Paper 2. Revised version.

NJ mods in blue

**Improvements in fleece weight and wool quality of Merino sheep selected visually for high fibre density and length.**

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**Abstract**

*A visual classing system for grading Merino sheep according to fibre density and length is evaluated. In a dam – progeny assessment, the classing types are shown to be strongly inherited. In 3 closed Merino flocks, the selection system led to increases of 0.101, 0.196 and 0.201 kilograms per year in clean fleece weight and corresponding decreases of 0.276, 0.258 and 0.199 microns per year for fibre diameter. (Neville, please check these figures – there is some mixup between 0.101 and 0.196 in the graph I need the data file to sort it out). The numbers of secondary follicles per follicle group is increased to levels not previously reported. Fibre length and uniformity, alignment and shape are improved along with softness, lustre and whiteness of the fleece.*

**Introduction**

It seems logical that selection of Merino sheep for high fibre density and length will produce high fleece weights of fine diameter wool. However, to avoid the high costs of direct measurement, an accurate method of visually classifying Merino sheep for density and length is required.

A method presented here was identified in pilot studies by one of us (JW) in 1987. The initial clue came from observing that the sheep needed to be plain bodied Merino sheep, and when shorn, produce a low bulk but dense fleece that has a high fleece weight. These sheep were also found to have measurably high fibre density and length and often, low fibre diameter. The fleeces consist of very long and closely packed fibre bundles\* and thin staples (Figure 1 left). The wool is very soft, lustrous and has high crimp amplitude (“deep” crimp) and low crimp frequency (“bold” crimp). This fleece structure is very different to that of most Merino sheep which have wrinkly skins, thick, stiff staples and closed backs (Figure 1 right). Also, the wool of these wrinkly sheep is not as long, soft, lustrous or deeply crimped as the high density and length animals.

(insert photo here)

**Figure 1. SRS ewe (right) and wrinkly ewe (left) from stud B in 1994. The sheep are 15 months old and carrying … months wool growth.**

*\* Footnote: a fibre bundle is the cluster of fibres produced by a follicle group (reference). It is only about 0.5 to 2 square millimetres in cross-sectional area*

The heritability of the classing grades was examined in a Merino stud flock where full pedigreed records were available. Changes in fleece weight, fibre diameter, follicle density, secondary follicle development, fibre length and wool quality were examined in three closed Merino stud flocks over 8 years.

**Materials and methods**

*Classing types*

Each sheep was classed into one of four types:

* plain bodied sheep with fleeces consisting of very long, and closely packed fibre bundles and thin staples. The wool is very soft, lustrous and has high crimp amplitude (“deep” crimp) and low crimp frequency (“bold” crimp). In long wool, the fleece parts along the backline. The skin is very loose. The sheep are referred to as “SRS” and were expected to have high density and length (see Figure 1a).
* plain bodied sheep with fleeces consisting of long, thin staples. The wool is soft and semi-lustrous. The crimp amplitude is not as pronounced as for SRS animals. The skin is loose. The sheep are referred to as “semi SRS” and were expected to rank next best for density and length.
* relatively plain bodied sheep with fleeces consisting of wide, lightweight staples. The wool is non-lustrous and has low crimp amplitude. The skin is thick and taut. The sheep are referred to as “flat skin” and were expected to have low density.
* sheep with fleeces consisting of thick, stiff staples. The fleece is often excessively greasy, short in length and forms “closed “ backs. The skin is very thick and forms wrinkles to varying degrees over the body. No attempt was made to subdivide this class on degree of wrinkle . The sheep are referred to as “wrinkly” and are expected to have average to high density and low fibre length (see Figure 1b).

*Sheep*

In a Merino stud flock at Cooma, New South Wales, in (1996 ?), 448 fully pedigreed lambs were classified at … months of age. The lambs were the progeny of dams previously classified into one of the 4 types. The sires were all classified as SRS rams. We refer to this flock as Stud X.

Three closed Merino flocks of South Australian strong wool origin, located at Marnoo, Victoria, Australia, were used. The ewes and rams were classed at 14 months of age. All selection was done by visual classing. At most ewe classings, only the SRS and semi SRS types were kept, and the flat skin and wrinkly types culled. At ram classings, only the animals closest resembling the SRS type were kept. Young rams were retained each year as sires. There were approximately 1500 ewes in flock A, 1200 ewes in flock B and 600 ewe hoggets in flock C. Estimates of the proportions of ewes in each of the 4 classing types was made at the start and finish of the trials. Average fleece weights and fibre diameters were obtained from wool records at shearing.

