BREEDING OBJECTIVES AND SELECTION PROCEDURES
WITH SPECIAL REFERENCE TO MERINO SHEEP

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INTRODUCTION

The choice of breeding objectives and of selection procedures is a crucial step in the design of a breeding program. The breeding objective has to be chosen correctly if genetic change in a desirable direction is to occur. Having defined the breeding objective, selection procedures have to be such that they result in 'reasonable' progress in the traits in the objective. It is not easy to decide what 'reasonable' progress is. Here it may suffice to define it as economically worthwhile gains that are achieved using selection procedures of an acceptable level of technical difficulty and cost to the breeder.

I will not discuss formally the problems related to definition of breeding objectives and choice of selection criteria. The subject has been covered recently by James (1982), Jones (1982), Ponzoni (1979, 1982), and Rao (1982). Instead I will present a general view of recent developments and of problems likely to arise when defining breeding objectives and deciding on selection procedures. I will also discuss some aspects on which different sectors within the Merino sheep industry (for example, breeders, classifiers, scientists) have views that are not in total agreement. When possible I will try to reconcile such views, and when reconciliation appears difficult I shall suggest courses of action which could contribute towards settling the matter. Although the paper refers almost exclusively to the Merino industry the approach taken and the principles involved can be applied to other breeds of sheep and species of livestock.

INDUSTRY STRUCTURE

The aim in any sheep improvement program should be to define the breeding objective and to choose the selection procedures according to commercial producers' interests. Genetic progress in the Merino sheep industry is determined by selection practices in ram-breeding flocks, which represent a very small proportion of the total sheep population (approximately 3 per cent). In the past the lack of integration between traditional ram-breeding flocks (studs) and commercial producers has fostered the development of conflicts of interest between the two sectors. For example, many stud breeders continue to indulge in cosmetic practices that make the animals look well, but which are of little or no value to the commercial producer. Dissatisfaction with the selection policies at the stud level has led to the creation of an alternative breeding structure — namely, co-operative breeding groups, which in their simplest form consist of a number of flocks that contribute selected females to form a central ram-breeding nucleus. Rams bred in the nucleus are supplied to the contributing flocks. Because they are integrated systems, co-operative breeding groups can, in principle at least, avoid the problem of conflicting objectives. In the Merino stud breeding industry the aim should be that stud breeders' selection policies be defined according to commercial producers' interests, and that those producing stock of superior breeding value receive a premium for it. Ram buyers could perhaps exert pressure on stud breeders and ask them to be precise about their breeding objective.
BREEDING OBJECTIVES

General
The objective of sheep breeding should be the improvement of the profit derived from sheep flocks. Breeders, sheep-classers, and scientists would agree with this notion. However, differing views are often held regarding the way in which the greater profits could be achieved. Clean fleece weight, fibre diameter, reproduction rate, and liveweight are considered economically important traits, but the emphasis that ought to be placed on each one of them is a matter on which opinions are often at variance. Rising production costs are a constant worry for most producers, and this results in widespread interest in the so called 'easy-care' traits, supposedly associated with a reduction of the costs incurred in the supervision and care of the flock. However, few detailed studies have been conducted on the value of 'easy-care' traits, and the information that is necessary to incorporate them in a breeding program is often lacking.

In the past, breeding objectives have often been defined verbally in a loose manner that allows a considerable amount of scope for various interpretations of what the desired improvement might be. There is merit in attempting to achieve greater preciseness in the definition of the breeding objective, and in this section the steps that have to be taken in a formal definition of the breeding objective are described briefly.

Phases in the Definition of the Breeding Objective
Ideally, selection at the stud level could be conceived as being for a single composite trait which would be measured in dollars, and which would represent the monetary gain derived by commercial producers from their flocks. Because sheep produce a range of products it is necessary to identify the various sources of financial return and cost to the commercial producer. Thus, the process of defining the breeding objective can be considered as consisting of three phases which will be discussed in turn:

(i) Identification of sources of financial returns and costs in commercial flocks.
(ii) Determination of sheep traits which influence financial returns and costs.
(iii) Calculation of the relative economic value of each trait.

