. Prod. 32: 99-111.
- Colas, G. and Zinszner, F. (1975). Production spermatique et developpement testiculaire chez de l'agneau de race Ile-de-France et Pre-alpes. 1eres Journees de la Recherche Ovine et Caprine, 'Les Races prolifiques' Ed. Itovic. pp. 235-243.
- Colyer, R. J. (1971). Development of the testis and epididymis of the Clun Forest ram. J. Agric. Sci. Camb. 76: 433-441.
- Coulter, G.H. and Siegel, P.B. (1980). Scrotal circumference and its heritability in yearling bulls. J. Anim. Sci. 49 (Suppl.1): 288-289.
- Courot, M. (1962). Developpement du testicule chez l'agneau. Etablissement de la spermatogenese. Ann. Biol. anim. Biochim. Biophys. 2: 25-41.
- Courot, M. (1965). Action des hormones gonadotropes sur le testicule de l'agneau. Ann. Biol. anim. Biochim. Biophys. 5: 145-149.
- Courot, M. (1971). Etablissement de la spermatogenese chez l'agneau (Ovis aries). Etude experimentqale de son controle gonadotrophe; importance des cellules de la lignee sertolienne. These Doct. Sci., Paris, CNRS, No. 6317.
- Courot, M. (1976). Semen quality and quantity in the ram. In "Sheep Breeding". Proc. Inter. Congr., Muresk, Perth, August, 1976. Eds. Tomes, G.J., Robertson, D.E. and Lightfoot, R.J. WA Inst. Tech. Perth pp. 276-285.
- Courot, M., Hochereau de Reviers, M. T. and Ortavant, R. (1970). Spermatogenesis. In "The Testis" 1st. Ed. Eds. Johnson, A. D., Gomes, W. R. and Van Demark, N. L., Academic Press, New York. Vol. 1, pp. 339-432.
- Courot, M. and Ortavant, R. (1981). Endocrine control of spermatogenesis in the ram. J. Reprod. Fert. Suppl. 30: 47-60.

- Courot, M., de Reviere, M. M. and Pelletier, J. (1975). Variations in pituitary and blood LH during puberty in the male lamb. Relation of time of birth. Ann. Biol. anim. Biochim. Biophys. 15: 509-516
- Cummins, L. J., Bindon, B. M., Lee, V. W. K. and Findlay, J. K. (1983). Ovarian inhibin content and sensitivity to inhibin in Booroola and control strain Merino ewes. J. Reprod. Fert. 67: 1-7
- Cundiff, L. V., Gregory, K. E. and Koch, R. M. (1982). Selection for increased survival from birth to weaning. 2nd. Wld. Congr. Genet. appl. Livest. Prod. Ed. Garsi. Madrid, Spain. VI. pp. 107-116.
- Cunningham, E.P. (1969). Animal Breeding Theory. Internordic Licentiat. Course in Quantitative Genetics. Landbruksbokhandelen/Universitetsforlaget. Oslo.
- Curtis, Y. M., Cheers, M. A., Nethery, R. D., Piper, L. R. and Bindon, B. M. (1980). Testis size in Booroola and control Merino crossbred rams. Proc. Aust. Soc. Reprod. Biol. 12: 7.
- Dacheaux, J. L., Pisselet, C., Blanc, M. R., Hochereau de Reviere, M. T. and Courot, M. (1981). Seasonal variations in rete testis fluid secretion and sperm production in different breeds of ram. J. Reprod. Fert. 61: 363-371.
- Davis, G. H., Montgomery, G. M., Allison, A. J., Kelly, R. W. and Bray, A. R. (1982). Segregation of a major gene influencing fecundity in progeny of Booroola sheep. NZ. Jl. Agric. Res. 25: 525-529.
- Draper, N. R. and Smith, H. (1966). Applied Regression Analysis. Wiley New York.
- Dun, R. B. (1955). Puberty in Merino rams. Aust. Vet. J. 31: 104-106.
- Dun, R. B. (1964). Skin folds and Merino breeding. 1. The net reproductive rates of flocks selected for and against skin fold. Aust. J. Exp. Agric. Anim. Husb. 4: 376-385.
- Dun, R.B. and Eastoe, R.D. (1970). Science and the Merino breeder. NSW Government Printer. Sydney.
- Dyrmundsson, O.R. (1972). Studies on the attainment of puberty and reproductive performance in Clun Forest ewe and ram lambs. PhD Thesis. University College of Wales. Aberystwyth, UK.
- Dyrmundsson, O. R. (1973). Puberty and early reproductive performance in sheep. II. Ram lambs. Anim. Breed. Abstr. 41: 419-430.
- Dyrmundsson, O. R. and Lees, J. L. (1972). Puberal development of Clun Forest ram lambs in relation to time of birth. J. Agric. Sci. Camb. 79: 83-89.
- Edey, T. N., Kilgour, R. and Bremner, K. (1978). Sexual behaviour and reproductive performance of ewe lambs at and after puberty. J. Agric. Sci., Camb. 90: 83-91.
- Eisen, E. J. and Johnson, B. M. (1981). Correlated responses in male reproductive traits in mice selected for litter size and body weight. Genetics. 99: 513-524.

