First group.

The first group considered was that employed in a genetic experiment which had been commenced with 30 stud ewes, all the progeny of one sire. The same sire was employed in the experiment, and later one of his progeny. No culling had been practised, and the rams and ewes, except for being separated in adjacent camps, were given identical treatment.

Ten fleeces from rams and ten from ewes were selected at random after one shearing. On investigation it appeared that the ages of the rams varied from two and a half years to three and a half years with an average of two and three-quarter years, while those of the ewes varied between the same limits with an average of three years. It has been found [see Section 8 (*d*)] that the resistance to compression of fleeces grown by other sheep did not change from the second to the third years, and the two groups may thus be regarded as comparable in respect of age.

Representative samples were taken from the fleeces after removal of locks and bellies, and the resistance to compression, fibre thickness, and number of crimps per inch were determined. The results are given in Table 46, in the order of decreasing resistance to compression.

TABLE 46.

The resistance to compression, fibre thickness, and number of crimps per inch of wool from rams and ewes. (First group.)

RAMS.				EWES.			
Ram No.	Fibre Thickness (Microns).	Crimps per Inch.	Resistance to Compression (Kg. cm.^{7} per 5 gm.).	Ewe No.	Fibre Thickness (Microns).	Crimps per Inch.	Resistance to Compression (Kg. cm.^{7} per 5 gm.).
1	21·5	15·8	10·8 × 10^3	1	22·9	18·8	14·6 × 10^3
2	23·7	15·6	10·5 × 10^3	2	22·5	14·7	13·5 × 10^3
3	22·2	14·9	10·1 × 10^3	3	24·1	14·7	10·2 × 10^3
4	25·9	11·5	9·7 × 10^3	4	24·5	13·5	9·3 × 10^3
5	21·6	13·6	9·1 × 10^3	5	22·5	11·6	8·9 × 10^3
6	22·7	14·4	8·5 × 10^3	6	23·6	12·0	8·8 × 10^3
7	23·1	14·2	8·4 × 10^3	7	21·4	13·9	8·4 × 10^3
8	21·5	13·5	8·2 × 10^3	8	21·0	12·1	7·3 × 10^3
9	21·3	13·0	7·4 × 10^3	9	18·6	14·2	7·0 × 10^3
10	19·6	10·0	5·1 × 10^3	10	19·8	13·9	7·0 × 10^3
Mean.....	22·3	13·7	8·8 × 10^3	Mean.....	22·1	13·9	9·5 × 10^3

The slightly higher value of the ewes' wool did not differ significantly from that of the rams' wool ($t = 0{\cdot}72$). The effect of fineness and crimping was determined by comparing the variance in the resistance to compression with that obtained after adjustment, assuming a linear relation and calculating the partial regression coefficients from the variance within the groups. The results are given in Table 47.

TABLE 47.

Analysis of variance of resistance to compression, before and after adjustment for the effects of fibre thickness and crimping (First Group.)

Variance.	Before Adjustment.		After Adjustment.	
	D.F.	Standard Deviation. (Kg. cm.^{7} per 5 gm.).	D.F.	Standard Deviation. (Kg. cm.^{7} per 5 gm.).
Between sexes...........................	1	$1 \cdot 610 \times 10^3$	1	$1 \cdot 382 \times 10^3$
Within sexes...........................	18	$2 \cdot 207 \times 10^3$	16	$1 \cdot 176 \times 10^3$

The difference in the resistance to compression between the sexes was still insignificant after adjustment for the effects of fibre thickness and crimping ($z = 0 \cdot 161$). The insignificance of the differences between the sexes could not therefore be due to a chance distribution of fibre thockness and crimping between the two groups.

Second group.

The second group of fleeces was derived from a stud in which the breeder had consistently bred for one type of sheep for at least ten years. The fleeces of fifty stud ewes considered to be typical of the stud were submitted for testing, and it was found that the fleeces were remarkably similar as regards mean fibre thickness, for the coefficient of variability of mean fibre thickness was only 4 per cent. Moreover, the ewes were all (according to teeth) of the same age, viz., 4-tooth.

The breeder also submitted 36 fleeces from his top sires, varying in age from 2-tooth to 6-tooth. Again a remarkable uniformity in mean fibre thickness was revealed, the coefficient of variability of mean fibre thickness being 6 per cent. The mean fibre thickness of the ram fleeces was, moreover, found to be identical to that of the ewe fleeces.

The breeder expressly stated that he did not select for " substance ", so that it was unlikely that any bias in the matter of resistance to compression could be present. The sheep had all been run on Karroo pasture, and no difference had been made in the treatment of the rams and of the ewes.

Ten fleeces were taken at random from each group, and representative samples drawn from each fleece as before. The results of the measurements are given in Table 48, in the order of decreasing resistance to compression.

Again there was no difference between the sexes as regards the resistance to compression of the wool ($t = 0 \cdot 10$). An analysis of the variance of the resistance to compression is given in Table 49.

Even after adjustment for fibre thickness and crimping, the whole of the difference between the sexes could be accounted for by the variation within the groups.

TABLE 48.

The resistance to compression, fibre thickness and number of crimps per inch of wool from rams and ewes. (Second group.)

RAMS.				EWES.			
Ram No.	Fibre Thickness. (Microns).	Crimps per Inch.	Resistance to Compression. (Kg. cm.^{7} per 5 gm.).	Ewe No.	Fibre Thickness. (Microns).	Crimps per Inch.	Resistance to Compression. (Kg. cm.^{7} per 5 gm.).
1	22·4	10·5	$8{\cdot}3 \times 10^3$	1	21·5	12·0	$8{\cdot}6 \times 10^3$
2	22·6	11·3	$8{\cdot}2 \times 10^3$	2	22·2	12·0	$8{\cdot}1 \times 10^3$
3	21·8	10·2	$8{\cdot}0 \times 10^3$	3	21·9	12·2	$7{\cdot}7 \times 10^3$
4	22·1	9·9	$7{\cdot}8 \times 10^3$	4	22·3	11·7	$7{\cdot}5 \times 10^3$
5	21·5	12·2	$7{\cdot}7 \times 10^3$	5	22·6	11·2	$7{\cdot}5 \times 10^3$
6	21·2	11·2	$6{\cdot}9 \times 10^3$	6	22·1	12·6	$7{\cdot}2 \times 10^3$
7	21·6	10·4	$6{\cdot}9 \times 10^3$	7	21·2	9·8	$6{\cdot}9 \times 10^3$
8	21·7	7·5	$6{\cdot}8 \times 10^3$	8	21·6	12·2	$6{\cdot}6 \times 10^3$
9	21·5	11·7	$6{\cdot}6 \times 10^3$	9	21·8	10·0	$6{\cdot}2 \times 10^3$
10	20·2	8·7	$4{\cdot}9 \times 10^3$	10	20·2	10·6	$6{\cdot}2 \times 10^3$
Mean.....	21·7	10·4	$7{\cdot}2 \times 10^3$	Mean.....	21·7	11·4	$7{\cdot}3 \times 10^3$

TABLE 49.

Analysis of variance of resistance to compression, before and after adjustment for the effects of fibre thickness and crimping. (Second group.)

Variance.	BEFORE ADJUSTMENT.		AFTER ADJUSTMENT.	
	D.F.	Standard Deviation. (Kg. cm.^{7} per 5 gm.).	D.F.	Standard Deviation. (Kg. cm.^{7} per 5 gm.).
Between sexes..........................	1	$0{\cdot}089 \times 10^3$	1	$0{\cdot}551 \times 10^3$
Within sexes............................	18	$0{\cdot}915 \times 10^3$	16	$0{\cdot}631 \times 10^3$

In the case of two groups of sheep, therefore, on the average no difference in resistance to compression between the wool from rams and that from ewes has been found, and the results suggest that where systematic differences are encountered, the reason must be sought for in other factors than merely those of sex.

(*d*) *Age of sheep.*

The changes which take place in the fleece characteristics with the age of the sheep are of importance to the breeder and wool producer. The knowledge of such changes enables the sheep breeder to predict the fleece characteristics of the adult sheep from those of the young sheep, a point which is often useful in assessing the degree to which Merino sires transmit the desired fleece characteristics.

Moreover, when Merino fleeces are judged, allowances have sometimes to be made for differences in the ages of the sheep concerned.