(i) Identification of Sources of Financial Returns and Costs in Commercial Flocks
Table 1 shows the main sources of returns and costs to the producer in commercial flocks. The sale of wool, surplus offspring, and cull-for-age animals generate returns, while the production and marketing system requires that costs be incurred in the production of the necessary feed for the sheep, in harvesting and marketing the wool, in marketing surplus offspring and cull-for-age animals, in veterinary treatments, and in the labour required to manage the flock. It is possible to determine which are the sheep traits that influence these sources of returns and costs, and the aim of the breeding program should be to achieve genetic change in those traits in such a way that it results in greater profit to the producer.

Table 1: Sources of returns and costs, and traits influencing them in Merino sheep

<table>
<thead>
<tr>
<th>a. Sources of Returns and Costs</th>
<th>b. Traits Influencing Returns and Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Returns</td>
<td></td>
</tr>
<tr>
<td>Wool</td>
<td>Clean fleece weight, fibre diameter, absence of pigmented fibres</td>
</tr>
<tr>
<td>Surplus offspring</td>
<td>Ewe reproduction rate, lamb survival, sale weight, carcass quality</td>
</tr>
<tr>
<td>Cull-for-age animals</td>
<td>Mature liveweight, carcass quality</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
</tr>
<tr>
<td>Feed</td>
<td></td>
</tr>
<tr>
<td>Wool harvesting and marketing</td>
<td>Feed consumption</td>
</tr>
<tr>
<td>Marketing of surplus offspring and cull-for-age animals</td>
<td>Clean fleece weight</td>
</tr>
<tr>
<td>Veterinary treatments</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Disease resistance</td>
</tr>
<tr>
<td></td>
<td>Easy-care traits</td>
</tr>
</tbody>
</table>
Determination of Sheep Traits which Influence Financial Returns and Costs

The traits that have the greatest influence on returns and costs to the producer are shown in Table 1b. In principle, all traits influencing returns and costs should be included in the breeding objective, but in practice, the paucity of information about some traits makes their inclusion in the breeding objective very difficult. Examples of such traits are: feed consumption, carcass quality, and easy-care traits. Each one of them will be commented on briefly.

Feed consumption

It is difficult to include feed consumption in the breeding objective because of the lack of economic and genetic parameters for that trait with grazing sheep. Several authors (cited by Ponzoni 1982) have taken into account costs assumed to be associated with increased feed requirements resulting from genetic improvement in reproduction and growth rate by discounting the economic value of these traits, but James (1982) pointed out that this approach is not strictly correct, although in many cases it should not lead to serious errors.

Carcass quality

A reduction in the amount of fat and an increase in the amount of lean meat have been recognised as desirable changes in carcass attributes, but under the prevailing marketing system sheep for slaughter are sold on the basis of a visual appraisal of the live animal. This system does not offer an effective price structure involving an economic reward to producers improving carcass traits. However, a number of developments currently taking place in this area may lead to marketing systems that identify and pay for desirable carcass characteristics.

Easy-care traits

Easy-care traits can be defined as those which are associated with a reduction in costs incurred in the supervision and care of the flock. They include the need for attention at lambing, disease control, and the labour costs associated with other management and harvesting procedures. When the financial situation is unfavourable, approaches that increase net farm income by cost cutting are likely to be more readily accepted by the farming community than those where extra output increases net farm income, but which imply greater production costs. Although there is genetic variation at least in some of these traits (Ponzoni 1983) at present we do not know enough from either an economic or a genetic point of view, to be able to incorporate them as traits in a formal definition of the breeding objective. A recent study (Ponzoni, submitted to Wool Tech. Sheep Breed.) highlighted the importance of the anticipated treatment program on the economic value of resistance to fleece-rot and to body strike, but further work is necessary before these results can be generalised.

Relative Economic Value of Each Trait

The relative importance of each trait is usually referred to as its economic value. When estimating economic values, information on the effect of variation in fleece traits on manufacturing performance of wool; on the association between carcass traits and the price the manufacturer or the consumer will pay; and on the relationship between production costs and specific traits is utilised.