- Echternkamp, S.E. and Laster, D.B. (1976). Plasma LH concentrations for prepubertal, postpubertal, anoestrous, and cyclic ewes of varying fecundity. J. Anim. Sci. **42**: 444-447.
- Falconer, D. S. (1981). "Introduction to Quantitative Genetics". 2nd Edition, London and New York, Longman.
- Findlay, J. K. and Bindon, B. M. (1976). Plasma FSH in Merino lambs selected for fecundity. J. Reprod. Fert. **46**: 515.
- Fletcher, I. C. (1976). Sexual activity in Merino rams. In "Sheep Breeding". Proc. Inter. Congr. Muresk, Perth, August, 1976. Eds. Tomes, G. J., Robertson, D. E. and Lightfoot, R. J. W.A. Inst. Tech, Perth. pp. 345-351.
- Fogarty, N. M., Lunstra, D. D., Young, L. D. and Dickerson, G. E. (1980). Breed effects and heritability of testis size in sheep. J. Anim. Sci. **51**: Suppl. 1: 117.
- Foster, D. L., Cruz, T. A. C., Jackson, G. L., Cook, B. and Nalbandov, A. V. (1972). Regulation of luteinising hormone in the fetal and neonatal lamb. III. Release of LH by the pituitary in vivo in response to crude ovine hypothalamic extract or purified porcine gonadotrophin releasing factor. Endocrinology. **90**: 673-690
- Foster, D. L., Mickelson, I. H., Ryan, K. D., Coon, G. A. Drongowski, R. A. and Holt, J. A. (1978). Ontogeny of pulsatile luteinising hormone and testosterone secretion in male lambs. Endocrinology. **102**: 1137-1146.
- Fowler, D. G. (1975). Mating activity and its relationship to reproductive performance in Merino sheep. Appl. Anim. Ethol. **1**: 357-368.
- Fowler, D. G. and Jenkins, L. D. (1976). The effects of dominance and infertility on rams reproductive performance. Appl. Anim. Ethol. **2**: 327-337.
- Gidley-Baird, A.A. and Bindon, B.M. (1976). Solid phase assay for luteinising hormone in mouse plasma. Aust. J. Biol. Sci. **29**:105-116.
- Goddard, M.E. (1980). Behaviour Genetics and Animal Production. In "Reviews in Rural Science. 4. Behavior in relation to reproduction, management and welfare." Eds. Wodzicka-tomaszewska, M., Edey, T.N. and Lynch, J.J. New England Univ. Press. pp. 29-36.
- Goerke, T. P., Thrift, F. A. and Dutt, R. H. (1970). Heritability of semen traits and their relation to fertility in Southdown sheep. J. Anim.Sci. **31**: 445-450.
- Hammond, K. and Nicholas, F.W. (1972). Sampling variance of the correlation coefficients estimated from two-fold nested and offspring-parent regression analyses. Theoret. and Appld. Genet. **42**: 97-100.
- Hanrahan, J. P. (1974). Ovulation rate as a selection criterion for fecundity in sheep. Proc. 1st Wld. Congr. Genet. Appld. Livest. Prod. Ed. Garsi. Madrid, Spain. **III**: 1033-1038.

- Hanrahan, J. P. (1979). Genetic and phenotypic aspects of ovulation rate and fecundity in sheep. Paper presented to the 21st British Poultry Breeders Roundtable, Glasgow.
- Hanrahan, J. P. (1980). Ovulation rate as the selection criterion for litter size in sheep. Proc.Aust. Soc. Anim. Prod. **13**: 405-408.
- Hanrahan, J. P. (1982). Selection for increased ovulation rate, litter size and embryo survival. 2nd Wld. Congr. Genet. Appld. Livest. Prod. Ed. Garsi. Madrid, Spain **V**: 294-309.
- Hanrahan, J. P. and Quirke, J.F. (1982). Selection on ovulation rate in sheep aided by the use of superovulation and egg transfer. Proc. Wld. Congr. Sheep and Cattle Breed. Eds. Barton, R. A. and Smith, W. C. Dunsmore Press Ltd. Palmerston North, New Zealand. **I**. pp. 329-335.
- Hanrahan, J.P., Quirke, J.F. and Gosling, J.P. (1977). Genetic and non-genetic effects on plasma LH concentrations in lambs at 4 and 8 weeks of age. J. Reprod. Fert. **51**: 343-349.
- Hanrahan, J. P. and Timon, V. M. (1978). Response to selection for increased litter size in Galway sheep. Anim. Prod. **26**: 372.
- Harvey, W.R. (1982). Mixed model capabilities of LSML76. J. Anim. Sci. **54**: 1279-1285.
- Haughey, K. G. (1959). Preliminary report on a tupping survey, Ashburton County 1957-1958. Sheepfarming Annual (New Zealand) : 17.
- Haughey, K.G. (1983). Selective breeding for rearing ability as an aid to improving lamb survival. Aust. Vet. J. **60**: 361-363.
- Haughey, K.G. (1984). Can rearing ability be improved by selection? In "Reproduction in Sheep". Eds. Lindsay, D. R. and Pearce, D.T. Aust. Acad. Sci. Canberra. pp. 237-239.
- Hawker, H. H. (1976) The effect of age on sheep production in an arid environment. PhD. Thesis, University of NSW.
- Henderson, C.R. (1973). Sire evaluation and genetic trends. In Proc. Anim. Bred. Genet. Symp. in honour J.L. Lush. U.S.A. ASA and ADSA. pp. 10-41.
- Hochereau de Reviers, M. T. (1981). Control of spermatogonial multiplication. In "Reproductive Processes and Contraception". Eds. McKerns, K. W. Plenum Publishing Co. 1981 pp. 307-331.
- Hochereau de Reviers, M. T. and Courot. M. (1978). Sertoli cells and development of seminiferous epithelium. Ann. Biol. Anim. Biochim. Biophys. **18**: 573-583.
- Hochereau de Reviers, M. T., Loir, M. and Pelletier, J. (1976). Seasonal variations in the response of the testis and LH levels to hemicastration of adult rams. J. Reprod. Fert. **46**: 206-209.
- Howles, C. M., Webster, G. M. and Haynes, N. B. (1980). The effect of rearing under a long or short photoperiod on testis growth, plasma testosterone, and prolactin concentrations and the development of sexual behaviour in rams. J. Reprod. Fert. **60**: 437-447.