Little research work is on record where the influence of age has been directly investigated. Bosman and van Wyk (1941) found a reduction with age in the percentage difference between the coefficients of friction in the two directions of the fibres composing uniformly grown staples. No record of measurements of the influence of age on the resistance to compression is available.

In studies of this nature it is essential that the sheep shall have been kept under uniform and controlled conditions, especially of feed. Eight sheep were accordingly selected from a group which had been kept on an optimum ration for growth and production since the time of weaning, and had been reared together in a small, bare paddock. The selection included different fleece types.

Representative samples were taken from the fleeces each year, and the resistance to compression, fibre thickness and number of crimps per inch were determined. The experiment is still proceeding, but the results of the first four years are given in Table 50.

The extent to which the differences between the years are associated with the difference in fibre thickness and crimping, may be judged from the variance and co-variance analysis of Table 51.

While the variance "between years" differs significantly from the error variance at the 5 per cent. probability level before adjustment ($z = 0 \cdot 624$), it equals the error variance after adjustment ($z = 0 \cdot 009$). It is evident, therefore, that the differences between the years may be directly attributed to the changes in fibre thickness and crimping with age.

Taking averages for the group (Table 50), the resistance to compression showed an increase with age, the difference between the first and fourth years being $1 \cdot 4 \times 10^3$ (Kg. cm.^{7} per 5 gm.), with a t value of $2 \cdot 57$ which is significant at the 5 per cent. probability level. This was accompanied by an increase in the fibre thickness, and a small increase in the number of crimps per inch. With the regression coefficients of resistance to compression on fibre thickness of 730 and on the number of crimps per inch of 1,006, it is evident that the contribution of the change in the fibre thickness of $1 \cdot 8\mu$ was large compared to the contribution of the number of crimps per inch, which increased by only $0 \cdot 5$.

In the case of sheep Nos. 6 and 7, the resistance to compression tended to diminish with age, while the fibre thickness did not show the increase evident in the other fleeces. In general it may be inferred that on the average the resistance to compression increases with age for the first four years, but exceptions to this rule occur in cases where the fibre thickness does not increase.

It is interesting to note the large reduction in the variance between sheep, showing that a large part of the differences between the sheep was due to differences in fibre thickness and crimping, although the value of z ($0 \cdot 849$) after adjustment was still highly significant.

It is evident from the results that the age of the sheep should be taken into account when judging the fleece. The case of the two sheep which failed to show the increase in resistance to compression illustrates the individual variation among sheep with the consequent difficulties encountered in predicting the fleece characteristics of the adult sheep from those of the lamb. In flock improvement, where large numbers are ordinarily dealt with, it is convenient to practise selection at as early an age as possible, and exceptions to the general rule do not have such serious consequences as in stud breeding, where each individual sheep plays an extremely important part.

TABLE 50.

The resistance to compression, fibre thickness, and number of crimps per inch for the first four years.

Sheep No.		YEAR OF GROWTH.				Mean per Sheep.
		First.	Second.	Third.	Fourth.	
1	Resistance to compression..	7·2	8·5	8·4	9·3	8·4 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	20·5	22·8	21·9	23·4	22·2μ
	Crimps per inch...........	11·2	11·2	9·7	12·5	11·2
2	Resistance to compression..	8·6	11·7	11·1	10·9	10·6 × 10^3 (Kg. cm.^{7} per 5 gm..).
	Fibre thickness............	22·4	23·5	22·9	23·4	23·1μ
	Crimps per inch...........	11·9	11·4	12·8	11·4	11·9
3	Resistance to compression..	10·3	10·1	10·7	11·6	10·7 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	25·9	27·9	25·5	26·5	26·5μ
	Crimps per inch...........	9·8	10·4	10·2	11·9	11·9
4	Resistance to compression..	10·9	13·3	13·6	14·6	13·1 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	21·2	25·6	24·9	25·1	24·2μ
	Crimps per inch...........	13·3	13·4	13·4	13·8	13·5
5	Resistance to compression..	8·4	9·1	9·6	10·5	9·4 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	21·5	24·2	25·8	24·5	24·0μ
	Crimps per inch...........	9·6	9·9	9·4	10·4	9·8
6	Resistance to compression..	8·1	7·4	6·8	7·4	7·4 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	19·4	18·5	19·1	18·8	19·0μ
	Crimps per inch...........	12·6	12·2	12·6	12·7	12·5
7	Resistance to compression..	9·9	9·6	7·5	8·8	8·9 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	24·2	23·5	21·5	24·0	23·3μ
	Crimps per inch...........	11·1	11·1	10·7	10·4	10·8
8	Resistance to compression..	9·2	9·8	11·1	11·2	10·3 × 10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	20·9	22·4	24·3	24·8	23·1μ
	Crimps per inch...........	11·9	11·7	13·3	12·3	12·3
Yearly mean	Resistance to compression..	9·1	9·9	9·8	10·5 ×	10^3 (Kg. cm.^{7} per 5 gm.).
	Fibre thickness............	22·0	23·6	23·2	23·8μ	
	Crimps per inch...........	11·4	11·4	11·5	11·9	

TABLE 51.

Analysis of variance of resistance to compression, before and after adjustment for fibre thickness and crimping.

Variance.	Before Adjustment.			After Adjustment.		
	D.F.	Standard Deviation. (Kg. cm.^{7} per 5 gm.).	z	D.F.	Standard Deviation. (Kg. cm.^{7} per 5 gm.).	z
Between years..................	3	$1 \cdot 698 \times 10^3$	0·624	3	$0 \cdot 431 \times 10^3$	0·009
Between sheep.................	7	$3 \cdot 475 \times 10^3$	1·340	7	$0 \cdot 998 \times 10^3$	0·849
Error..........................	21	$0 \cdot 910 \times 10^3$	—	19	$0 \cdot 427 \times 10^3$	—

An interesting feature of the results is the striking reduction in the variation between the years as a result of the adjustment for fibre thickness and crimping. This result is in contrast to the residual variation among different sheep, and even among the regions of a sheep, and suggests that the other factors which influence resistance to compression either remain constant or alter with the fibre thickness and crimping in a manner which is constant for a sheep. Although the results refer to wool grown under uniform conditions, it is reasonable to conclude that a pre-experimental period in sheep experiments will increase the accuracy greatly as far as resistance to compression is concerned. The same conclusion has been reached with regard to other fleece characteristics, for Malan, van Wyk and Botha (1935), found that approximately 60 per cent. of the variation in fleece attributes during one year could be expressed in terms of that of the previous year, and it was concluded that for the same accuracy the number of sheep in an experiment had to be approximately five times as great when no pre-experimental results were available.

(*e*) *Feed.*

Wool studies in regard to nutrition have been confined to the characteristics of fibre length, fibre thickness, crimping, tensile strength and the total wool production, and marked effects on these characteristics have been recorded.

The only recorded results of compressibility determinations in regard to nutrition are those of Swart and van Rensburg (in course of publication). These authors examined the phenomenon of straight-fibred wools in the south-western districts of the Cape, and found that the crimping could be restored by the addition of certain supplements to the diet of the sheep. In spite of changes in the fibre thickness and crimping, the resistance to compression remained constant in some cases, and altered in others.

In the present study compressibility measurements were made on the wool grown by sheep under controlled feeding conditions.

After a preliminary period of three months on veld hay, the sheep were divided into four groups, designated (1), (2), (3) and (4), and fed on the following rations:—

First period (9 months): (1) Lucerne, (2) Green Feed, (3) Maize, (4) Oats.

Second Period (3 months): Veld Hay (All Groups).

Third Period (12 months): (1) Maize, (2) Oats, (3) Lucerne, (4) Green Feed.

The rations fed during the first and third periods were given *ad lib*. During the second period, when the sheep had access to veld hay only, they became so emaciated that the period could not be prolonged beyond three months. The average body weight dropped from 38 Kg. to 30 Kg.

At the end of the third period, samples were taken from the shoulder region of each sheep, and the staples were cut into three portions corresponding to the three periods. The divisions were clearly visible and the portions were readily separated.

The wool grown during the undernourished period was found to have lost its staple form to such an extent that it was impossible to measure the crimping, and only fibre thickness measurements were made in conjunction with the compressibility tests.

The results showed no difference between the rations fed during the well-fed periods, and for the purpose of the present study, the periods will, therefore, be regarded only as well-fed and under-fed periods. The experimental results are given in Table 52.