The economic value of a trait may be defined as the change in profit associated with a one-unit change of that trait. In the estimation of economic values we have to take into consideration not only the prices of the various products (wool, lambs, cull-for-age animals) but also the number of times each characteristic is expressed during an animal's lifetime. For example, a ewe will produce approximately five fleeces during her lifetime, but the ewe herself is sold only once as an animal for slaughter. This means that while clean fleece weight and average fibre diameter are expressed approximately five times during a ewe's lifetime, the trait liveweight of the ewe is expressed only once. Similar considerations are made when calculating the economic value of reproduction rate or of any other economically important trait.

Example of a Practical Breeding Objective for Merino Sheep

Given our present knowledge the following traits should be included in the breeding objective of Merino sheep (absence of pigmented fibres in the fleece is assumed): clean fleece weight, fibre diameter, reproduction rate, liveweight of surplus offspring at sale, and liveweight of cull-for-age animals. Of these, clean fleece weight and reproduction rate are often the two traits with the greatest economic value. Fibre diameter and liveweight of surplus offspring are of some importance whereas liveweight of cull-for-age animals has a negligible economic value. The emphasis placed on each of these traits can be defined precisely for a given set of assumptions. These will vary with the strain, the environment and the production and marketing system under which genetic improvement is desired.

As an example, consider a commercial Merino flock consisting of breeding ewes, and
from which all surplus offspring are sold at approximately one-and-a-half years of age after the hogget shearing (surplus offspring are those in excess of replacement needs). Assume that feed requirements increase as a consequence of genetic gain in reproduction rate and growth traits. Table 2 shows the sources of financial return, the sheep traits influencing returns, and the economic value of each trait. With such a flock a producer derives income from the sale of wool, surplus offspring, and cull-for-age animals.

- The value of the wool sold will be largely determined by the amount of clean wool produced and its average fibre diameter. Thus, clean fleece weight and fibre diameter are the two traits on which our attention should be focused when trying to achieve genetic improvement in wool production.
- The value of the surplus offspring sold will be affected by the number of animals available for sale and by their liveweight. Improved reproduction rate and hogget liveweight are the two important sheep characteristics in this case.
- Liveweight at sale is the important trait influencing the value of cull-for-age animals. Table 2 shows that clean fleece weight and number of one-and-a-half-year-old hoggets are the two characteristics with the highest economic values, whereas ewe liveweight has the lowest economic value.

Table 2: Sources of financial return, traits influencing return, and economic value of each trait in a commercial Merino flock of breeding ewes from which surplus offspring are sold at approximately one-and-a-half years of age.

<table>
<thead>
<tr>
<th>Source of Financial Return</th>
<th>Sheep Traits</th>
<th>Economic value* ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wool</td>
<td>Clean fleece weight (CFW)</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>Average fibre diameter (FD)</td>
<td>-2.0</td>
</tr>
<tr>
<td>Surplus offspring</td>
<td>No. of 1½-year-old hoggets (NHP)</td>
<td>30.9</td>
</tr>
<tr>
<td></td>
<td>Hogget liveweight (HW)</td>
<td>0.5</td>
</tr>
<tr>
<td>Cull-for-age animals</td>
<td>Liveweight of 5½-year-old ewes (MW)</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* Breeding objective = $H = 14.5_{CFW} - 2.0_{FD} + 30.9_{NHP} + 0.5_{HW} + 0.1_{MW}$, where $g$ represents the additive genetic merit of each trait

**SELECTION PROCEDURES**

**General**

Despite the general agreement among breeders, sheep-classers, and geneticists regarding broad definitions of breeding objectives, opinions are often divided when it comes to selection procedures, with geneticists on the opposite side to breeders and classers. There can be no doubt that Australian breeders, assisted by professional sheep-classers, have done a good job of improving the Merino. They have bred an animal capable of producing meat and a valuable fibre in a difficult environment. This has been achieved largely by selection procedures based on a visual assessment of the animals. Emphasis has been directed against wool and body faults, and towards an improvement of the quantity and quality of wool produced, with varying degrees of attention to body size. Consciously or unconsciously this kind of selection discriminated against twin-born animals, and hence the lack of improvement in litter size observed in most stud flocks.