- Hulet, C.G., Ercanbrack, S.K., Price, D.A., Blackwell, R.L. and Wilson, L. O. (1962a). Mating behaviour in the one-sire pen. J. Anim. Sci. 21: 857-864.
- Hulet, C.G., Ercanbrack, S.K., Blackwell, R.L., Price, D.A. and Wilson, L.O. (1962b). Mating behaviour of the ram in the multi-sire pen. J. Anim. Sci. 21: 865-869.
- Hulet, C. V., Blackwell, R. L. and Ercanbrack, S. K. (1964). Observations on sexually inhibited rams. J. Anim. Sci. 23: 1095-1097.
- Hultnas, C. A. (1959). Studies on variation in mating behaviour and semen picture in young bulls of the Swedish Red-and-White breed and on causes of this variation. Acta. Agric. Scand. 9 (Suppl.) 1-82.
- Illius, A. W., Haynes, N. B. and Lamming, G. E. (1976). Effects of ewe proximity on peripheral plasma testosterone levels and behaviour in the ram. J. Reprod. Fert. 48: 25-32.
- Islam, A. B. M. M., Hill, W. G. and Land, R. B. (1976). Ovulation rate of lines of mice selected for testis weight. Genet. Res. (Camb.) 27: 23-32.
- Islam, A. B. M. M. and Land, R. B. (1977). Seasonal variation in testis diameter and sperm output of rams of breeds of different prolificacy. Anim. Prod. 25: 311-317.
- Jackson, N. (1983). Effect of ignoring full-sib relationships when making half-sib estimates of heritability. Theor. Appl. Genet. 65: 61-69.
- Jacubec, V. (1977). Productivity of crosses based on prolific breeds of sheep. Livest. Prod. Sci. 4: 379-392.
- Jegou, B., Dacheau, J. L., Garnier, D. H., Terqui, M., Colas, G. and Courot, M. (1979). Biochemical and physiological studies of androgen-binding protein in the reproductive tract of the ram. J. Reprod. Fert. 57: 311-318.
- Johnston, I. L. (1948). The growth and development of the penis in sheep: their possible relationship to posthitis. Aust. Vet. J. 24: 86-88.
- Kelly, R. W., Davis, G. H. and Allison, A. J. (1980). Productive changes in long wool breeds in New Zealand following crossbreeding with Booroola-type rams. Proc. Aust. Soc. Anim. Prod. 13: 413-416.
- Kilgour, R. and Winfield, C. G. (1974). Sheep mating behaviour. N.Z. Jl. Agric. 128(4): 17-23.
- Kilgour, R. J. (1980). The assessment and significance of sexual drive in the ram. In "Reviews in Rural Science. 4. Behaviour in relation to reproduction, management and welfare." Eds. Wodzicka-Tomaszewska, M., Edey, T. N. and Lynch, J.J. New England Univ. Press pp.43-46.
- Kilgour, R. J. (1981). The mating performance of rams in pens and its usefulness in predicting flock mating performance. M.Sc.Agr. Thesis. University of Sydney.

Land, R.B., Carr, W.R. and Lee, G.J. (1980). A consideration of physiological criteria of reproductive merit in sheep. In "Selection Experiments in Laboratory and Domestic Animals". Ed. A. Robertson, Slough C.A.B.. pp 147-150.

Land, R.B., Atkins, K.D. and Roberts, R.C. (1983). Genetic improvement of reproductive performance. In "Sheep Reproduction". Ed. W. Haresign. Butterworths. pp 515-536.

- Kilgour, R. J. and Whale, R. G. (1980). The relation between mating activity of rams in pens and subsequent flock mating performance. Aust. J. Exp. Agric. Anim. Husb. 20: 5-8.
- Kilgour, R.J. and Wilkins, J.F. (1980). The effect of serving capacity of the ram syndicate on flock fertility. Aust. J. Exp. Agric. Anim. Husb. 20: 662-666.
- Knight, T. W. (1977). Methods for the indirect estimation of testes weight and sperm numbers in Merino and Romney rams. N.Z. Jl. agric. Res. 19: 211-216.
- Knudson, O. (1960). Testicular biopsy of the bull. Inter. J. Fert. V: 203-208.
- Lahlou Kassi, A. and Marie, M. (1984). Sexual and ovarian function of the D'man ewe. In "Genetics of reproduction in sheep". Eds. Land, R. B. and Robinson, D. W. Butterworths. London. pp. 245-260.
- Lambourne, L. J. (1956). Mating behaviour. Proc. Ruakura farmers Conf. Dept. Agric. Wellington. pp. 16-20.
- Land, R. B. (1973). The expression of female sex-limited characters in the male. Nature, London. 241: 208-209.
- Land, R. B. (1974). Physiological studies and genetic selection for sheep fertility. Anim. Breed. Abstr. 42: 155-158.
- Land, R. B. (1978). Reproduction in young sheep. Some genetic and environmental sources of variation. J. Reprod. Fert. 52: 427-
- Land, R. B. (1981). Physiological criteria and genetic selection. Livest. Prod. Sci. 8: 203-213.
- Land, R. B. and Carr, W. R. (1975). Testis growth and plasma LH concentration following hemicastration and its relation with female prolificacy in sheep. J. Reprod. Fert. 45: 495-501.
- Land, R. B. and Falconer, D. S. (1969). Genetic studies of ovulation rate in the mouse. Genet. Res. Camb., 13: 25-46.
- Land, R. B., Gauld, I. K., Lee, G. J. and Webb, R. (1982). Further possibilities for manipulating the reproductive process. In "Future developments in the genetic improvement of animals." Eds. Barker, J. S. F., Hammond, K. and McClintock, A. E. Academic Press, Sydney. pp. 59-87.
- Land, R.B., Pelletier, J. and Mauleon, P. (1973). A quantitative study of genetic differences in the incidence of oestrus, ovulation and plasma luteinizing hormone concentration in the sheep. J. Endocr. 58: 305-317.
- Land, R. B. and Sales, D. I. (1977). Mating behaviour and testis growth of Finnish Landrace, Tasmanian Merino and Crossbred rams. Anim. Prod. 24: 83-90.
- Lee, V. W. K., Cumming, I. A., de Kretser, D. M., Findlay, J. K., Hudson, B. and Keogh, E. J. (1976a). Regulation of gonadotrophin secretion in rams from birth to sexual maturity. I. Plasma LH, FSH and testosterone levels. J. Reprod. Fert. 46: 1-6.