The fibre thickness suffered a definite reduction as a result of the underfeeding, but there was no corresponding change in the resistance to compression. In the absence of data on the crimping, the cause of the failure of the plane of nutrition to influence the resistance to compression cannot be established with certainty, but it can be assumed that the number of crimps per inch of individual fibres had increased, although the crimping was not defined in the staple form. The effects of the reduction in fibre thickness and the increase in the number of crimps per inch may, therefore, have counteracted each other, but an influence on the elastic properties must also be considered.

While the criticism may be made that the period of underfeeding was too short, it may be pointed out that the condition of the animals after three months was such that the period could not be extended, and in fact several sheep were lost during this period.

The results apply only to the conditions of the experiment, and cannot be applied to other nutritional conditions, but they illustrate one type of effect which may occur, viz., a reduction in fibre thickness with no corresponding alteration in compressibility.

Besides the results obtained by Swart and van Rensburg, in which inconsistencies occurred as regards the resistance to compression, a few instances to illustrate the complexity of the nutritional effect may be mentioned.

One instance is afforded by a sample submitted by a breeder, who stated that on transferring his sheep from one farm to another, the wool lost " substance ". Athough the sample was unsuitable for a determination, tactual examination suggested a low resistance to compression, which was presumably due to the fact that while the crimping indicated a 60's wool, the fibre thickness corresponded to a 70's quality number. In this case, therefore, the nutritional effect had been greater on the fineness than on the crimping. This is usually the case with " hungerfine " wools, and it is for this reason that Duerden stated that his standards were not applicable to droughty or impoverished wools. Swart (1936) also found indications that the quantity of feed had a greater effect on the fineness than on the crimping.

TABLE 52.

The resistance to compression and fibre thickness of wool from sheep kept at different planes of nutrition.

Sheep No.		Well-fed.	Under-fed.	Well-fed.
1	Resistance to compression	$6\cdot6 \times 10^3$	$6\cdot6 \times 10^3$	$7\cdot0 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$17\cdot0\mu$	$16\cdot6\mu$	$18\cdot1\mu$
2	Resistance to compression	$8\cdot3 \times 10^3$	$8\cdot8 \times 10^3$	$9\cdot0 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$20\cdot3\mu$	$16\cdot5\mu$	$17\cdot8\mu$
3	Resistance to compression	$5\cdot9 \times 10^3$	$6\cdot4 \times 10^3$	$6\cdot7 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$19\cdot0\mu$	$18\cdot1\mu$	$21\cdot1\mu$
4	Resistance to compression	$8\cdot1 \times 10^3$	$8\cdot7 \times 10^3$	$6\cdot9 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$19\cdot0\mu$	$17\cdot6\mu$	$23\cdot5\mu$
5	Resistance to compression	$7\cdot1 \times 10^3$	$7\cdot4 \times 10^3$	$6\cdot5 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$22\cdot0\mu$	$17\cdot6\mu$	$21\cdot2\mu$
6	Resistance to compression	$6\cdot8 \times 10^3$	$6\cdot6 \times 10^3$	$7\cdot0 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$16\cdot6\mu$	$15\cdot2\mu$	$19\cdot4\mu$
7	Resistance to compression	$7\cdot9 \times 10^3$	$6\cdot8 \times 10^3$	$7\cdot6 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$23\cdot3\mu$	$18\cdot1\mu$	$21\cdot5\mu$
8	Resistance to compression	$6\cdot7 \times 10^3$	$8\cdot0 \times 10^3$	$7\cdot2 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$18\cdot9\mu$	$15\cdot9\mu$	$21\cdot1\mu$
9	Resistance to compression	$8\cdot4 \times 10^3$	$7\cdot1 \times 10^3$	$7\cdot0 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$19\cdot7\mu$	$16\cdot9\mu$	$21\cdot7\mu$
Mean...	Resistance to compression	$7\cdot3 \times 10^3$	$7\cdot4 \times 10^3$	$7\cdot2 \times 10^3$ (Kg. cm.^{7} per 5 gm.).
	Fibre thickness	$19\cdot5\mu$	$16\cdot9\mu$	$20\cdot6\mu$

The complexity of the nutritional effect is not, however, confined to the relation between the fineness and the crimping, as was shown by a staple submitted by another breeder. The number of crimps per inch showed a relatively sudden change from 10 to 16 at about the middle of the staple, and the crimping was regular and well-defined throughout both portions. The fibre thickness showed a corresponding reduction from 23μ to 18μ, but the remarkable feature lay in the variability in fibre thickness, for the standard deviation was the same for the two portions, viz., $3\cdot4\mu$. The result was an increase in the coefficient of variability from 15 per cent. to 19 per cent.

This result is in direct contrast to the findings of Malan, van Wyk and Botha (1935), for the coefficient of variability in the case of 50 sheep remained sensibly constant in spite of relatively large changes in the mean values, and it was concluded that for each sheep there was a proportionate relation between the standard deviation and the mean, determined by genetic factors only. The same conclusion appears to emerge from the results of Swart (1936), for he states: " Quantity of feed, although affecting the fibre diameter, has very little influence on its frequency distribution ".

The influence of feed offers a wide field of investigation, as regards not only the plane of nutrition, but also the composition of the ration, the latter phase assuming special importance owing to the deficiencies occurring in certain areas of the Union.

9. THE DISTRIBUTION OF COMPRESSIBILITY.

The range and the distribution of the properties of South African Merino wool can only be determined on representative samples. A truly representative selection of the Union's wool clip is difficult to obtain, since it is necessary that each wool growing area and each type of wool in the area should be taken into account in its correct proportion. Such factors as pasturage and climate vary during a season and from season to season, and any set of observations would consequently apply to a particular period only.

In the present study no systematic attempt was made to procure so representative a series of samples. The samples tested were nevertheless obtained from many different sources, and included stud wools from various breeders, lots submitted by farmers and brokers for testing, prize wools from shows, and wool from experimental sheep in different areas. It is reasonable to assume that a fair representation has been achieved, and the results provide features of general interest.

The frequencies and percentage frequencies of the resistance to compression, *a*, as defined in Part I of the study, are given in Table 53.

TABLE 53.

The frequencies and percentage frequencies of the resistance to compression of all samples tested.

Resistance to Compression. (Kg. cm.^{7} per 5 gm.).	Frequency.	Percentage Frequency.
4– 5 × 10^3	3	1·0
5– 6 × 10^3	16	5·2
6– 7 × 10^3	37	11·9
7– 8 × 10^3	65	21·0
8– 9 × 10^3	55	17·7
9–10 × 10^3	54	17·4
10–11 × 10^3	47	15·2
11–12 × 10^3	17	5·5
12–13 × 10^3	8	2·6
13–14 × 10^3	5	1·6
14–15 × 10^3	3	1·0
	310	100·1

Mean = 8·7 × 10^3 (Kg. cm.^{7} per 5 gm.).
Standard Deviation = 1·92 × 10^3 (Kg. cm.^{7} per 5 gm.).
Coefficient of Variability = 22 per cent.

The distribution is evidently not symmetrical, since it tails off towards the higher values. Testing for normality by calculating g_1 and g_2 (Fisher, 1932) the value of $0 \cdot 405 \pm 0 \cdot 139$* for g_1 is highly significant at the 1 per cent. probability level. The distribution must, therefore be regarded as being distinctly skew, suggesting that, of the values in the vicinity of the mean, the lower values are more frequent than the higher values, while very high values are relatively more frequent than very low values. The quantity g_2, a measure of the " flatness " of the curve, has the value of $0 \cdot 044 \pm 0 \cdot 276$, which is insignificant, so that the distribution cannot be regarded as departing from normality in this respect.

On the other hand, the logarithms of the values may be taken to be normally distributed, for $g_1 = -0 \cdot 148 \pm 0 \cdot 139$, and $g_2 = -0 \cdot 006 \pm 0 \cdot 276$, both values being insignificant.

The values for resistance to compression range from $4 \cdot 5 \times 10^3$ to $14 \cdot 6 \times 10^3$ (Kg. cm.^{7} per 5 gm.). Among South African Merino wools, therefore, a range occurs of at least 3:1. The mean value is $8 \cdot 7 \times 10^3$ Kg. cm.^{7} per 5 gm., and the standard deviation $1 \cdot 92 \times 10^3$ Kg. cm.^{7} per 5 gm., giving a coefficient of variability of 22 per cent.

The range of values indicates that the manufacturer has at present a considerable choice in the matter of resistance to compression, when selecting a wool to meet his specific requirements.