During the past thirty years a considerable amount of information about the inheritance of many traits in Merino sheep has been obtained by Australian scientists. This information sometimes reinforces breeders' and classers' views on sheep selection, but sometimes it does quite the contrary! It would be desirable, through a greater understanding of genetics and sheep breeding, to reconcile the geneticists' approach to sheep improvement with that of breeders and classers. If it were possible to arrive at a consensus it would be easier to achieve a widespread implementation of efficient breeding programs for Merino sheep.

**Culling for Wool and Body Faults**

Animals with major wool faults (for example, pigmented fibres) or structural faults and physical deformities can be culled before the application of other selection procedures, thus reducing the number of animals that have to be assessed for other traits. If the amount of culling carried out on this basis is small it is unlikely to affect seriously the selection
differential for production traits. This will vary from one flock to another and it will also depend on the breeder's or classer's concept of what constitutes 'acceptable' animals. Napier and Jones (1982) reported that 6.8 per cent of rams in a Corriedale flock were rejected by the classer because of faults, whereas McGuirk et al. (1982) found that an average of 20.3 and 14.4 per cent of rams were classed as visual culls in two Merino studs.

In general, geneticists do not favour the elimination of animals purely on aesthetic grounds. However, this practice may have desirable social effects in that it may contribute to the program's acceptability by breeders, classers, and ram buyers. Provided that the number of animals culled for aesthetic reasons is small it is unlikely to have any detrimental effect on the genetic gain achieved in economically important traits.

Skin wrinkles and face-cover are two characteristics considered to be sheep faults because they are associated with the general ability of the sheep to thrive (Turner 1977), and culling excessively wrinkly and face-covered sheep is desirable. If scored, the degree of skin wrinkles and of face-cover can be included in a selection index, where they contribute useful information about the breeding value of the sheep (Ponzoni 1979).

Visual Appraisal and Objective Measurement of Sheep

Visual assessment led to genetic change in many traits during the early stages of the development of all sheep breeds. The main impact has been on wool production, body size, and conformation – traits in which highly developed breeds differ markedly from unimproved breeds. This is so because these traits have a moderate-to-high heritability and they can easily be assessed visually early in life. But visual assessment has achieved little progress in reproduction rate or in milk production. Practical breeders find visual assessment convenient because decisions can be made on the spot, and the practice does not require individual identification or costly and laborious measurements. Nevertheless, visual assessment can be misleading (for example, twin-born sheep are generally smaller than their single-born counterparts), and it is difficult to remain consistent when several characteristics are being evaluated at the same time. When selection is for traits like reproduction rate (which may require the use of information from relatives) inevitably one must resort to objectively recorded performance.

Evaluations conducted during the 1950s and 1960s on the effectiveness of visual appraisal indicated that it could achieve about 40 per cent of the selection differential for fleece-weight that was possible with objective measurement. However, more recent assessments (Napier & Jones 1979; McGuirk et al. 1982) show that sheep-classers can achieve 70 per cent or more of the potential selection differential for fleece-weight. It is not possible with certainty to attribute the increase in efficiency to any one reason, but it is possibly a consequence of breeders' greater awareness about the economic importance of fleeceweight and of an improved ability to identify heavy cutting sheep because of classers' exposure to fleece-weighing.

Provided that good sheep-classers are available there are at least four ways in which visual appraisal is likely to continue being useful in the Australian Merino industry:

(i) In selection against wool and body faults.
(ii) In the elimination of small numbers of aesthetically undesirable sheep.
(iii) In a preliminary round of selection in order to reduce the number of individuals from which full measurements have to be taken.
(iv) Culling in ewe flocks.

However, if the rate of genetic gain in economically important traits is to be maximised, objective measurement should be an essential ingredient of sheep breeding programmes because of its greater accuracy.

Combining Information Recorded and Making Selection Decisions

Breeders using objective measurement vary in the intensity of their performance-recording programs, and this variation is often a reflection of their breeding objective. For example, breeders whose objective is the improvement of wool production would record clean fleeceweight and fibre diameter in rams, whereas those whose objective includes reproduction rate and liveweight as well as wool production would record type of birth (single, twin, and so on) and liveweight in addition to clean fleeceweight and fibre diameter.