- Lee, V. W. K., Cumming, I. A., de Kretser, D. M., Findlay, J. K., Hudson, B. and Keogh, E. J. (1976b). Regulation of gonadotrophin secretion in rams from birth to sexual maturity. II Response of the pituitary - testicular axis to LH-RH infusion. J. Reprod. Fert. 46: 7-11.
- Lee, V. W. K., Bremner, W. J., Cumming, I. A., de Kretser, D. M. and Findlay, J. K. (1981). Effects of LH-RH infusion, castration and cryptorchidism on gonadotrophin and testosterone secretion in developing rams. J. Reprod. Fert. Suppl. 30: 111-118.
- Lees, J. (1965). Seasonal variation in the breeding activity of rams. Nature, London. 207: 221-222.
- Lightfoot, R. J. (1968). Studies on the number of ewes joined per ram for flock matings under paddock conditions. II. The effect of mating on semen characteristics. Aust. J. agric. Res. 19: 1043-1057.
- Lincoln, G. A. (1977). Changes in pituitary responsiveness to luteinising releasing hormone in rams exposed to artificial photoperiods. J. Endocr. 73: 519-527.
- Lincoln, G. A. (1979a). Use of a pulsed infusion of luteinising hormone releasing hormone to mimic seasonally induced endocrine changes in the ram. J. Endocr. 83: 251-260.
- Lincoln, G. A. (1979b). Photoperiodic control of seasonal breeding in the ram: participation of the cranial sympathetic nervous system. J. Endocr. 82: 135-147.
- Lincoln, G. A., Almeida, O. F. X. and Arendt, J. (1981). Role of melatonin and circadian rhythms in seasonal reproduction in rams. J. Reprod. Fert. Suppl. 30: 23-31.
- Lincoln, G. A. and Davidson, W. (1977). The relationship between sexual and aggressive behaviour and pituitary and testicular activity during the seasonal sexual cycle of rams and the influence of photoperiod. J. Reprod. Fert. 49: 267-276.
- Lincoln, G. A. and Short, R. V. (1980). Seasonal breeding nature's contraceptive. Recent Progress in Hormone Research. 36: 1-52.
- Lindsay, D.R. (1966). Modification of behavioural oestrus in the ewe by social and hormonal factors. Anim. Behav. 14: 73-83.
- Lindsay, D. R. (1976). Mating behaviour in sheep. In "Sheep Breeding: Proc. Inter. Congr., Muresk, Perth, August, 1976. Eds. Tomes, G. J., Robertson, D. E. and Lightfoot, R. J. W.A. Inst. Tech, Perth. pp. 294-298.
- Lindsay, D. R. and Ellsmore, J. (1968). The effect of breed, season, and competition on mating behaviour in rams. Aust. J. Exp. Agric. Anim. Husb. 8: 649-652.
- Lindsay, D. R., Gherhardi, P. B. and Oldham, C. M. (1976). The effect of feeding a high protein supplement before joining on testicular volume of rams. In "Sheep Breeding". Proc. Inter. Congr., Muresk, Perth, 1976. Eds. Tomes, G. J., Robertson, D. M. and Lightfoot, R. J. W. A. Inst. Tech, Perth. pp. 294-298.

- Lindsay, D. R. and Robinson, T. J. (1961). Studies on the efficiency of mating in the sheep. II. The effects of freedom of rams, paddock size and age of ewes. J. Agric. Sci. (Camb.) **55**: 141-
- Louda, F., Doney, J. M., Stolc, L., Krizek, J. and Smerha, J. (1981). The development of sexual activity and semen production in ram lambs of two prolific breeds: Romanov and Finnish Landrace. Anim. Prod. **33**: 143-148.
- Louw, D. F. and Joubert, D. M. (1964). Puberty in the male Dorper sheep and Boer goat. S. Afr. J. agric. Sci. **7**: 509-520.
- Lyon, M. F. (1977). Genetic nomenclature and nomenclatorial rules in the mouse. Immunogenetics. **5**: 393-403.
- Mann, T. L. J., Taplin, D. E. and Brady, R. E. (1978). Response to partial selection for fecundity in Merino sheep. Aust. J. Exp. Agric. Anim. Husb. **18**: 635-642.
- Marincowitz, G., Pretorius, P. S. and Herbst, S. H. (1966). Dominance in sexual behaviour and mating dexterity in Merino rams. S. Afr. J. Agric. Sci. **9**: 971-980.
- Mason, I.L. (1964). Genetic relations between milk and beef characters in dual-purpose cattle breeds. Anim. Prod. **6**: 31-45.
- Mattner, P. E. (1980). Gonadal hormone control of male sexual behaviour. In "Reviews in Rural Science. 4. Behaviour in relation to reproduction, management and welfare." Eds. Wodzicka-Tomaszewska, M., Edey, T. N. and Lynch, J. J. New England Univ. Press.. pp.11-18.
- Mattner, P. E. and Braden, A. W. H. (1967). Studies in flock mating of sheep. 2. Fertilization and prenatal mortality. Aust. J. Exp. Agric. Anim. Husb. **7**: 110-116.
- Mattner, P. E. and Braden, A. W. H. (1975). Studies of flock mating of sheep. 6. Influence of age, hormone treatment, shearing and diet on libido of Merino rams. Aust. J. Exp. Agric. Anim. Husb. **115**: 330-336.
- Mattner, P. E., Braden, A. W. H. and George, J. M. (1971). Studies in the flock mating of sheep. 4. The relation of libido tests to subsequent service activity of young rams. Aust. J. Exp. Agric. Anim. Husb. **11**: 473-477.
- Mattner, P. E., Braden, A. W. H. and George, J. M. (1973). Studies in the flock mating of sheep. 5. Incidence, duration and effect on flock fertility of initial sexual inactivity in young rams. Aust. J. Exp. Agric. Anim. Husb. **13**: 35-41.
- Mattner, P. E., Braden, A. W. H. and George, J. M. (1973-1974). Ram libido. CSIRO Animal Physiology Annual Report 183-1974. p.3.
- Mattner, P. E., Braden, A. W. H. and Turnbull, K. E. (1967). Studies in flock mating of sheep. 1. Mating behaviour. Aust. J. Exp. Agric. Anim. Husb. **7**: 103-109.