In the following analysis of the differences between groups, use will be made of the two regression coefficients of resistance to compression on fibre thickness and on number of crimps per inch, as obtained from all the samples tested (equation 30). An adjustment to the mean values of fibre thickness ($21 \cdot 5\mu$) and the number of crimps per inch ($12 \cdot 5$) will therefore be made by means of the equation

$$a' = a + 357\,(21 \cdot 5 - d) + 623\,(12 \cdot 5 - n) \ldots\ldots\ldots\ldots \quad (33)$$

where a is the resistance to compression as defined, d the fibre thickness in microns, and n the number of crimps per inch.

A study of the effects of environment and pasturage is complicated by variations within a small area as a result of breeding and other factors. A case in point is afforded by the samples employed for determining the differences between rams' wool and ewes' wool, as recorded in Section 8(c). The two groups were bred in adjacent districts, and were run on the same type of pasture (Karroo), so that a difference between them must be attributed almost entirely to breeding.

The means of the groups are recorded in Table 54, and the adjusted values are given in the last column.

There is a significant difference between the two groups as regards resistance to compression ($t = 3 \cdot 6$), which, however, disappears as a result of the adjustment. There is little difference in the mean fibre thickness, so that the major part of the difference between the groups is due to the difference in the number of crimps per inch.

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* The *standard error* is employed throughout.

TABLE 54.

The mean fibre thickness, number of crimps per inch, and resistance to compression of the wool from two groups of sheep in adjoining districts, and the resistance to compression adjusted to the mean value of fibre thickness and crimping.

Group.	Fibre Thickness. (Microns).	Crimps per Inch.	Resistance to Compression. (Kg. cm.^{7} per 5 gm.).	Adjusted Resistance to Compression. (Kg. cm.^{7} per 5 gm.).
First...........................	22·2	13·8	$9 \cdot 1 \times 10^3$	$8 \cdot 2 \times 10^3$
Second.........................	21·7	10·9	$7 \cdot 2 \times 10^3$	$8 \cdot 3 \times 10^3$

In the first group the sheep had been employed in a breeding experiment, and no culling had taken place. If this group were to be replaced by a stud where, as is often the case, sheep are among other characteristics selected for the " substance " of their wool, the difference between the groups would probably be greater, since the breeder of the second group expressly stated that he did not breed for " substance ".

Karroo and Grassveld wool.

In the marketing of South African wool, brokers and buyers discriminate between Karroo and Grassveld wools, and regard them as two distinct types, each with its own peculiar properties. While the variation within each type is large, an attempt was made to compare the two types by examining samples from a wool show. The wools on show were all prize wools and were authentic representatives of the two types. They consisted of an equal number of each type.

The results of the measurements are given in Table 55, where the means have also been adjusted to correspond to the mean values of fibre thickness and crimping.

The two groups do not differ significantly as regards resistance to compression ($t = 0 \cdot 39$). As a result of the adjustment, the Grassveld wool has a lower resistance to compression than the Karroo wool, although with the small number of observations the difference cannot be regarded as significant ($t = 1 \cdot 60$).

Hence, on the same basis of fibre thickness and crimping, Grassveld wool shows a tendency towards a lower resistance to compression than Karroo wool, but on the average no difference may exist owing to a possibly greater number of crimps per inch of the Grassveld wools.

Various wool growing areas.

A summary of the mean values obtained for various wool growing areas is given in Table 56, in increasing order of resistance to compression.

TABLE 55.

The fibre thickness, number of crimps per inch and resistance to compression of samples from the Karroo and Grassveld areas, obtained at wool show.

KARROO.				GRASSVELD.			
Sample.	Fibre Thickness. (Microns).	Crimps per Inch.	Resistance to Compression. (Kg. cm.^{7} per 5 gm.).	Sample.	Fibre Thickness. (Microns).	Crimps per Inch.	Resistance to Compression. (Kg. cm.^{7} per 5 gm.).
1	18·8	14·4	7·6 × 10^3	1	19·8	14·4	6·9 × 10^3
2	21·3	12·8	7·8 × 10^3	2	20·0	15·0	8·2 × 10^3
3	21·3	14·2	8·8 × 10^3	3	19·0	16·5	8·4 × 10^3
4	22·8	12·5	9·1 × 10^3	4	20·6	16·7	8·8 × 10^3
5	22·1	12·4	9·3 × 10^3	5	19·6	15·1	9·1 × 10^3
6	22·5	15·1	9·3 × 10^3	6	19·6	15·3	9·4 × 10^3
7	20·9	16·3	9·6 × 10^3	7	22·9	14·0	9·7 × 10^3
8	17·9	17·2	9·7 × 10^3	8	19·4	15·6	9·8 × 10^3
9	21·0	12·2	9·8 × 10^3	9	21·6	14·8	10·1 × 10^3
10	19·0	16·4	10·9 × 10^3	10	20·3	17·6	10·2 × 10^3
11	21·9	14·7	11·6 × 10^3	11	18·9	18·3	10·8 × 10^3
Mean.....	20·9	14·4	9·4 × 10^3	Mean.....	20·2	15·8	9·2 × 10^3
Adjusted..........................			8·5 × 10^3	Adjusted..........................			7·7 × 10^3

TABLE 56.

The resistance to compression of wool from various wool growing areas.

Area.	No. of Samples.	Fibre Thickness. (Microns)	Crimps per Inch.	RESISTANCE TO COMPRESSION. (Kg. cm.^{7} per 5 gm.).		
				Range.	Mean.	Adjusted.
Transvaal Grassveld..............	12	20·4	12·5	5·4–10·3	7·4	7·9 × 10^3
South Western Cape Districts......	27	20·3	12·5	4·5–10·5	7·8	8·3 × 10^3
Eastern Province Grassveld........	11	20·2	15·8	6·9–10·8	9·2	7·7 × 10^3
Karroo........................	78	21·2	12·9	5·1–14·6	9·2	9·2 × 10^3
Basutoland......................	22	20·2	14·4	7·7–13·9	9·9	9·3 × 10^3

While the small number of observations in each group does not permit of general conclusions, certain features of the results may be mentioned.

Transvaal Grassveld.

The lowest average was given by a series of samples grown in the Transvaal Grassveld and obtained at a wool show. The mean was increased by the adjustment for fibre thickness and crimping, but it must be concluded that wool from this area has a lower resistance to compression than Merino wools generally, even taking into account the fibre thickness and crimping.

South-western Districts of the Cape.

Part of the samples tested was obtained from a broker who had specially selected different types, and though the types may have been representative they may not have been present in their correct proportions. Part was derived from a supplementary feeding experiment and the inclusion of these samples was considered to be justified by the lack of a definite difference between the treated and untreated groups, but on the other hand, the samples were grown in one area. The selection of samples cannot, therefore, be regarded as truly representative of the south-western districts, but their low average can hardly be due to chance. The adjustment for fibre thickness and crimping increased the resistance to compression to $8 \cdot 3 \times 10^3$ Kg. cm.^{7} per 5 gm., which is still below the average of $8 \cdot 7 \times 10^3$ Kg. cm.^{7} per 5 gm. The results confirm the conclusion of Swart and van Rensburg, who stated that Western Province wools had a low resistance to compression. The low average may to some extent be attributed to the fineness of fibre, since the number of crimps equals the average. In addition it is to be noted that several of the samples were of the so-called "straight" type, whose fibres were on examination found to have a shallow type of crimping.

Eastern Province Grassveld.

This series of samples was obtained from a wool show, and the results have been considered in a comparison with Karroo wool (Table 55). It was inferred that there was a tendency for Grassveld wools to have a lower resistance to compression than Karroo wools on the same basis of fibre thickness and crimping, but that a possibly greater number of crimps per inch might in practice increase the resistance to compression of the Grassveld wools to equal that of the Karroo wools.

Karroo.

The high average of Karroo wools remained unaltered by the adjustment. It may be concluded that as far as the Union is concerned, Karroo wools offer the greatest resistance to compression.

Basutoland.

The Basutoland samples were the result of a definite attempt, for two years in succession, to obtain as representative a series as possible from the various wool growing areas. The average resistance to compression is exceptionally high, but after adjustment for fibre thickness and crimping, it equals that of Karroo wool. Since the mean fibre thickness is lower than that of Karroo wool, the inordinately high resistance to compression must for the greater part be attributed to the number of crimps per inch.

Discussion (Part II).