After 6 years of selection in stud A, skin and fleece samples were taken from a random sample of classed ewes, 20 months of age, to compare the fleece and follicle characteristics of the two main sheep types (SRS and semi SRS). Some of the measurements of these samples were reported by Brown (1995). One hundred and five ewes drawn at random from a larger mob in stud A were classed into SRS or semi SRS types. Fifteen animals of the wrinkly and flat skin types were excluded, leaving groups of 47 SRS and 43 semi SRS ewes respectively.

*Histology*

Midside skin samples were collected using a one centimetre circular trephine and fixed in 10% formol saline solution. Horizontal skin sections were prepared and measurements made as described by Maddocks and Jackson (1988) using the frozen section technique and measurement procedures of Nay (1973). The trio group of primary follicles along with the associated cluster of secondary follicles constitute the follicle group (Carter 1943). The secondary follicle to primary follicle ratio and the total follicle density were measured.

Additional fibre measurements were made on skin sections from the ewes in stud A. Fibre alignment was measured on 100 fibre cross sections per animal by determining the angle of the boundary between orthocortex and paracortex in relation to the horizontal plane. The proportion of cylindrical fibres (ie fibres of near-circular cross section) was calculated from a visual estimate of each of 100 fibres after confirming that such a visual estimate agreed with measurements of major and minor axes. A fibre was regarded as cylindrical when the minor axis was more than 0.9 of the major axis.

*Fleece measurements*

Records of fleece weight, yield and fibre diameter were available for the total ewe flock in studs A and B and for the ewe hoggets in stud C. The corresponding numbers of ewes in each flock each year were known exactly.

Individual fleeces of the ewes from stud A in 1994 were weighed and yield, staple length and fibre diameter measured on midside samples. Wool samples were analysed for mean fibre diameter using the Optical Fibre Diameter Analyser (OFDA). The mean values for these measurements were reported by Brown (1996). Part of the midside samples were measured for fibre length and the ratio of fibre length to fleece length.

*Subjective wool assessments*

In blind tests on midside wool samples collected from the ewes in stud A in 1994, the animals were reclassified on visual appearance as SRS or semi SRS. This enabled a comparison of on-sheep assessment with on-wool-sample assessment, and also constitutes a study of repeatability of scoring.

Scores were then allocated to each sample for softness, lustre, whiteness and elasticity of the wool. Each characteristic was rated on a score of 1 to 4 (4 best).

**Results**

*Dam-progeny classing grades*

Table 1 lists the numbers of progeny of each classing type according to the classing type of the dam.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Dam grades | Progeny grades | | | | Dam frequencies | Daughter frequencies |
| SRS | semi SRS | flat skin | wrinkly skin |
| SRS | 12 | 5 | 2 | 4 | 0.05 | 0.30 |
| semi SRS | 75 | 48 | 31 | 49 | 0.45 | 0.20 |
| flat skin | 36 | 27 | 35 | 66 | 0.37 | 0.18 |
| wrinkly skin | 13 | 10 | 12 | 23 | 0.13 | 0.32 |

*Neville, could you please analyse results in Table 1 and comment here and in the Discussion about the genetic implications.*

*Jim, can you add the dam and daughter frequencies to above table as an extra column and row. They are dam frequencies (0.05,0.45,0.37,0.13) and daughter frequencies (0.30,0.20,0.18,0.32) in order ( srs,semi,flat,tight).*

*Table 1 is a contingency table. A test of independence of the dam and daughter grades gave a Chi-squared value of 27.4 with 9 degrees of freedom. That is highly significant. The dam and daughter grades are correlated. This, in itself, is an indication of some degree of inheritance of the classers grades.*

*We can consider the four grades to be a threshold trait. That is we can assume that there is actually an underlying continuously distributed variate ( perhaps something related to fibre*

*density and length), and that the three cutoff points between grades are each represented by a threshold value on the underlying scale. With this assumption, we can compute a polychoric correlation between dams and daughters on the underlying scale. A maximum likelihood estimate of this correlation was 0.255 with a standard error of 0.053. This correlation is doubled to obtain a heritability estimate of 0.51 with a standard error of 0.106.*