When the improvement of wool production is the objective, the recommendation (Turner 1977) has been to select for clean fleeceweight in rams, rejecting those with a fibre diameter more than 2 microns above the average, but it can be shown that the use of a selection index in which appropriate weights are given to clean fleeceweight and to fibre diameter would result in greater gain in economic units (Ponzoni 1979). Some wool testing houses can, if provided with the necessary information, calculate an overall index score.
This is important because it means that the argument of computational difficulty sometimes used against selection indices is no longer valid. Furthermore when several characters are recorded it is difficult to use them to make selection decisions unless they are combined in an overall index score.

Practical breeders have recognised this difficulty, and two indices have been used in the Australian Merino sheep industry for some time. One of the indices has been described by Anderson (1982) and it is of the form:

\[ I_A = a \left( \frac{CWF}{FD^3} \right) + HW \]

where \( CWF \) = clean fleeceweight, \( FD \) = fibre diameter, \( HW \) = hogget liveweight, and \( a \) is a factor calculated from the records to which \( I_A \) is to be applied as:

\[ a = \frac{HW}{\left(\frac{CWF}{FD}\right)^3} \times 1000 \]

where the bar above each character's symbol means average.

The other index was developed by J. Maple-Brown (personal communication) and is as follows:

\[ I_{MB} = m \left( CWF \left[ 1 - (FD - i\%)^p \right] + HW \right) \]

where \( m \) is a factor calculated from the records to which \( I_{MB} \) is to be applied as: \( m = \frac{HW}{CWF} \) and \( p \) is the difference in wool price per micron difference in FD expressed as a proportion of the price per kilogram of wool of average FD.

\( I_A \) and \( I_{MB} \) were devised without using selection index theory. They have proved to be valuable selection tools and they represent ingenious attempts at combining all the information collected into an overall score of merit. An evaluation of the expected consequences of using \( I_A \) and \( I_{MB} \) (Ponzoni, unpublished data) indicated that both indices should result in genetic gain measured in economic units, via genetic improvement in wool production, reproduction rate, and growth-rate. \( I_A \) places more emphasis on reproduction rate and growth-rate than does \( I_{MB} \), whereas the opposite is true for wool production.

The South Australian Department of Agriculture (Ponzoni & Walkley, unpublished data) has defined a broad range of breeding objectives for Merino sheep, and for each of them a number of indices have been derived using selection index theory. Indices derived formally refer to a specific breeding objective. When \( CWF \), \( FD \), and \( HW \) are selection criteria, formal indices are more efficient than \( I_A \) or \( I_{MB} \) and the magnitude of the difference in efficiency varies with the breeding objective being considered (Ponzoni, unpublished data). Nevertheless, breeders involved in the development of \( I_A \) and \( I_{MB} \) are to be commended for their attempt to make the best possible use of objective measurement, and formal indices should be regarded merely as a refinement of the basic tool.

Table 3: Index coefficients and correlations between index and breeding objective \((r_{IH})\) for indices 1 to 4. Breeding objective as defined in Table 2

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Index Number*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( I_1 )</td>
</tr>
<tr>
<td>CWF</td>
<td>5.18</td>
</tr>
<tr>
<td>FD</td>
<td>-1.07</td>
</tr>
<tr>
<td>Dam's NLW*</td>
<td>1.35</td>
</tr>
<tr>
<td>HW</td>
<td>0.38</td>
</tr>
<tr>
<td>( r_{IH} )</td>
<td>0.51</td>
</tr>
</tbody>
</table>

