Progress in sheep breeding practice and technology since the last World Congress is briefly reviewed. Gains have been made in breeding objective specification, genetic parameter availability, breeding value estimation, and in the design and execution of breeding programmes. Performance based recording schemes for breeding value estimation are now in place in most of the major sheep producing countries. The future for continued improvement seems assured.

The main session on sheep breeding at a World Congress on Genetics Applied to Livestock Production should adopt a broad perspective and cover topics of general interest to sheep breeders around the world. This session contains contributions from some of the leading workers in the field of quantitative genetics and sheep breeding. There is no specific theme, and the approach of reviewing developments in the traditional categories (breeding objectives, breeding value estimation, breeding programme design, cross breeding theory and results) has not been followed. This may disappoint the purists, but I hope that the majority of delegates will welcome the opportunity to concentrate on current developments, rather than a collection of exhaustive (and perhaps exhausting?) reviews. Other sessions at this Congress contain invited material directly concerned with sheep breeding as well as an array of related free contributions.

Important advances in quantitative genetic theory and statistical methodology of interest to all animal breeders including sheep breeders, have occurred since the last Congress in Nebraska.

The long standing difficulty about methods for estimating relative economic weights for traits in breeding objectives has been resolved by Smith et al. (1986). The basic problem was that the estimated weights depended on the perspective taken (producer, investor, consumer), and on the accounting approach adopted (ratios of economic efficiency or profit equation). If all costs are regarded as variable, and any changes which can be matched by rescaling the enterprise are excluded, the profit equation gives the same economic weights for all perspectives, and the weights are equivalent to those derived from the ratio of economic efficiency. Definitions of breeding objectives for sheep which properly account for returns and costs are still hampered by lack of variance-covariance estimates for food intake. Some recent attempts have adopted different strategies to account for expected changes in food intake and other costs following genetic changes in production (Ponzoni, 1986; Atkins, 1987), but the basic deficiency remains. Inclusion of disease resistance traits in breeding objectives can present special problems, as discussed by Piper and Barger (1988). Significant developments have occurred in genetic parameter estimation techniques, particularly since the advent of mixed-model REML procedures combined with the so-called animal model. The animal model
includes random effects for the breeding values of each animal and the relevant variances are estimated directly rather than from interpretations of covariances between relatives. These procedures are robust in situations of non-random mating and are thus ideal for analysis of data from long term selection experiments (Meyer, 1989). The procedures are computationally demanding, especially for multivariate analyses, but as the computing power available to animal breeders increases, and as user friendly software is developed, they will become the standard. As noted by Henderson (1988), "a remarkable property of REML is, that under certain restrictions, it estimates free of bias due to selection the parameters of the population that existed prior to selection". These parameters are optimal for mixed-model evaluation of animals in populations undergoing selection (Gianola et al., 1986) and by extension, to estimation of genetic trends in animal breeding programmes. Relevant software application packages are now becoming available, and will become the standard quantitative genetic analysis tools of animal breeders. A recent example in the sheep literature is provided by an analysis of genetic trends and parameters in a Merino population undergoing selection for helminth parasite resistance (Woolaston, 1990).

Mixed model genetic evaluation procedures are firmly entrenched as the method of choice for breeding value estimation in dairy cattle and to a lesser extent in the beef cattle and pig industries. They have not been used extensively in the sheep industry, though this will surely change for those breeds with full pedigree recording. It is also likely to change for those breeds which currently practise minimal pedigree recording as the wider powers of BLUP methodology are recognised. The pyramidal breeding structure of the sheep industry creates genetic linkages between flocks but without pedigree recording they cannot be exploited for breeding value estimation. Sire reference schemes also increase the degree of genetic linkage between flocks. Small numbers of sires may be used widely by AI across a large number of flocks thus permitting comparisons among "home bred" sires through the links between them and the reference sires (Lewer, 1987). Central sire evaluation schemes, if combined with well designed "on farm" progeny tests, provide similar information. Such schemes, encompassing different strains of Merino and different production environments are becoming more widespread in Australia (Roberts et al., 1988). They will provide data to help resolve the importance of sire x environment interactions. The paper by Kinghorn and Shepherd in this session, suggests strongly that recognition of the wider power of BLUP should result in changes to the design of sheep breeding programmes which increase genetic linkages and thereby create the opportunity to increase rates of genetic gain in both the short and long term.