*We can obtain the position of the thresholds on the underlying scale, from tables of the normal distribution, using the dam and daughter frequencies given in Table 1. These are shown in Table 2*

*Table 2. Estimates of the position of the thresholds between grades on the underlying scale in standard deviation units*

*Srs/semi semi/flat flat/tight*

*Dams -1.63 s1 0.01 s1 1.35 s1*

*Daughters -.52 s2 0.02 s2 0.48 s2*

*We can arbitrarily choose to make the units on the underlying scale equal to the width of the semi grade ( ie the interval between the srs/semi and semi/flat thresholds). We call this a 'threshold unit'. We can then calculate that the standard deviation of dams on the underlying scale is s1 = 0.617 threshold units, and that the standard deviation of the daughters on the underlying scale is s2 = 1.85 threshold units. In other words, the daughter population is about 3 times as variable as the dam population. This is because the dam population was culled, prior to the experiment, whereas the daughter population is a complete unculled drop of lambs. There is some concern that the above heritability estimate may have been biased by the dam culling, because we used a dam-daughter correlation rather than a regression. It is not possible to do a polychoric regression .What we can do is code the classers grades as (srs=1, semi=2, flat=3, tight=4) and do a simple regression of daughter on dam. From this we get a regression coefficient of 0.34 with a standard error of 0.073. This implies a heritability of 0.68 with a standard error of 0.146. The correlation from this regression analysis was 0.21, not seriously different from the polychoric correlation above. We conclude that the heritability estimate from polychoric correlation is not seriously biased in the upward direction.*

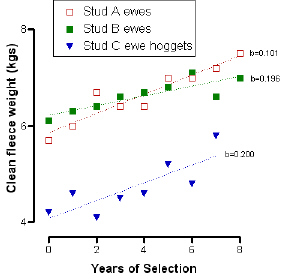
*The complete picture of these data on the underlying scale is shown in Figure 2, which depicts the frequency distributions of the dam and daughter populations, and the spacing of the thresholds. Note that the thresholds are almost uniformly spaced on the underlying scale. This why coding the grades as an equal spaced series of integers was satisfactory in the previous paragraph. The daughter population is shown with its mean -0.296 threshold units to the left of the dam population mean which is set to zero. This represents response to selection of the sires. We can calculate that the phenotypic selection differential from choosing all SRS grade rams would have been -1.8 s1 units. We have to average this with zero for ewes giving -0.9 s1 units or -0.9 \* .61 = -.549 threshold units. With a heritability of 0.5 this leads to an expected genetic selection differential of 0.5 \* -0.549 = -0.275 threshold units in the daughters. This agrees well with the observed dam-daughter difference of -0.296. So the realised response agrees with that predicted from the heritability estimate. Not surprising as they are both based on the same observations.*

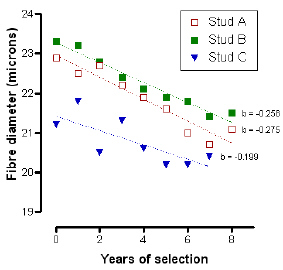


Figure 2. Frequency distributions of the dam and daughter populations for the underlying continuous variable, which is divided into four grades by the thresholds shown in red, green and blue. Note that the thresholds are spaced the same for the dam and daughter populations: this is because we are grading sheep for the same trait in both populations. The dam population has a considerably lower standard deviation than the daughter population, on the underlying scale. The daughter population has its mean shifted 0.3 threshold units to the left, this being the expected genetic shift due to selection of only grade "SRS" sires for mating to the dams. The three thresholds are close to equally spaced, indicating that the grading system achieves and approximately linear separation on the underlying scale.

*Correlated responses in fleece weight and fibre diameter in studs using the SRS selection system*

Annual measurements of clean fleece weight and mean fibre diameter for the stud flocks A, B and C are shown in Figures 2a and 2b respectively. The responses are from in-stud selection of rams and ewes, there being no introduction of sheep from outside sources. The data used for studs A and B are for the total ewe flock while the data for stud C are for ewe hoggets.





**Figure 2a to 2b.** The clean fleece weight and fibre diameter responses to selection using the SRS classing system in studs A, B and C.