* For example: Index number 1 = \( I_1 = 5.18 CWF - 1.07 FD + 1.35 \text{ dam's NLW} + 0.38 \text{ HW} \).
+ CWF = greasy fleeceweight; CWF = clean fleeceweight; FD = fibre diameter; NLW = number of lambs weaned; HW = hogget weight.
\footnote{One record.}
For illustration purposes, Table 3 shows the coefficients for a number of selection indices derived for the breeding objective defined in Table 2. The value (accuracy) of each index can be measured by the correlation between the index and the breeding objective \( r_{IH} \). Indices \( I_1 \) and \( I_2 \) are suitable for rams since they include measurements of CFW and FD, which are relatively expensive. Indices \( I_3 \) and \( I_4 \), involving measurements that do not require laboratory and analyses, are suitable for ewes. Note that, given the parameter values assumed when calculating the indices, recording a dam's NLW (that is, whether the individual was reared as a single or a twin) contributes little to the value of the index measured by \( r_{IH} \). This is an important observation because recording type of birth or type of rearing, especially in large flocks, is a very laborious task. So, formal indices have the additional advantage that the effectiveness of indices including different combinations of selection criteria can be assessed by the \( r_{IH} \) value and, on the basis of this information, the breeder can decide which characters he wishes to record.

Given the appropriate information, some wool testing houses can calculate not only an overall score of merit, but also an estimated breeding value for each trait in the objective, based on all the characters measured. This information can be valuable for the stud breeder when he is selecting his replacements, and also for the ram buyer when choosing rams for his commercial flock.

Controversial Areas

There are areas in which the approach of breeders and sheep-classers differs from that taken by geneticists. Unfortunately, both sides often adopt a cynical attitude about each other's views and this does not contribute to greater mutual understanding. In this section I consider some of these areas and when possible I present scientific evidence on the matter.

(i) Skin Thickness

Some sheep-classers emphasise the importance of selecting for the 'right' kind of skin (thick and loose) when attempting to improve wool production. They say that sheep with such a skin maintain wool production during their lifetime more than do sheep with thin skin. They also say that flocks that have been selected for clean fleeceweight are noted for their thin skin, and that sheep that have a high fleeceweight as hoggets may, with age, decline rapidly in wool production.

The only estimates available of phenotypic and genetic correlations between skin thickness and clean fleeceweight (both characters measured at fifteen to sixteen months of age) are those of Gregory (1982). Skin thickness was measured with a micrometer on a skin section of 1 cm diameter taken from the midside area of the sheep. Gregory obtained values of 0.23 and 0.39 for the phenotypic and genetic correlations, respectively. This finding is contrary to sheep-classers' beliefs as it suggests that selection for clean fleeceweight would result in greater skin thickness in both current and future generations. It also suggests that sheep-classers may be correct in using skin thickness as an indicator of clean fleeceweight.

There is very little information on the genetic correlation between fleeceweight at fifteen to sixteen months of age and fleeceweights at later ages. Records taken at fifteen to sixteen months of age are recommended as a basis for selection because they are available before the animals attain breeding age, and because it is thought that they are a good indication of an animal's breeding value for wool production. The limited information reported on this area indicates that selection for hogget fleeceweight results in an increase in fleeceweight at all adult shearings (McGuirk & Atkins 1976), but there is evidence which suggests that the genetic correlation between hogget fleeceweight and the average of mature (two, three, four, and five years old) fleeceweights is significantly lower than unity (Lewer et al. 1983). Detailed analyses of records collected by State Departments of Agriculture and CSIRO could provide the evidence needed on this area to elucidate sheep-classers' claim that wool cuts from some sheep of high fleeceweight as hoggets decline rapidly with age.

(ii) Selection for Clean Fleeceweight and Positive Micron Sheep

Sheep may have wool of a fibre diameter finer than, equal to, or stronger than what the visual count indicates (the number of crimps per inch is the main indicator of visual count). Such sheep are classed as being positive micron, equal micron, or negative micron, respectively. Some sheep-classers claim that sheep that are positive micron produce offspring of greater fleeceweight than do sheep of the same fleeceweight and fibre diameter but that are negative micron.

Published estimates (Dolling 1970) suggest that the negative genetic correlation between clean fleeceweight and crimps per inch may be of greater magnitude in Medium Merinos.
than in South Australian Strongwool Merinos (for example, -0.7 and -0.4, respectively), in which case the value of crimps per inch as indicator of clean fleeceweight would be greater in the former strain.