GENETIC PARAMETERS AND THE DESIGN OF BREEDING PROGRAMMES

In most sheep breeding programmes, selection decisions are made on the basis of measurements taken on young animals. One exception, where reproduction rate is part of the breeding objective, is the use of lifetime reproduction records of the dam to select among incoming young replacements. However, the traits of economic importance are usually expressed on a number of occasions throughout the productive lifetime of sheep. It is therefore important to know whether it is valid to make the usual assumption that the repeated expressions of a trait have equal heritability and pairwise genetic correlations of unity. If this assumption is not valid, it becomes necessary to know the genetic covariance between traits measured on young animals and the component traits of lifetime
economic performance, in order to devise the optimum selection strategy. The paper by Atkins in this session examines the heritabilities of and genetic correlations among the repeated expressions of economically important traits in Australian Merino sheep. For clean fleece weight and fibre diameter, the genetic correlations between hogget and later measurements were significantly less than unity, while those among later measurements were not different from unity. For fibre diameter the heritability remained basically constant, but for clean fleece weight the estimates were more variable but with no clearly discernible age related pattern. These analyses establish the need to consider early and later performance for clean fleece weight and fibre diameter as separate traits when defining breeding objectives for Merino sheep. This situation may also hold or at least be worthy of careful examination in Merino-derived and other dual purpose breeds.

Bennet's paper in this session comprehensively reviews selection for growth and carcase composition in sheep. For producers of sheep meat, the variance-covariance relationships among carcase weight and composition traits are now well defined. Breeding objectives for meat sheep vary in terms of the relative emphasis given to growth rate, carcase quality and efficiency. There is a degree of unanimity among consumers in affluent countries about the need to reduce fat intake. This should be, but is not always, translated into differential pricing schedules which penalise over-fat carcases. An exciting development which should improve selection efficiency in meat sheep breeding programmes, is the use of computer aided tomography to obtain detailed composition measurements on live animals (Simm, 1987).

MAJOR GENES IN SHEEP BREEDING

Genes affecting traits such as coat colour and hornedness have been important in establishing breed trademarks. Genes affecting wool pigmentation are economically important in specialist wool breeds like the Merino because pigmented fibres reduce product quality. There have been few genes described that influence quantitative traits in sheep. The notable exception is the Booroola F gene which markedly increases ovulation rate (Piper and Bindon, 1982). Since the discovery of the F gene, there have been several reports concerning genes with similar effects on prolificacy in a range of breeds and synthetics (Piper and Bindon, 1988). Major genes affecting helminth parasite resistance have been postulated but not confirmed in populations of Merino sheep (Piper and Barger, 1988; Woolaston, these proceedings).

Recombinant DNA technology has opened up the possibility of producing detailed genetic maps for all species, including sheep. With increasing numbers of RFLP markers available, marker assisted selection methods will become more efficient and more widely used in animal breeding (Smith and McMillan, 1989). RFLP marker techniques are currently being applied in an effort to map the F gene (Montgomery et al., 1990), but will increasingly be directed to the task of producing a detailed map of the sheep genome. Information from the huge effort being directed to mapping the human genome, and from other mammalian mapping studies will directly assist this endeavor.
PERFORMANCE BASED SHEEP BREEDING SCHEMES

At the Second International Congress on Quantitative Genetics, Bichard (1988) ventured the view that quantitative genetic technology had only recently begun to have a significant impact on sheep and beef cattle breeding. However, papers presented at the Third World Congress on Sheep and Beef Cattle Breeding in 1988, and elsewhere (e.g. meetings of the Australian Association of Animal Breeding and Genetics in 1988 and 1990) indicate that the pace of change has increased substantially. Performance based recording schemes for breeding value estimation are now available in most of the major sheep producing countries and are becoming increasingly sophisticated. For those breeds with large flock sizes, widespread adoption of BLUP procedures for breeding value estimation is inhibited by lack of pedigree information. DNA fingerprint techniques may in the future be used to overcome this problem, but unit costs will need to be substantially reduced. New reproductive technologies have so far had little impact on genetic improvement of sheep. Increasing use is being made of frozen semen AI, but costs of intra-uterine insemination are high. Research is urgently required to improve fertility following cervical insemination with frozen semen. The theoretical advantages of MOET schemes are clear, but care needs to be exercised to ensure that effective population size is kept at a level consistent with long term selection gain.

REFERENCES