There is a problem in Fig2a. Stud A has a slope of b=0.101 but is shown as a steeper slope than Stud B which has b=0.196? Have these two been labelled wrongly? I need the data if you want me to check the regressions.

At stud A, the 1983-87 flock average for ewes was 7.5 kilograms greasy fleece weight and 22.2 microns fibre diameter. For 1990-94, the average was 8.6 kilograms and 21.1 microns and for 1994 alone, 9.1 kilograms and 20.7 microns. After 13 years of selection, the ewes averaged 8.8 kilograms greasy fleece weight and 18.2 microns for fibre diameter.

At stud B in 1987, the flock average for ewes was 7.8 kilograms for greasy fleece weight and 23.5 microns for fibre diameter. By 1994 the values were 9.5 kilograms and 21.3 microns. After 13 years of selection, the ewes averaged 8.8 kilograms for greasy fleece weight and 18.8 microns for fibre diameter.

At stud C in 1988, the flock average for the ewe hoggets was 4.1 kilograms clean fleece weight and 21.4 microns for fibre diameter. By 1994 the values were 5.5 kilograms clean fleece weight and 20.4 microns for fibre diameter. After 13 years of selection, the ewe hoggets averaged 6.1 kilograms greasy fleece weight and 17.2 microns for fibre diameter.

Previous 3 paragraphs:

It is confusing to present CWW in the Figure then talk about GFW in the text. Either include a GFW Figure too, or talk only CWW in text.

Because there were no randomly mated control flocks included in these trials, it cannot be assumed that all of the changes in fleece weight and fibre diameter in Figure 2 are genetic. It may have been due to improved nutrition. However, this seems unlikely as fibre diameter would be expected to increase, not decrease, if better nutrition was the cause.

The proportions of ewes in the four classing types of each flock at the start and finish of the in-stud selection trials are listed in Table 1. These give us an estimate of the direct response to selection in the studs A, B, and C.

Table 1. Estimates of the percentages of ewes of the four different classing types in each flock at the start and finish of the 8 year trials.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Flock | Timing of assessment | SRS (%) | Semi SRS (%) | Flat skin and wrinkly skins (%) |
| Stud A | 1988 | 20 | 40 | 40 |
| 1994 | 50 | 40 | 10 |
| Stud B | 1988 | 10 | 30 | 60 |
| 1994 | 50 | 40 | 10 |
| Stud C | 1988 | 0 | 30 | 70 |
| 1994 | 40 | 40 | 20 |

Only 10 to 20 % of the ewes in flocks A and B, and none of the ewe hoggets in flock C were estimated to be SRS types at the start of the trials. At the finish of the trials, the estimates had risen to 50%, 50% and 40 % respectively. In all flocks, the estimates of semi SRS types were high (30 to 40%) at the start and finish.

These changes in proportions correspond to shifts in the mean on the underlying scale of -0.84 s for Stud A, -1.28 s for Stud B, and -1.36 s for Stud C. If these are cumulated genetic selection differentials over the four years, and if the heritability is 0.5, they correspond to phenotypic selection differentials of -.42 s, -.64 s, and -.68 s per year. To get those phenotypic selection differentials one would have had to have selected proportions of 0.34, 0.26, and 0.24 respectively, averaged over rams and ewes. This is entirely feasible – for example selecting 1% of rams and 65% of ewes leads to an average proportion of 0.34. So the direct response in classing grades seen here is compatible with the heritability estimate.

Phenotypic selection differentials

*The classing technique described here is a multi-trait procedure. There is some interest in seeing how much phenotypic selection differential was being placed on the various skin and fleece traits. Two sets of data were available, one of skin-traits on visually selected sires and the other of a comprehensive set of wool and skin traits on ewes classed as 'srs' and 'semi-srs'.*

*Subhead: Skin traits of selected rams.*

Follicle and fibre measurements were made on visually selected sires, mostly 15 months of age, on several occasions over the 8 year period of selection in studs A and B. Table 1 lists the mean values and standard errors.