According to genetic theory, because of the negative genetic correlation between clean fleeceweight and crimps per inch, if two individuals have the same clean fleeceweight and fibre diameter, the one with fewer crimps per inch has a greater estimated breeding value for clean fleeceweight (EBV_CFw). Table 4 shows an example of two South Australian Strongwool Merino rams, assuming the genetic correlation between clean fleeceweight and crimps per inch is -0.4. Ram No. 1 has fewer crimps per inch and a greater EBV_CFw than has ram No. 2.

This is a case in which sheep-classers' views can be reconciled with the geneticists' approach based on genetic theory. Although clean fleeceweight itself is the selection criterion providing the greatest amount of information about the breeding value for that trait, crimps per inch provide additional information. Sheep-classers have attempted to use that information by grouping the sheep into positive, equal, and negative micron, whereas geneticists would construct a selection index combining clean fleeceweight, fibre diameter, and crimps per inch.

### Table 4: Clean fleeceweight (CFW), fibre diameter (FD), crimps per inch (CPI), and estimated breeding value for CFW (EBV_CFW) of two South Australian Strongwool Merino rams

<table>
<thead>
<tr>
<th>Ram No.</th>
<th>CFW (kg)</th>
<th>FD (microns)</th>
<th>CPI</th>
<th>EBV_CFW* (%I</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.0</td>
<td>25.0</td>
<td>7.0</td>
<td>100.0</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>25.0</td>
<td>10.0</td>
<td>96.7</td>
</tr>
</tbody>
</table>

* EBV_CFW expressed as a percentage of the greatest value

(iii) Selection for Resistance to Fleece-Rot and Body Strike

Resistance to fleece-rot and to body strike was mentioned briefly in the section on breeding objectives. Fleece-rot in itself has a small economic value, but it is often the major predisposing factor to body strike, which can result in serious economic losses. Both traits have a low-to-moderate heritability and it should be possible to achieve improvements within a flock by selecting resistant animals. However, because the occurrence of fleece rot and body strike depends on the environment being favourable for their development, direct selection of resistant animals is not possible in some (dry) years or in some environments. Because of the difficulties encountered with direct selection, practical breeders and geneticists have sought other skin and wool traits that could be used as indicators of resistance to fleece-rot and body strike. Characteristics such as wool colour, wool character, wool handle, wax and suint content, wax : suint ratio, and coefficient of variation of fibre diameter have been advocated, on occasions very strongly, as indicators of resistance to fleece-rot and body strike. However, they should be used with prudence (if at all) because although in some studies they were found to be correlated with resistance, none of them is so strongly or consistently correlated that it can be recommended as a generally useful selection criterion.

A considerable amount of sheep research is currently directed towards the identification of characteristics that may be genetically associated with fleece-rot and body strike in Merino sheep. Also, progress is likely to take place in the area of artificial induction of fleece-rot, so that it may become possible to identify susceptible animals with certainty, independently of the environmental conditions.

Conformational faults such as 'broad withers' or 'devil's grip' make the animals more susceptible to fleece-rot and body strike. When the reduction of susceptibility to fleece-rot and body strike is seen as a desirable aim, sheep exhibiting these faults should be culled.

### CONCLUDING REMARKS

Recommendations on sheep breeding given by geneticists are often different from those given by breeders and classers. This will continue to be so unless the two groups work in closer association. Besides those mentioned in the previous section of this paper there are...
several other areas in which the opinions of breeders and classers differ from those of geneticists. A joint effort should be made to gain further knowledge in those areas. Of course, it will not be possible to test all 'novel' ideas (from either side) about genetic improvement, and only areas likely to have the greatest impact on industry should be chosen. At present some sections of the Merino industry follow the breeders' and classers' advice, whereas other sections follow the guidelines given by geneticists. There have also been attempts to combine the two kinds of advice. If the breeding strategy suggested by any one of the groups mentioned above is superior to that of the others, followers of the less effective strategies will not be achieving the potential for genetic gain available in their flocks. Having large sections of an industry working below their potential is not in the interest of the individual producers concerned, nor is it in the national interest. An industry with a well co-ordinated strategy for genetic improvement has a greater chance of thriving during favourable periods and of surviving during unfavourable ones than has a fragmented one that is plagued with unsubstantiated differences of opinion. Ideally, all recommendations to industry should be based strictly on documented evidence.

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