Wool is the most important pastoral product of the Union, so that the future of wool is a major issue to the country. Until quite recently wool has always been acknowledged as the supreme clothing material by virtue of its unique properties, but this superiority is now being seriously threatened by competition from artificial fibres.

While world wool production has increased by some 30 per cent. during the last twenty years, that of artificial fibres has increased about fifty-fold. Admittedly a portion of these textiles are not intended to supplant wool, and are not suitable for this purpose, but a considerable portion consists of a number of types of staple fibre, which if not supplanting wool entirely at present, at least are used in mixtures with wool fibres. It is stated that during the past four years, the production of staple fibre has increased sixfold in two countries alone. Within a short space of time, therefore, the production and consumption of staple fibre have increased enormously.

Although no fibres have yet been produced which possess simultaneously all the desirable properties of wool as clothing material, this fact is hardly a cause for consolation. Recent improvements in all types of artificial fibre, including casein fibre, the production of twist and crimp in the cellulose staple fibre, and the introduction of the truly synthetic fibres such as Nylon, whose properties can be readily varied, show the large measure of success which has already crowned the efforts of the manufacturer of artificial fibres in this direction.

In many respects the producer of artificial fibres has a considerable advantage over the wool grower. Once research has shown a method of improving the artificial product or of reducing production costs, the manufacturer can avail himself of the result almost immediately. The wool producer, on the other hand, can alter his product only by breeding, the results of which become established only after many years. The same applies to the matter of research which the manufacturer conducts in the laboratory under strictly controlled conditions which he can imitate in his manufacturing plant, while the breeder has to conduct his research over periods of many years under variable conditions on an extremely variable animal product. In the matter of production costs, the manufacturer of artificial fibres is not faced with such factors as droughts and sheep diseases, which are costly to combat and place the farmer at a serious disadvantage.

If the artificial product can advance to the stage where it possesses all the desirable properties of wool, this fact alone should not be sufficient to affect the demand for wool. It will then depend on which fibre is most economically produced and converted into fabric. Even if wool remains the superior product, it could not hold its own if its costs of production are high compared to those of other fibres. It may safely be argued, therefore, that the future of wool will depend on the extent to which it is possible to reduce production costs. This applies not only to the cost of producing the raw product, which is only a fraction of the cost of the finished material, but also to manufacturing costs.

The wool manufacturer's problems are being investigated in his domain but the producer has to bear a great responsibility, since he hands the raw material with its inherent properties over to the manufacturer, and the finished cloth depends to a great extent on the virtues of the raw product.

The results of the present study apply mainly to breeding, which is one of the major factors in wool production, and the discussion which follows will, therefore, be devoted mainly to some aspects of breeding.

For the producer to be able to hold his own in the future, it is essential that he shall know his product, and the means whereby its characteristics are altered. The present investigation comprises a study of the compressibility of wool, but the results obtained are not confined to this attribute alone, for fleece and fibre characteristics are inter-related, and in practice must be considered together.

To the breeder the importance of correlations is two-fold. In the first place, when his breeding policy is directed towards enhancing one characteristic, the values of other characteristics may be altered, a phase of breeding which assumes a special importance in view of the reliance placed by breeders on subjective estimation of wool attributes. In the second place, correlations enable the breeder to assess the relative importance of different fleece attributes and to decide to what extent the value of each of such attributes should be changed in order to enhance the quantity and quality of the fleece most profitably.

On a broad basis the correlations mentioned may be divided into two classes, those existing within individual fleeces, and those existing between different fleeces. An extremely complicating factor is, however, that of selection, for the breeder is able by selective breeding to reduce or enhance an existing correlation or to introduce a new one. As a result, correlations found within one stud may not apply to another stud, and generalisations based on selected groups often have value only for those groups. In the present study an attempt has been made to include wool from as many sources as possible, and the result may, therefore, in some respects be regarded as providing a general background for the intensive study of individual studs and flocks.

In applying the results obtained to breeding, a complication is introduced by the fact that breeders employ terms to denote characteristics not expressible arithmetically. The properties of " harshness " and " softness " have been considered. These terms are self-explanatory, and it only remains to analyse the factors which determine them. Other terms, such as " substance ", are less well-defined, and are consequently more difficult to analyse.

Some of the relations found in the present study may be regarded as of purely mechanical origin, and it is proposed to discuss these relations first.

A factor whose effect may be regarded as purely mechanical, is adsorbed water. Speakman (1930) has shown that, whereas the rigidity of wool is reduced in the ratio 15 : 1 from dryness to saturation, the corresponding change in Young's modulus (by stretching) is only 2·6 : 1. In the case of cotton, Clayton and Pierce (1929) found that " the effect of humidity is rather less marked on the flexural than on the torsional rigidity ". If the compression of the fibre mass is regarded in the light of simple bending of the fibres, the elastic constant involved should be Young's modulus, but in view of the structure of the wool fibre, the value obtained is not likely to be the same as that obtained by stretching the fibre. Even when values obtained with different amounts of adsorbed water are compared on the basis of equal total lengths of fibre, the relative change in compressibility with adsorbed water has been shown to be almost twice that for Young's modulus obtained by stretching. When the values are compared on the basis of equal masses including adsorbed water, the change in compressibility corresponds to that of rigidity. It must be concluded, therefore, that the resistance of the fibre to bending is affected by the reduction, as a result of water adsorption, in the attraction between adjacent micelles, whose long axes are orientated in the direction of the fibre axis. In addition, some torsion of the fibre during bending must be considered as a possibility owing to the twist already present in the fibre and the reversals corresponding to the crests and troughs of the crimp waves (Rossouw, 1931; Woods, 1935).

The considerable difference in the effects of adsorbed water on the rigidity of Young's modulus has been associated by Speakman (1930) with the large difference between the lateral swelling of the fibre and the increase in length. In this connection he states: " Lateral cohesion between micelles will be reduced to a striking degree by water adsorption and the rigidity of the fibre will suffer a corresponding diminution. Since the micelles are long in comparison with their diameter, the number of breaks between them will be much less frequent along the length of a fibre than along the diameter. The changes in length and strength caused by water adsorption will, therefore, be far smaller than the corresponding changes in cross-sectional area and rigidity ".

A possible effect of adsorbed water is also suggested by an observation made by Woods (1935), that the radius of curvature of fibre elements previously immersed in water increases by about 30 per cent. from dryness to saturation. A parallel may be drawn between this phenomenon and the crimping of the fibre. The resistance to compression has been found to diminish when the number of crimps diminishes, and hence with an increase in the radius of curvature of the fibre elements, so that the increase in radius of curvature with adsorption of water may be taken as a contributory cause to the reduction in the resistance to compression of the fibre mass.

The results stress the necessity of performing compressibility measurements under controlled conditions, in view of the fact that an increase of 5 per cent. in the relative humidity, corresponding to an increase of about 1 per cent. in the moisture content of wool, causes a reduction of 12 per cent. in the resistance to compression. This precaution has not been taken by some previous investigators who employed the balloon method. The influence of humidity may also be expected to play an important part in the practical estimation of compressibility by hand, so that while it is possible to compare samples under the same conditions, the comparison of different samples on different days, especially during changeable weather, will be unreliable.

As regards the effect of length, the resistance to compression of the fibre mass evidently depends on the total length of fibre present, and not on the length of individual fibres. Such a conclusion is in agreement with the view expressed in Part I of the study, viz., that during compression the units which bend are not the complete fibres but the elements between adjacent contacts. The possible reduction in the resistance to compression for staple lengths below one inch may be attributed to the increasing number of free ends produced by the separation of elements connected in longer fibres. Attempts to employ still shorter lengths proved unsuccessful owing to the rapidity with which short fibres tend on washing and teasing to develop small lumps, the complete removal of which is practically impossible.

It is recommended that, where possible, sheep experiments involving wool compressibility determinations should be extended over a period sufficient to ensure an adequate length of staple. A length of at least two inches or five cm. is suggested.

Assuming the effects of fibre thickness and crimping to be real, the failure to account for the whole of the differences in the resistance to compression of various wools by means of fibre thickness and crimping, must, in part at least, be due to differences in the elastic properties of the fibres. While admittedly both the mean fibre thickness and the mean number of crimps per inch are subject to sampling errors, these are not sufficiently large to account for the residual variation. As no experimental data are available on the variation in the elastic moduli among Merino wools, the degree to which this factor can account for the residual variation in compressibility cannot be estimated.