Table 1. Follicle and fibre measurements (mean + - standard errors) of visually selected rams used in the breeding programs of studs A and B.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Measurement | Stud A | | Stud B | | |
| 1988  n = 7 | 1995  n = 12 | 1988  n = 18 | 1991  n = 4 | 1994-95  n = 4 |
| S/P ratio | 35.7 (2.5) a | 48.8 (1.1) b | 31.1 (1.1) a | 41.4 (1.4) b | 44.2 (4.2) b |
| follicle density | 98.6 (13.2) a | 96.7 (7.1) a | 77.3 (4.0) a | 71.2 (7.2) a | 70.1 (8.8) a |
| Dp | 20.8 (0.92) a | 18.9 (0.49) a | 23.6 (0.61) a | 19.5 (1.12) b | 19.5 (0.65) b |
| DpSD | 3.17 (0.26) a | 2.73 (0.17) a | 3.33 (0.15) a | 2.25 (0.22) b | 2.25 (0.26) b |
| Ds | 21.8 (0.48) a | 20.5 (0.32) b | 23.8 (0.36) a | 20.9 (0.71) b | 21.7 (0.86) b |
| DsSD | 2.37 (0.25) a | 2.44 (0.14) a | 3.26 (0.16) a | 2.95 (0.34) a | 3.20 (0.43) a |

Footnote: within each flock, mean values with different superscripts are significantly different at P < 0.001.

For the rams bred and kept as sires, the S/P ratios increased whilst primary fibre diameter and secondary fibre diameter decreased during the course of the trials. Follicle densities remained unchanged at the high starting levels.

*Subhead:Comparison of the fleece, follicle and fibre characteristics of ewes (stud A)*

The classing of wool samples into SRS and semi SRS grades was highly repeatable. Sixty four of the 70 samples were reclassified correctly.

Jim: we should actually calculate a repeatability. Can you make up a table 2 x 2 of srs and semi counts on-sheep against on wool. I will then be able to calculate it. It should be larger than the heritability.

The measurements and scores for these ewes are listed in Table 2.

**Table 2. Follicle, fibre and fleece characteristics of SRS and semi SRS ewes (stud A)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Characteristic | **SRS** | | **semi SRS** | | **P value** |
| **mean** | **sem** | **mean** | **sem** |  |
| clean fleece weight (kgs) \* | 6.61 | 0.11 | 5.72 | 0.13 | <0.0001 |
| yield (%) | 72.7 | 0.62 | 72.6 | 0.74 | ns |
| fibre diameter of fleece | 20.4 | 0.21 | 21.8 | 0.23 | <0.0001 |
| S/P ratio | 38.8 | 0.70 | 27.2 | 0.51 | <0.0001 |
| follicle density | 92.6 | 3.79 | 78.6 | 2.80 | <0.005 |
| Dp | 19.0 | 0.42 | 21.6 | 0.40 | < 0.0001 |
| DpSD | 2.57 | 0.08 | 2.79 | 0.12 | Ns |
| Ds | 18.0 | 0.27 | 19.1 | 0.29 | <0.0001 |
| DsSD | 2.76 | 0.12 | 3.10 | 0.11 | < 0.05 |
| laneways | 135 | 5.26 | 81.4 | 4.25 | <0.001 |
| fibre alignment (%) | 71.2 | 1.90 | 54.8 | 0.66 | <0.0001 |
| cylindrical fibres (%) | 88.0 | 0.99 | 69 | 1.83 | <0.0001 |
| fibre length | 90.4 | 1.50 | 81.13 | 1.59 | <0.0001 |
| fibre length SD | 9.07 | 0.43 | 13.11 | 0.84 | <0.0001 |
| fibre length to fleece length ratio | 1.28 | 0.01 | 1.18 | 0.01 | <0.0001 |
| softness | 3.1 | 0.14 | 2.2 | 0.13 | <0.0001 |
| lustre | 2.8 | 0.12 | 2 | 0.09 | <0.0001 |
| elasticity | 3.8 | 0.19 | 2.6 | 0.23 | <0.001 |
| whiteness | 2.8 | 0.13 | 1.8 | 0.10 | <0.0001 |

*\* footnote: clean fleece weights were obtained for 12 months wool growth. All other fibre and fleece measurements and fleece scores were obtained from midside wool samples collected 5 months earlier (7 months wool growth)*

All but two of the mean values of the 14 traits were significantly better in the SRS ewes than in the semi SRS ewes. The exceptions were wool yield and DpSD.