Piper, L.R. (1982). Selection for increased reproduction rate. 2nd World
Congr. Genet. Appld. Livest. Prod. Ed. Garsi. Madrid, Spain, I: 271-280.

- Means, A. R. (1977). Mechanism of action of follicle stimulating hormone (FSH) In "The Testis". Vol. IV. Eds. Johnson, A. D., Gomes, W. R. Academic Press, New York. pp.168-188.
- Means, A. R., Dedman, J. R., Tash, J. S., Tindall, D. J., Sickle, van M. and Welsh, M. J. (1980). Regulation of the testis sertoli cell by follicle stimulating hormone. Ann. Rev. Physiol. 42: 59-70.
- Moule, G. R., Braden, A. W. H. and Mattner, P. E. (1966). Effects of season, nutrition and hormone treatment on the fructose content of ram semen. Aust. J. agric. Res. 17: 923-931
- Nitter, G. (1978). Breed utilisation for meat production in sheep. Anim. Breed. Abstr. 46: 131-143.
- Numerical Algorithm Group. (1984). NAG Fortran Reference Library. MKII. New York.
- Okolski, A. (1975). Effect of various protein levels in feed rations, on sexual behaviour and semen properties in rams. Acta. Agrar. Silvestria. Zootechnia. 15: 101-121.
- Oldham, C. M., Adams, N. R., Gherardi, P. B., Lindsay, D. R. and Mackintosh, J. B. (1978). The influence of level of feed intake on sperm producing capacity of testicular tissue in the ram. Aust. J. agric. Res. 29: 173-179.
- Oldham, C. M., Gray, S. J. and Carrick, M. J. (1984). Testicular growth and the expression of the 'F' gene in young Merino rams. In "Reproduction in Sheep". Eds. Lindsay, D. R. and Pearce, D. T. Aust. Acad. Sci. Canberra. pp. 257-259.
- Orgebin-Christ, M. C. (1969). Studies on the function of the epididymis. Biol. Reprod. Suppl 1: 155-175.
- Parker, G. V. and Thwaites, C. J. (1972). The effects of undernutrition on libido and semen quality in adult Merino rams. Aust. J. agric. Res. 23: 109-115.
- Patterson, H.D. and Thompson, R. (1971). Recovery of inter-block information when block sizes are unequal. Biometrika. 58: 545-554.
- Pattie, W. (1968). Selection for weaning weight in Merino sheep. PhD. Thesis. University of NSW.
- Peart, G.R. (1982). Australian group breeding schemes. Proc. Wld. Congr. Sheep. Cattle. Breed. Eds. Barton, R. A. and Smith, W. C. Dunsmore press Ltd. Palmerston North, New Zealand. II. pp.113-122.
- Pelletier, J. and Ortavant, R. (1975). Photoperiodic control of LH release in the ram. 1. Influence of increasing and decreasing light photoperiods. Acta Endocrinologica, Copenhagen, 78: 435-441.
- Pepelko, W. E. and Clegg, M. T. (1965). Studies of mating behaviour and some factors influencing the sexual response in the male sheep, Ovis Aries. Anim. Behav. 13: 249-258.
- Piper, L. R. and Bindon, B. M. (1982a). Genetic segregation for fecundity in Booroola Merino sheep. Proc. Wld. Congr. Sheep and Cattle Breed. Eds. Barton, R. A. and Smith, W. C. Dunsmore Press. Palmerston North, New Zealand. I. pp.395-400.

- Piper, L. R. and Bindon, B. M. (1982b). The Booroola Merino and performance of medium non-Peppin crosses at Armidale. In "The Booroola Merino: Proceedings of a Workshop". Eds. Piper, L. R. Bindon, B. M. and Nethery R. D. CSIRO, Melbourne, Australia.
- Piper, L. R. and Bindon, B. M. (1984). Genetic and non-genetic manipulation of reproduction rate in sheep. Proc. 2nd. Wld. Congr. Sheep. Cattle Breed. Pretoria, South Africa. pp. 46-57
- Piper, L. R., Bindon, B. M., Atkins, K. D. and McGuirk, B. J. (1980). Genetic variation in ovulation rate in Merino ewes aged 18 months. Proc. Aust. Soc. Anim. Prod. 13: 409-412.
- Piper, L. R., Bindon, B. M., Atkins, K. D. and Rogan, I. M. (1984). Ovulation rate as a selection criterion for improving litter size in Merino sheep. In "Reproduction in Sheep". Eds. Lindsay, D. R. and Pearce, D. T. Aust. Acad. Sci. Canberra. pp. 237-239.
- Piper, L. R., Bindon, B. M. and Davis, G. H. (1985). The single gene inheritance of the prolificacy of the Booroola Merino. In "The Genetics of Reproduction in Sheep." Eds. Land, R. B. and Robertson, D. W. Butterworths, London. pp. 115-126.
- Ponzoni, R. (1975). PhD. Thesis. University of NSW.
- Pretorius, P. S. (1967). Libido and mating dexterity in rams reared and kept in isolation from ewes. Proc. S. Afr. Soc. Anim. Prod. 6: 208-212
- Pretorius, P. S. and Marincowitz, G. (1968). Post-natal penis development, testes descent and puberty in Merino ram lambs on different planes of nutrition. S.Afr. J. agric. Sci. 11: 319-334.
- Proud, C., Donovan, D, Kinsey, R., Cunningham, P. J. and Zimmerman, D. R. (1976). Testicular growth in boars as influenced by selection for ovulation rate. J. Anim. Sci. 42: 1361-1362. (Abstr.).
- Purvis, I. W., Piper, L. R., Bindon, B. M., Edey, T. N., Curtis, Y. M. and Nethery, R. D. (1983). Further studies of testis size in crossbred Booroola rams. Proc. Aust. Soc. Reprod. Biol. 15: 34. (Abstr.)
- Purvis, I. W., Edey, T. N., Kilgour, R. J. and Piper, L. R. (1984). The value of testing young rams for serving capacity. In "Reproduction In Sheep". Eds. Lindsay, D. R. and Pearce, D. T. Aust. Acad. Sci. Canberra. pp. 59-61.
- Purvis, K., Illius, A. W. and Haynes, N. B. (1974). Plasma testosterone concentrations in the ram. J. Endocr. 61: 241-253.
- Purser, A. F. (1965). Repeatability and heritability of fertility in hill sheep. Anim. Prod. 7: 75-82.
- Rae, A.L. and Land, R. B. (1981). Genetics and Reproduction in farm Livestock- A Review of 50 Years' Research. and Prospects for the Future. Perspectives in World Agriculture. C.A.B. London.
- Raadsma, H. W. (1981). Studies on the paddock mating of rams and bulls. M.Sc. Ag. Thesis. University of New England.