There are, however, other important factors which have not been taken into account. One of these is the shape of the crimp wave, for a large number of wave forms occur among fibres, and even along the length of a single fibre (Nathusius, 1866; Barker and Norris, 1930). Another factor is the ellipticity of the fibre cross-section, and the twist present in the fibres, which suggests that during compression the fibres are twisted as well as bent. In this connection it is significant that Barker (1931) states: " Where the trade opinion of the fleeces noted a particularly soft handle, it was subsequently found that the wool of that particular fleece . . . more nearly approached the circular. Although the contour or degree of ellipticity is not the only factor concerned in the production of good ' handle ', yet it probably has a decided influence ".

In the case of fibre thickness, it was concluded that the fibre thickness has a positive influence on the resistance to compression, but that in general its effect is masked by the crimping. This view seems to be supported by the results of Henning (1934), which showed an increase in resistance to compression with an increase in fibre thickness in the case of wools whose crimping had been reduced by the " Lisseuse " process. That the crimping could not have been completely removed is shown by the further observation that the resistance to compression fell on passing over to the long coarse wools.

In view, however, of the fact that theoretically the fibre thickness has no influence on the resistance to compression, the effect found after removal of the effect of crimping may only be apparent, in the sense that it is caused by other factors correlated with the fibre thickness. For example, factors mentioned above as possible causes of the residual variation may be correlated with fibre thickness, although no data on this point are available.

On the other hand, it is to be noted that if the crimping has an influence on the element length, a point to be considered later, a relation between resistance to compression and fibre thickness may thereby be introduced, for no account was taken of the crimping in the theoretical considerations.

In connection with the effect of fibre thickness, Burns and Johnston (1936) state that " Larose and Winson have both found that an increase in volume under pressure is definitely associated with an increase in fibre thickness ". Now the yarns tested by Larose (1934) differed by half a micron in a fibre thickness of 30 microns. In Figure 5 of Winson's (1932) paper are given the pressure-volume curves of two Shropshire samples, according to which the wether sample had a slightly larger ratio of $\frac{v}{v_0}$, and it is stated that the wool of the wether was very slightly coarser, no measurements being being given. On the other hand, accordingto Figure 7 of the same paper, the comparison of " the Veld wool 70's " and the " fine Cape kid mohair " suggests the very opposite effect, for the 70's wool must have had a considerably finer fibre than the mohair, and yet it had a much greater value of $\frac{v}{v_0}$ at any pressure. The author can therefore not agree with the statement quoted. The present study has suggested that no correlation exists owing to the complicating effect of the crimping. If the effect of the crimping could be removed, the results of the present study would agree with those of Burns and Johnston. Since these authors found, in their own tests, that the coarser wool occupied a greater volume, it is suggested that the crimping of the wools examined by them was of such a nature that its effect was insignificant, or that the extremely high pressures employed overcame the effect of the crimping, and the fibre thickness alone was operative.

Before considering the effect of the crimping, it must be remarked that the number of crimps was measured on the greasy staple, while the compressional measurements were made subsequent to cleansing in water. The fibres must thereby have lost their original form, but according to Woods (1935), the periodicity in the new forms corresponds to that of the original crimping, though the new forms as observed by Woods would probably not have been completely attained owing to inter-fibre action in the mass.

While it has been stated that the effect of fibre thickness may be only apparent, the same argument is applicable to the crimping. Thus, Barker and Norris (1930) have suggested a mathematical relationship between fibre thickness, number of crimps per inch, and Young's modulus. The possibility must, therefore, be seriously considered that fibre thickness and crimping have no direct effect on the resistance to compression at all, but that they merely indicate the magnitude of other properties which determine the resistance to compression. In the case of the elastic properties, however, if a relationship as exact as that suggested by Barker and Norris exists, the fibre thickness and crimping may be expected to account for a greater, if not the greatest, portion of the variation between samples.

The crimping may also be regarded as an indication of the degree of twist in the fibre, so that the apparent effect of the crimping may be a result of the effect of the twist already present, and possibly also of the ellipticity of the fibre cross-section.

In addition, the crimping may have a real mechanical effect on the resistance to compression. In the first place, the crimping increases the flexural rigidity of the fibre. The finer and more numerous the crimps, the smaller will be the radius of curvature of the fibre elements, and the greater will be the pressure necessary to bend them still further. In this connection an apparent inconsistency must be considered. In Part I of the study, it was deduced, by analogy with a solenoid, that the total volume is proportional to the mean radius of curvature of the fibre elements, suggesting that the coarsely crimped wools should occupy a greater volume than the finely crimped wools, while the present study has shown that in general the opposite is the case. The explanation of the apparent inconsistency lies in the fact that the proportionality between the volume and the mean radius of curvature was deduced on the basis of a constant length of fibre being compressed to different volumes, while the results of the present study are based on the comparison of equal masses of different wools being compressed to the same volume.

In the second place, it is highly probable that the length of a fibre element which bends as a complete unit during compression will be influenced by the crimp wave-length, i.e., that the points of contact between fibres will tend to concentrate at the crests and troughs of the crimp waves. In such an event, the fibre elements will be the shorter, the greater the number of crimps per unit length, and the resistance to compression of the mass will be correspondingly greater. Support is given to this view of the effect of the crimping by the finding that the resistance to compression is not associated with the surface friction of the fibres, for fibre slippage may be prevented by the crimps rather than by the surface friction of the scales.

If the main effect of the crimping is to influence the length of fibre elements which bend as complete units, the question arises in how far the mean element length may be regarded as proportional to the crimp wave-length for a given density of packing. In the ideal case, the lengths of the elements will be fractions or multiples of the crimp wave-length. These lengths will follow some law of distribution, and there will be a value of greatest frequency, to which the mean value will be related. The question then arises as to what factors will determine the most probable and mean values.

In Part I of the study, it was suggested, by analogy with a pile of rods (equation 24) that the mean element length would be proportional to the fibre thickness for a given density of packing. For the mean element length to be proportional to both the fibre thickness and the crimp wave-length, the product of the fibre thickness and the number of crimps per inch must be constant. It follows, therefore, that the mean element length will be the same multiple (or fraction) of the crimp wave-length for all wools which have the same product of fibre thickness and number of crimps per inch.

For other wools, the position will be somewhat different. In the case of a fine-fibred wool with a few crimps to the inch, i.e., a large wave-length, the element length will be smaller, since the fibre thickness is small and the length of fibre large, and the mean element length will be a smaller multiple of the crimp wave-length. In the same way, the mean element length will be a greater multiple of the crimp wave-length when the fibres are coarse and at the same time have many crimps to the inch.

The relation between the crimp wave-length and the estimated element length may be judged from Table 57, where wools following Duerden's standards are considered. In this case twice the element length is likely to be the relevant quantity, representing as it does the distance between two contacts on the same side of the fibre where the forces act in the same direction.

TABLE 57.

Twice the element length as calculated from equation (24) compared with the crimp wave-length of wools which agree with Duerden's standards.

DUERDEN'S STANDARDS.				TWICE ELEMENT LENGTH (cm.).	
Quality No.	Mean Fibre Thickness. (Microns).	Mean Crimps per Inch.	Crimp Wavelength. (cm.).	20 c.c./gm.	10 c.c./gm.
80's............	17·5	18·5	0·137	0·036	0·018
70's............	18·4	16·5	0·154	0·038	0·019
66's............	19·5	14·5	0·175	0·040	0·020
64's............	20·7	12·5	0·203	0·042	0·021
60's............	22·2	10·5	0·242	0·045	0·023
58's............	24·3	8·5	0·299	0·050	0·025

It is seen that for wools whose fineness-crimping relation follows Duerden's standards, twice the mean element length is approximately $^1/_5$ of the crimp-wavelength at 20 c.c./gm. and $^1/_{10}$ of the crimp-wavelength at 10 c.c./gm. The influence of the crimping on the element length is, therefore, likely to be confined to the longer elements, and in the case of a fine-fibred wool with a few crimps to the inch, the effect is probably smaller than with a coarse-fibred wool with many crimps to the inch.

Such considerations suggest yet another reason for the residual variation in the resistance to compression after the effects of fibre thickness and crimping have been eliminated.