SRS ewes produced 15 % more clean wool of 1.4 microns finer diameter than the semi SRS ewes. Density, secondary follicle development and fibre length were also higher. The fibres were more uniform in diameter and length and proportionally longer than the fleece length. The wool was softer, more lustrous, more elastic and whiter. The primary fibres were 2.7 microns finer and the secondary fibres 1.0 microns finer, resulting in a lower Dp/Ds ratio.

It is quite clear that the SRS classing system leads to a phenotypic selection differential for a large number of traits. Means for classing grades can be converted to a phenotypic selection differential for any trait, if we know the proportion or number of sheep of each grade selected.

**Discussion.**

The dam-progeny study of classing types indicates that the classing method separates sheep into 4 grades which can be mapped onto an underlying continuous scale. Variation on the underlying scale is highly heritable, as evidenced by a polychoric correlation estimate of heritability of 0.5, and by shifts in the proportions of sheep in each grade under selection.

There is some element of surprise, that a subjective grading would have such a high heritability. Most subjectively graded attributes in sheep have heritabilities of 0.3 or less. The explanation has to be that this is a multi-trait grading. It is analagous to the mean of a number of measurements and therefore exhibits the phenomenon of attenuation of errors. Errors which are random for each trait tend to cancel each other out when several traits are combined.

A single measured trait, such as CFW or fibre diameter, has a repeatability of 0.5 to 0.7 (Turner and Young (1969)). This means that at least 30% of the observed or phenotypic variance is measurement error. SRS classing grades have a repeatability of … ( we need to do this!). This means that SRS classing grades have only …% of the phenotypic variance as measurement error. This explains the higher heritability.

We need to compare the correlated responses in CFW and fibre diameter in Figure 2 , with those that might be achieved by direct selection for measured CWW or Fibre diameter. To do this we need to imagine a flock with one age group of rams ( 2 years old) and five age groups of ewes ( ages 2,3,4,5,6 years). For every 100 ewes there will be approximately 20 per age group, so we need 20 ewe replacements each year, to be chosen from say 50 ewe lambs, a selected proportion of 0.40 giving a selection differential of 0.9 standard deviations. We also require 2 ram replacements per 100 ewes mated, and these are to be chosen from about 50 ram lambs, giving a selected proportion of 0.04 or a selection differential of 2.0 standard deviations. The average selection differential of rams and ewes then would be (2.0 + 0.9)/2 = 1.45 standard deviations. If this were single trait selection for CFW the response per generation would be selection differential x heritability x standard deviation = 1.45 x 0.4 x 0.9 = 0.522 Kg per generation. The generation interval for this imaginary flock would be 2 years for rams and 4 years for ewes, an average of 3 years. So the expected response in CWW per year is 0.522/3 = 0.17 Kg per year. This is remarkably similar to the annual rates of change shown in Figure 2a ( 0.101, 0.196, 0.200). This is not a precise comparison. There is no guarantee that the flock structures in Studs A, B, and C is the same as we assumed in our imagined flock. Also the responses in Studs A, and B are measured on the whole ewe flock and should be 'damped' compared to what they would have been if only successive drops of hogget ewes had been measured, as in Stud A.

The same calculation for Fibre diameter leads to a response for our imagined flock of -1.74 micron per generation or -0.58 micron per year. This is larger than the annual rates of change shown in Figure 2b (-0.258, -0.275, -0.199). The SRS classing procedure clearly does not put as much negative selection diffferential on Fibre diameter as would be achieved by single trait direct selection.

In practice one would be unlikely to use single trait selection for either CWW or Fibre diameter, but rather some index combining the two with the aim of achieving zero or negative genetic change in Fibre diameter combined with maximun possible genetic increase in CWW. There are a whole array of options here, including use of information from relatives as well as phenotypic observations to increase accuracy of selection.

The most that can be said from this somewhat imprecise comparison is that the observed annual rates of change in CWW and Fibre diameter in Figure 2 are within the bounds of feasibility for a conventionally structured self replacing sheep flock. We are not dealing with a 'magic' huge response, such as might be observed if a major gene had been allowed to segregate; nor are we dealing with a very much reduced correlated response to selection, such as might be observed if the heritability of SRS classing grade were low, or if its genetic correlations with CWW and Fibre diameter were low.