Sales, J. and Hill, W.G. (1976). Effect of sampling errors on efficiency of selection indices. 2. Use of information on associated traits for improvement of a single important trait. Anim. Prod. 23: 1-14.

- Reeves, J. J., Arimura, A., and Schally, A. V. (1970). Studies on dose response relationship of luteinising hormone-releasing hormone (LH-RH) in sheep. J. Anim. Sci. 31: 933-936.
- Restall, J. B., Brown, G. H., Blockey, M. DeB., Cahill, L. and Kerins, R. (1976). Assessment of reproductive wastage in sheep. 1. Fertilization failure and early embryonic survival. Aust. J. Exp. Agric. Anim. Husb. 16: 329-335.
- de Reviers, M., Hochereau de Reviers, M. T., Blanc, M. R., Brillard, N. P. Courrot, M. and Pelletier, J. (1980). Control of Sertoli and germ cell populations in the cock and sheep testes. Reprod. Nutr. Develop. 20(1B): 241-249.
- Rival, M. and Chenoweth, P. J. (1982). Libido testing of rams. Proc. Aust. Soc. Anim. Prod. 134: 174-175.
- Ricordeau, G. (1982). Selection for reduced seasonality and post-partum anoestrus. In 2nd. Wld. Congr. Genet. appld. Livest. Prod. Ed. Garsi. Madrid, Spain. pp. 338-347.
- Ricordeau, G., Pelletier, J., Courrot, M. and Thimonier, J. (1979). Phenotypic and genetic relationships between endocrine criteria and testis measurements of young Romanov rams and the ovulation rates at 8 months of their half sisters. Ann. Genet. Sel. Anim. II: 145-159.
- Robards, G. E. and Pattie, W. A. (1967). Selection for crimp frequency in wool of Merino sheep. I. Direct response to selection. Aust J. Exp. Agric. Anim. Husb. 7: 552-558.
- Robertson, A. (1959). The sampling variance of the genetic correlation coefficient. Biometrics. 15: 469-485.
- Robertson, D. M., Ellis, S., Foulds, L. M., Findlay, J. K. and Bindon, B. M. (1983). Pituitary gonadotrophins in Booroola and control Merino sheep. Proc. Aust. Soc. Reprod. Biol. 15: 10.
- Salamon, S. (1964). The effect of nutritional regimen on the potential semen production of rams. Aust. J. agric. Res. 15: 645-656.
- Sanford, L. M., Winter, J. S. D., Palmer, W. M. and Howland, B. E. (1974). The profile of LH and testosterone secretion in the ram. Endocrinology 95: 627-631.
- Sanford, L. M., Simaraks, S., Palmer, W. M. and Howland, B. E. (1982). Circulating estrogen levels in the ram: influence of season and mating, and their relationship to testosterone levels and mating frequency. Can. J. Anim. Sci. 62: 85-93
- Sapsford, C. S. (1962). The development of the testis of the Merino ram, with special reference to the origin of the adult stem cells. Aust. J. agric. Res. 13: 487-502.
- Scaramuzzi, R. J. and Radford, H. M. (1983). Factors regulating ovulation rate in the ewe. J. Reprod. Fert. 69: 353-367.
- Schaeffer, L. R., Wilton, J. W. and Thompson, R. (1978). Simultaneous estimation of variance and covariance components from multi-trait mixed model equations. Biometrics. 34: 199-208.

- Schanbacher, B. D. (1979). Increased lamb production with rams exposed to short day lengths during the non-breeding season. J. Anim. Sci. 49: 927-932.
- Schanbacher, B. D. (1980). The feedback control of gonadotrophin secretion of testicular steroids. 9th Inter. Congr. Anim. Reprod. Artif. Insem. Madrid. II: 177-184.
- Schanbacher, B. D. and Crouse, J. D. (1980). Growth and performance of growing finishing lambs exposed to long or short photoperiods. J. Anim. Sci. 51: 943-948.
- Schanbacher, B. D. and Ford, J. J. (1976). Seasonal profiles of plasma luteinising hormone, testosterone and extradiol in the ram. Endocrinology 99: 752-757.
- Shrestha, J., Fiser, P. S., Langford, G. A. and Heaney, D. P. (1983). Influence of breed, birthdate, age and bodyweight on testicular measurements of growing lambs maintained in a controlled environment. Can. J. Anim. Sci. 63: 835-847.
- Schreffler, C. and Hohenboken, W. D. (1974). Dominance and mating behaviour in ram lambs. J. Anim. Sci. 39: 725-731.
- Scott, R. S., Burger, H. G. and Quigg, H. (1980). A simple and rapid in vitro bioassay for inhibin. Endocrinology 107: 1536-1542.
- Setchell, B. P., Davies, R. V. and Main, S.J. (1977). Inhibin. In "The Testis", Vol. IV. Eds Johnson, A. D. and Gomes, W. R. Academic Press, New York. pp. 189-238.
- Setchell, B. P., Waites, G. M. H. and Lindner, H. R. (1965). Effects of undernutrition on testicular blood flow and metabolism and the output of testosterone in the ram. J. Reprod. Fert. 9: 149-162.
- Short, B. F. and Carter, H. B. (1955). An analysis of the records of the registered Australian Merino Stud flocks. Bull. No. 276 CSIRO Australia. Melbourne.
- Siegel, S. (1956). Non-Parametric Statistics for the Behavioural Sciences. McGraw-Hill. New York.
- Skinner, J. D. and Rowson, L. E. A. (1968). Puberty in Suffolk and cross-bred rams. J. Reprod. Fert. 16: 479-488.
- Skinner, J. D., Booth, W. D., Rowson, L. E. A. and Karg, H. (1968). The post-natal development of the reproductive tract of the Suffolk ram, and changes in the gonadotrophin content of the pituitary. J. Reprod. Fert. 16: 463-477.
- Snedecor, G. W. and Cochran, W. G. (1967). Statistical Method. Iowa State Univ. Press, Iowa.
- Steele, R. G. and Torrie, J. H. (1981). Principles and Procedures of Statistics. McGraw-Hill. New York.
- Steinberger, A. and Steinberger, E. (1977). The Sertoli Cells. In "The Testis", Eds. Johnson, A. D. and Gomes, W. R., Academic Press New York. Vol. 4. pp. 371-399.