The lack of a relationship between the resistance to compression and the surface friction of the fibres at 65 per cent. relative humidity may be due to the fact that the minimum surface friction of the samples examined is sufficient to control fibre slippage, but the cause already suggested, viz., that the crimping is the main factor which controls the slippage, appears more probable. Partial confirmation of this view is given by a comparison of the resistance to compression and the milling shrinkage of a blend. In the case of milling shrinkage, where the surface scale structure is the determining factor, the shrinkage of the blend bears no proportionate relationship to the amounts of the respective constituents (Speakman and Stott, 1931). The resistance to compression of a blend, on the other hand, has been shown to be the weighted mean of the values of the constituents. The comparison suggests that the surface friction is a factor of small moment in determining the resistance to compression.

In either case, the pressure-volume relation of a mass of wool fibres may be expected to differ from that of other fibres which lack the surface scale structure and the crimped form, and in consequence have a greater tendency towards fibre slippage. At the same time the hysteresis between the compression and release curves should be smaller in the case of wool. Pidgeon and van Winsen (1934) were able to explain the reduced resistance to compression of a mass of asbestos fibres with increasing relative humidity by the greater ease of slippage of the fibres over one another, while the present study has shown that in the case of wool, the reduction in resistance to compression may be attributed to an alteration in the elastic moduli of the fibres.

Recently, A. F. Barker (1942) advocated the production of straight fibres, since these should give " a better combing result and a finer count and a stronger yarn, other things being equal ". He further regarded crimp " as being simply evidence of variable length of fibre growth ". In the present study an attempt was made to procure straight-fibred samples for a study of the effect of fibre thickness in the absence of crimps. No such wools were found, for the so-called straight-fibred wools were found on examination to consist of crimped fibres, and the apparent straightness was due to the fact that the fibres did not combine to form a crimped staple. It was also observed that the crimping of the individual fibres was rather shallow.

Assuming, however, that the production of straight-fibred wools of the Merino qualities is possible, this may be expected to have a pronounced effect on present manufacturing methods, for the crimp serves to some extent as a protection for the fibre when it is stretched during the various manufacturing processes. In this connection Smith (1938) states: " Recent experiments in artificial fibres seem to show that up to a certain point a better spinning result can be obtained (that is to say a finer count and a more even yarn can be reached) by the introduction of a certain amount of crimp ". Examination of artificial fibres shows that some types are made permanently crimped and twisted in order to resemble wool.

In view of the existing correlations, straightness of fibre will possibly be accompanied by an increase in uniformity in fibre length, an increase in the circularity of the fibre cross-section, and an absence of twist. It will, however, remove some of the most suitable properties of wool as clothing material, for the crimpy structure produces a large number of inter-fibre interstices which are not only partly responsible for the heat insulating properties of wool fabric, but also impart to the fabric a certain sponginess and softness lacking in the more compact structures made up of straight fibres.

From the point of view of the present study, the possible production of straight fibres assumes special importance. The attainment of straightness will presumably be the result of breeding, either for fewer crimps to the inch until they are absent altogether, or for shallower crimps to the limit of straightness. In view of the pronounced effect of the crimping on the resistance to compression, both methods of breeding will tend towards wool with an abnormally low resistance to compression. A possible way of counteracting this tendency would be to increase the fibre thickness, and hence to eliminate the main characteristic which distinguishes Merino wool from other wool. At the same time the harshness will be increased, for the fibre thickness has a greater effect on harshness than the resistance to compression has on this property. If fineness of fibre is maintained, the resulting low resistance to compression will have to be compensated for by a more greasy fleece in order to prevent the fleece from opening up on the sheep and exposing the fibres to the detrimental influences of climate and atmosphere, for it is unlikely that a sufficient fleece density can be attained to prevent this condition. Unless definitely bred for, the amount of grease will probably diminish, since the present study has shown a negative correlation between percentage yield and both resistance to compression and number of crimps per inch.

Another possible effect of the absence of crimp is a reduction in the " springiness " or " loftiness ", resulting from a larger hysteresis loop, for with the lack of control of fibre slippage by the crimps, a greater degree of irreversible inter-penetraion of the fibres may be expected.

The author is, however, of the opinion that breeding for straight fibres may result in the production of crimped fibres without a crimped staple, unless individual fibres are examined.

In the case of 130 samples from various sources, no relationship has been found between the resistance to compression and the tensile strength. This does not necessarily mean that no correlation exists, for there is evidence to show that certain factors may affect one attribute and not the other. Thus, underfeeding had no effect on the resistance to compression in the experiment described, while the tensile strength of the same samples showed a definite reduction (publication by Bosman and co-workers pending). Further, the average resistance to compression of belly samples equalled the mean for the six regions, while the tensile strength of the belly samples was consistently lower than that of the other regions (van Wyk, 1941). In view of these results, it will be a difficult matter to ascertain whether a real correlation exists between the two attributes.

It is probable that the relationship between resistance to compression, fibre thickness and crimping is one of the most important factors in existing wool practice, and hence in breeding, as the following examples will show.

In his random selection of 1,000 samples, Bosman (1937:1) found that 72 per cent. of the samples showed a divergence from the average relation between the fibre thickness and the number of crimps per inch, and consequently concluded that the estimation of fineness by means of the crimps alone would be in error in 72 per cent. of cases. In practice the crimping does form the main basis of fineness estimation, but wool is usually handled in order to estimate its " quality ". Thus Rose (1933) states that all harsh handling wools must be classed down. Whether the resistance to compression or the harshness, or both, are involved in the handling, a high value of either property will, on the basis of the relations found in the present study, indicate too coarse a fibre for the crimping, while a low value of either property will indicate too fine a fibre for the crimping. It is thus seen that the handling of wool in classification serves to correct for the errors in the visual estimation of fineness caused by variations in the fineness-crimping relation.

Another possible result of the effect of the fineness and crimping on the resistance to compression is its bearing on a property known as " substance ". According to Mellet (1923), " substance is the power of resistance of the wool, by which it is enabled to stand at right angles to the skin, keeping the fleece closed ", while Rose (1930) states that " substance is indicated by fullness of handle, non-compressibility ". In view of the above definitions, it is reasonable to regard " substance " as being determined by the factors (1) resistance to compression, (2) quantity and quality of yolk (i.e., grease and suint) and (3) size and density of the staple.

In breeding for " substance ", if the breeder is influenced by the resistance to compression, he will tend to breed a coarser fibre than the crimps indicate, although he may not be conscious of the fact, unless he employs means other than the crimping to estimate the fineness of the wool. It will be the policy of the breeder to cull rams lacking this attribute, and the rams retained will bear fleeces which *on the average* have a higher resistance to compression than those of the ewes and wethers. The results of the present study failed to reveal a difference in this respect between the fleeces from rams and ewes in flocks where no selection for " substance " had been practised. The impression that fleeces from rams have more " substance " than those of ewes may thus simply be due to the fact that in practice most rams have been selected partly for this attribute. In this connection it may be pointed out that there is also a belief which has not been experimentally demonstrated that such rams are also good breeders for wool production.

Furthermore, if the rams retained by the breeder have fleeces with a higher average resistance to compression than those of ewes and wethers, the correlations found suggest that their fleeces will also have a coarser fibre than the crimps indicate, compared to unselected material. Such a condition would be a possible reason why Bosman and Botha (1933) found that wool from stud rams was approximately two classes coarser than was indicated by the crimping, while Bosman (1937:1) found an average agreement in his random selection of samples.

With regard to the second factor assumed to determine " substance ", viz., the quantity and quality of the yolk, it is also true that selection may give to stud rams a higher average " substance " than that of other animals, but there is the possibility that the fleeces grown by rams and ewes may differ in respect of the yolk, a point not investigated in the present study. However, if in breeding for " substance ", the breeder is influenced by the yolk, of which the grease is the predominating constituent, he may obtain a misleading impression of the resistance to compression and of the density of the fleece. A high correlation exists between the greasy fleece weight and the scoured fleece weight within a stud (Bosman, 1937, 1941), so that breeding for greasy fleece weight will result in an increase in the scoured fleece weight. When the breeder, however, in aiming at " substance " and " density ", is misled by the grease and other impurities, he may reduce the yield of the fleeces and so to some extent nullify his attempts at a higher production per sheep.

The negative correlation coefficient found between the clean yield of the fleece and the resistance to compression of the wool suggests that when the breeder, in aiming at " substance " in the fleece is to some extent influenced by the non-wool impurities, he nevertheless tends to produce wool with a high resistance to compression. Alternatively, the correlation found may be the direct result of breeding for " substance " where both the amount of the non-wool portion of the fleece and the resistance to compression of the wool have been enhanced.