Although SRS classing seems to lead to similar genetic changes in CWW and Fibre diameter when compared to selection on measured CWW and/or Fibre diameter, the resulting sheep and their fleeces are very different. SRS classing puts a large selection pressure on the following

* Wrinkle-free loose-skinned sheep
* Development of secondary follicles ( S/P ratio)
* Fibre length growth rate (L) and some associated fibre properties ( Lustre, Softness, and Circularity)

Exactly how these three aspects are impacted on by SRS classing grades is not fully understood. We have the following insights

* The link to wrinkle and macro skin development is fairly obvious. The SRS grade definitions given here emphasize wrinkle, skin thickness, and skin looseness. It is the combinations that matter, not any one characteristics. Loose skin is clearly a path to increasing the skin surface area, without increasing body size, and without the undesirable attribute of skin folds. Thin skin is ...
* The impact on follicle development is probably controlled by the size of primary follicles (Dp). The pre-papilla cell theory of Moore et al (1989) holds that if few pre-papilla cells are used to initiate primary follicles, then there wil be more pre-papilla cells available later to form branching secondary follicles. The measurements of Dp and S/P on graded rams and ewes indicate that this is happening. The skin measurement called 'laneways' indicates an increase in the number of branches in compound follicles.
* The impact on follicle function (fibre length growth rate and the properties Lustre, Softness, and Circularity) is less well understood. It may be that highly branched compound follicles grow a different type of fibre. It may be that there is some other link not involving follicle development such as thin skin being directly associated with follicle function.

Some of the follicle characteristics observed in rams and ewes of the SRS grade were outside of the bounds of previous observations.

The SRS rams and ewes in the 3 closed flocks had levels of secondary follicle development and follicle density much higher than found in Merino stud flocks surveyed by Carter and Clarke (1956). Fibre length of the SRS ewes, measured at a mean value of … millimetres per day, are also considerably higher than normally found in Merino sheep (references).

We need to make due allowance for our observations here being on selected sheep, so they would be expected to be extreme. It is still quite surprising how extreme some SRS selected animals have become. It does suggest that there is potential for further improvement of Merino sheep in these directions. Extreme animals for one trait are interesting but not economically important. It is the extreme combinations of several traits that are of merit.

*(Neville, we should discuss implications of Phillip Moore’s pre-papilla cell hypothesis to these findings here ? Would you like to have Phil’s contribution to this section. I would be pleased to include Phil as a co-author). [I put it in above – do you want more. Happy with Phil included]*

*We said this above, but need to emphasize that it is the combinations of characteristics that are most exceptional.*

The combination of high density due to extensive secondary follicle branching and high fibre length and high fibre length to fleece length ratio appears to underpin the rapid increases in clean fleece weight and decreases in fibre diameter. These follicle and fibre traits in combination, also appear to be reliably identified by the SRS classing method. Mods needed this para. See email to JW.

It appears that in a breeding program, selection for high fibre length must accompany high secondary follicle development to avoid these plain bodied and loose skinned sheep becoming wrinkly. [ Where does this come from ?] High fibre length is closely associated with plain bodies and wrinkle free skins. Our minimum selection standard is 0.60 millimetres per day. The ram in Figure 3 is from stud B in 1994. It has very high secondary follicle development ( S/P ratio of 56.5 to 1) and high follicle density (94.1 follicles per square millimetre) but the fibre length was 0.50 mm/day. Whilst the fibre length is considerably higher than found in most Merino sheep, it may not be sufficient to offset the development of skin wrinkle (horizontal folds) which has started to develop on the legs and underside of the neck of an otherwise very loose and wrinkle free skin.

You want to argue that plain bodies and loose skinned sheep can become wrinkly? I dont get it? You already have at least a semi-srs sheep and you say you need to put weight on long thin staples – as your grade definitions say. What happens if you dont put weight on long thin staples? We have no data. There is no grade for a loose skinned plain sheep with wide short staples. Do they exist? I dont think so or you would have made another grade. Why dont they exist?. I think perhaps because thin skin is another of the outcomes of Phil's pp-cell model. Both the flat and tight grades are defined as thick skin – ie the wrong outcome of the pp-cell process. Once you et out of that into semi-srs or better, I dont think there is much risk of wrinkle. TELL ME I AM WRONG!

(photo to follow)

**Figure 3. Fifteen months old ram from stud B in 1995.**

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