- Stelmasiak, T., Bindon, B. M. and Galloway, D. B. (1978). Pituitary LH pools ratio as an index of a ram's genotype for prolificacy. Proc. Aust. Soc. Reprod. Biol. 10: 70.
- Sutama, I. Ketut. (1983). Studies of sexual development in growth-retarded Merino rams. M.Sc. Thesis. Univ. New England.
- Swiger, L. A., Harvey, W. R., Everson, D. O. and Gregory, K. E. (1964). The variance of the intra-class correlation involving groups with one observation. Biometrics. 20: 818-826.
- Tallis, G. M. (1959). Sampling errors of genetic correlation coefficients calculated from the analysis of variance and covariance. Aust. J. Statist. 1: 35-43.
- Thimonier, J. and Mauleon, P. (1969). Variations saisonnieres du comportement d'oestrus et des activites ovarienne et hypophysaire chez les ovins. Annls. Biol. anim. Biochim. Biophys. 9: 233-250.
- Thimonier, J., Pelletier, J. and Land, R. B. (1972). The concentration of plasma LH in male and female lambs of high and low prolificacy breed types. J. Reprod. Fert. 31: 498-499.
- Thorel, J. I. and Johansson, B. G. (1971). Enzymatic iodination of polypeptides with ^{125}I to high specific activity. Bioch. Biophys. Acta. 251: 363-369.
- Thorsteinsson, S. S., Thorsteinsson, S. and Dyrmondsson, O. R. (1982). Relationship between ram testis weight and ewe fertility. EAPP meeting, Leningrad, 1982.
- Tilton, W. A., Warnick, A. C., Cunha, T. J., Loggins, P. E. and Shirley, R. L. (1964). Effect of low energy and protein intake on growth and reproductive performance of young rams. J. Anim. Sci. 23: 645-650.
- Toelle, V. D. and Robison, O. W. (1984). Estimates of genetic correlations between testicular measurements and female reproductive traits in cattle. J. Anim. Sci. 60: 89-100.
- Trounson, A. O., Chamley, W. A., Kennedy, J. P. and Tassell, R. (1974). Primordial follicle number in ovaries and levels of LH and FSH in pituitaries and plasma of lambs selected for and against multiple births. Aust. J. Biol. Sci. 30: 229-241.
- Tsonis, C. G., Quigg, H., Lee, V. W. K., Leversha, L., Trounson, A. O. and Findlay, J. K. (1983). Inhibin in individual ovine follicles in relation to diameter and atresia. J. Reprod. Fert. 67: 83-90.
- Tulley, D. and Burfening, P. J. (1983). Libido and scrotal circumference of rams as affected by season of the year and altered photoperiod. Theriogenology. 20: 435-458.
- Turner, H. N. (1968). The effect of selection on lambing rates. Proceedings of a Symposium on Physiology of Reproduction in sheep, Stillwater, Oklahoma, pp. 67-93.
- Turner, H. N. (1978). Selection for reproduction rate in Australian Merino Sheep: Direct responses. Aust. J. Agric. Res. 29: 645-650.

- Turner, H. N. (1982). Origins of the CSIRO Booroola. In "The Booroola Merino: Proceedings of a Workshop". Eds. Piper, L. R., Bindon, B. M. and Nethery, R. D. CSIRO, Melbourne, Australia. pp. 1-7.
- Walker, S. K., Ponzoni, R. W., Walkley, J. R. W. and Morbey, A. S. C. (1984). The development of male reproductive traits in progeny of Merino strains of different reproductive performance. Anim. Reprod. Sci. 8: 61-78.
- Walkley, J. R. W. and Barber, A. A. (1976). The relation between libido score and fertility in Merino rams. Proc. Aust. Soc. Anim. Prod. 11: 141-145.
- Walkley, J. R. W. and Smith, C. (1980). The use of physiological traits in genetic selection for litter size in sheep. J. Reprod. Fert. 59: 83-88.
- Walton, J. S., Evins, J. D., Hillard, M. A. and Waites, G. M. H. (1980). Follicle-stimulating hormone release in hemicastrated prepubertal rams and its relationship to testicular development. J. Endocr. 84: 141-152.
- Walton, J. S., Evins, J. D., and Waites, G. M. H. (1978). Feedback control of follicle-stimulating hormone in pre- and postpubertal rams as revealed by hemicastration. J. Endocr. 77: 75-84.
- Warnick, A. C., Meacham, T. N., Cunha, T. E., Loggins, P. E., Hentges, J. F. and Shirley, R. L. (1961). Effect of source and level of nitrogen on semen production and libido in rams. In Proc. 4th Inter. Congr. Anim. Reprod. The Hague, Holland. p. 202.
- Watson, R. H., Sapsford, C. S. and McCance, J. (1956). The development of the testis, epididymis and penis in the young Merino ram. Aust. J. agric. Res. 7: 574-590.
- Webb, R. and England, B. G. (1982). Identification of the ovulatory follicle in the ewe: associated changes in follicle size, thecal and granulosa cell luteinising hormone receptors, antral fluid steroids and circulating hormones during the pre-ovulator period. Endocrinology 110: 873-881.
- Wiggins, E. L. and Terrill, C. E. (1953). Variation in penis development in ram lambs. J. Anim. Sci. 12: 524-535.
- Wiggins, E. L., Terrill, C. E. and Emik, L. O. (1953). Relationships between libido, semen characteristics and fertility in range rams. J. Anim. Sci. 12: 684-696.
- Winfield, C. G. and Kilgour, R. (1977). The mating behaviour of rams in a pedigree pen-mating system in relation to breed and fertility. Anim. Prod. 24: 1907-201.
- Wodzicka-Tomaszewska, M., Kilgour, R. and Ryan, M. (1981). Libido in the larger farm animals. Appl. Anim. Ethol. 7: 203-238.
- Wolfe, H. G., Bartke, A., Amador, A., Van Sickle, M., Dalterio, S. and Brown, D. (1981). Testicular function in strains of mice selected for differences in gonadotrophin-induced ovulation rate. J. Endocr. 90: 367-373.

Yeates, N. T. M. 1949). The breeding season of the sheep with particular reference to its modification by artificial means using light. J. Agric. Sci. Camb. 39: 1-43.

APPENDIX 1.

Genetic variances (δm^2 and δf^2 for male and female traits, respectively) of testicular diameter (TDM) at 5, 8, and 12 months of age and ovulation rate (OR) at 18, 30, 42, and 54 months of age and covariances between them (Cov_g), derived from REML analyses of data from the Trangie D flock half-sibs born in 1979-1981.

Trait pair		Year	δm^2	Cov_g	δf^2
TDM	OR				
5	18	1979	0.034282	0.005776	0.004476
		1980	0.022147	0.034638	0.010479
		1981	0.071097	0.010848	0.008193
8	18	1979	0.202403	0.002570	0.003454
		1980	0.486429	-0.004956	0.011248
		1981	0.632233	0.000797	0.002562
12	18	1979	0.151749	0.010330	0.004746
		1980	0.148747	0.011856	0.012692
		1981	0.199172	0.002488	0.008101
5	30	1979	0.042668	0.010198	0.023098
		1980	0.198711	0.001211	0.007498
		1981	0.076242	0.032393	0.028281
8	30	1979	0.211558	0.015711	0.022173
		1980	0.486814	0.001615	0.004595
		1981	0.626195	0.013825	0.021845
12	30	1979	0.153156	0.010740	0.021900
		1980	0.148130	-0.000064	0.004577
		1981	0.112575	0.027664	0.022040

APPENDIX 2

ANOVA mean squares for morphological and hormonal traits from rams in
Experiments 1 and 2

Trait

Source	df	Pituitary weight(g)	Testicular weight(g)	Epididymal weight (g)	Live weight (kg)	Testicular diameter(cm)	Plasma FSH (ng/ml)	Plasma LH (ng/ml)
Experiment	1	0.055633**	23570.179***	75.9376***	8930.215***	2.937716**	0.015451	4.090050
Strain	1	0.005971	840.364	23.1358	29.179	0.099835	0.086723	0.003286
Dam genotype w/n Booroola	1	0.001712	266.354	47.5541	0.493	0.544665	0.067526	0.157097
Sire	11	0.006974	1972.466	26.8332	101.206	0.343545	0.022369	0.061308
Birth type	3	0.005116	102.140	7.5904	7.701	0.144739	0.059997	0.046409
Remainder	26	0.004403	1098.844	26.1629	91.311	0.307811	0.071111	0.124077

APPENDIX 3

ANOVA mean squares for TDM, and mean plasma FSH and LH at 7 ages from rams
in Experiment 2

		<u>Testicular diameter (cm) at age:</u>						
Source	df	3 weeks	5 weeks	10 weeks	14 weeks	18 weeks	26 weeks	33 weeks
Strain	1	0.002447	0.031817	0.228285	0.094314	0.049025	0.159703	0.479318
Sire	4	0.040051	0.065461	0.103356	0.204612	0.116077	0.176440	0.379898
Birth type	2	0.089769*	0.164915*	0.112930	0.651576*	0.095210	0.186624	0.183050
Booroola dam genotype	1	0.022055	0.086243	0.067245	0.536150	0.051444	0.401986	0.575304
Remainder	14	0.019023	0.028913	0.125421	0.172312	0.158467	0.131738	0.291528

		<u>Mean plasma FSH (ng/ml) at age:</u>						
Source	df	3 weeks	5 weeks	10 weeks	14 weeks	18 weeks	26 weeks	33 weeks
Strain	1	0.070171	0.008369	0.002104	0.043969	0.010942	0.040102	0.007487
Sire	4	0.349775	0.409904	0.259969	0.130922*	0.019431	0.350582	0.026229
Birth type	2	0.285315	0.447656	0.191938	0.131646	0.011033	0.047001	0.038872
Booroola dam genotype	1	0.058923	0.486938	0.407523	0.044503	0.002886	0.275457	0.018037
Remainder	14	0.203644	0.207358	0.166852	0.041891	0.009004	0.207335	0.100989

		<u>Mean plasma LH (ng/ml) at age:</u>						
Source	df	3 weeks	5 weeks	10 weeks	14 weeks	18 weeks	26 weeks	33 weeks
Strain	1	0.025259	0.250646	3.900597	0.058540	0.033355	1.304325	0.101010
Sire	4	0.072307	0.205924	3.519880	0.719883	0.268059	0.670164	0.075880
Birth type	2	0.120910	2.018632	2.889191	0.003562	0.040350	2.307850	0.024174
Booroola dam genotype	1	0.002983	1.649170	12.109722*	0.189980	0.724204	0.008837	0.008920
Remainder	14	0.267907	0.579389	1.574955	0.515812	0.237023	1.102139	0.193932