No correlation has been found between the yield of the fleece and the fibre thickness, a result in contrast to the findings of Volkmann (1927) and Baumgart (1929). A highly significant negative correlation has, however, been found between the yield and the number of crimps per inch, a result which may be expressed by the statement that the *apparently* fine wools have a lower yield than the *apparently* coarse wools. Since the practical estimation of fineness depends to a large extent on the crimping, the question arises as to whether the correlation found has been introduced by breeding. For, in aiming at " substance ", the breeder may tend to produce, firstly, wools with a high resistance to compression, i.e., wools having a coarser fibre than the crimps indicate, and secondly, low yielding wools. He consequently introduces a negative correlation between yield and resistance to compression, and a negative correlation between yield and number of crimps per inch, and removes a possible correlation between yield and fibre thickness. At the same time he regards the crimping as an indication that he is maintaining a reasonable fineness of fibre, which may not be the case.

Now softness of handle, which Rose (1933) associates with " quality ", is a desirable property, and it has been shown to be associated with a fine fibre or a low resistance to compression. The attribute of " substance ", on the other hand, has in the present study been associated partly with the resistance to compression, which requires either a coarse fibre or a fine crimping. The question arises as to how these two apparently conflicting attributes are to be combined in a single fleece.

It has been shown that for wools whose fineness-crimping relation follows Duerden's standards, the resistance to compression increases with the quality number. Since the harshness is determined largely by the fibre thickness, the increase in resistance to compression with quality number is not accompanied by an increase in the harshness. In the finer wools, therefore, " substance " may be attained by a high resistance to compression without harshness, but with the coarser wools the effect of the fibre thickness in enhancing the harshness must be compensated for by a low resistance to compression, and the " substance " must be attained by other means. Ordinarily this is not produced by an increase in the grease content as shown by the negative correlation between yield and resistance to compression, although it is a possible method. The third factor suggested as being partly involved in " substance " is probably employed, viz., the size and density of the staple, for Rose (1930) states that " substance is indicated by fullness of handle ".

The possible implications of breeding for " substance ", viz., a coarser fibre than the crimps indicate, with the consequent difficulty of estimating the fineness, the tendency towards " harshness ", and an excessive amount of grease can hardly be considered desirable. Breeding for " substance " may, therefore, be regarded as of rather doubtful value. For a sheep of a certain size, the density of the fleece will be reflected in the wool production per unit length of staple, and provided the latter is satisfactory, and the fleeces do not open up on the sheep, breeding for the attribute of " substance " would seem to be superfluous, and in some respects even undesirable.

The effect of the relationship between fineness and crimping on the resistance to compression, and, therefore, on characteristics estimated by touch, seems to justify a closer examination of the relationship between the two quantities, especially in regard to the standards compiled by Duerden (1929). Measurements on two groups of sheep were compared with the standards by Swart (1937). His method of comparison consisted in relating the difference between the classes as given by the fibre thickness and by the crimping with fibre thickness. The author cannot, however, regard the method employed by Swart as adequate for testing the agreement between a set of observations and the standards, for the following reason.

Suppose the quality number class according to the crimping to be plotted as ordinate, y, against the quality number according to the fibre thickness as abscissa, x. Then the standards will be represented by a line $y=x$. A set of observations which agree with the standards will be symmetrically distributed about this line, and will roughly form the surface of an ellipse whose major axis lies on the line $y=x$. For a given value of x which is smaller than the mean of x, the mean value of y will be above the line, while for a given value of x which is greater than the mean of x, the mean value of y will lie below the line, and the means of y will lie approximately on the regression line of y on x. This is practically similar to the procedure adopted by Swart, except that in his case the mean value of $(x-y)$ was determined for various values of x. The author is of the opinion that such a procedure will give the effect found by Swart, viz., a negative difference between the classes for low values of the fibre thickness and a positive difference for greater values of the fibre thickness, for observations which agree with the standards.

It is suggested that a better test would be to relate the perpendicular distance from any observation to the line $y=x$ with the point where the perpendicular cuts the line. If the values are distributed symmetrically about the line, the sum of the perpendicular distances to any given element of the line should be zero. Since the perpendicular distance from any point (x', y') to the line $y=x$ is given by $\frac{(x'-y')}{\sqrt{2}}$, and the ordinate and abscissa of the point where the perpendicular cuts the line $y=x$ is $\frac{1}{2}(x'+y')$, the procedure suggested is equivalent to relating the differences between the classes with their mean (neglecting the factor $\sqrt{\frac{1}{2}}$).

For this purpose it is convenient to assign an index number to each class, as illustrated in Table 58.

The mean difference between the classes for each value of the mean of the two classes has been calculated for the data of Bosman (1937), Bosman and Botha (1933), Swart (1937), and those obtained in the present study, as shown in Table 59.

TABLE 58.

Quality Number.	Assigned Index Number.
150's	1
120's	2
100's	3
90's	4
80's	5
70's	6
66's	7
64's	8
60's	9
58's	10
56's	11
54's	12

TABLE 59.

The mean difference between the classes as given by fibre thickness and number of crimps per inch calculated for each value of the mean of the classes.

Mean of Class Values.	DIFFERENCE BETWEEN CLASSES.									
	Bosman (1937) (Random Samples).		Bosman and Botha (1933) (Stud Rams).		Swart (1937) (Experimental Sheep).		Swart (1937) (Veld Grazed Sheep).		Present Study (Various Sources).	
	Frequency.	Mean.	Frequency.	Mean.	Frequency.	Mean.	Frequency.	Mean.	Frequency.	Mean.
1·5	3	+1·0	—	—	—	—	—	—	—	—
2	3	0	—	—	—	—	—	—	—	—
2·5	—	—	—	—	—	—	—	—	—	—
3	24	0	—	—	2	−2·0	1	0	—	—
3·5	21	+0·4	—	—	1	−3·0	—	—	1	−1·0
4	33	0	1	0	4	−0·5	1	−6·0	—	—
4·5	51	−0·9	—	—	5	−1·8	2	−2·0	1	+3·0
5	81	−0·4	—	—	5	−0·4	2	−3·0	—	—
5·5	60	+0·4	1	+1·0	5	−1·0	3	+1·7	5	+1·0
6	87	+0·2	—	—	12	+0·2	10	+1·0	6	−0·3
6·5	66	+0·2	8	+0·3	15	+1·1	11	+0·8	25	+0·3
7	117	−0·4	5	+0·8	13	+1·5	7	+2·3	32	+0·6
7·5	66	+0·3	17	+0·8	24	+2·8	11	+1·5	35	+0·6
8	90	+0·4	12	+1·3	14	+2·8	7	+1·7	46	+0·9
8·5	84	−0·5	25	+2·3	14	+3·0	1	−1·0	58	+1·1
9	51	−0·2	31	+1·6	3	+3·3	2	+1·0	44	+0·7
9·5	57	−0·2	12	+1·3	—	—	2	0	31	+1·1
10	51	+0·7	8	+0·5	—	—	1	0	19	+1·6
10·5	30	0	2	+1·0	—	—	—	—	6	+1·0
11	18	0	1	0	—	—	—	—	—	—
11·5	9	+1·0	—	—	—	—	—	—	1	+1·0
	1,002	−0·03	123	+1·3	117	+1·5	61	+0·9	310	+0·8
Regression	0·0256		0·1405		1·1105		0·4754		0·2148	
	0·89		1·27		15·12		1·91		2·92	

Since the means are based on different frequencies and consequently are not of equal weight, the regression coefficient of the difference between the classes on the mean of the two class values has been calculated for each group, and it is given at the foot of each column. Agreement with the standards will give a zero value for the regression coefficient, and the significance of its departure from zero has been determined by calculating *t* (Fisher, 1932).

In the case of 1,002 random samples (Bosman, 1937), it is evident that there is no departure from the standards as regards the mean deviation (– 0·03) or the slope of the regression line (0·0256). In the case of the stud rams (Bosman and Botha, 1933), there is a mean difference of +1·3 from the standards, but the slope of the regression line (0·1405) does not differ significantly from zero, suggesting a general shift of the fineness-crimping relation from that of the standards. The samples from the experimental sheep (Swart, 1937) show a mean difference of +1·5 and a marked departure of the regression coefficient from zero (1·1105), confirming Swart's conclusion for these samples, viz., that for high values of fibre thickness the class according to the fibre thickness is coarser than the class according to the crimping, while for the finer wools the thickness is smaller than the crimps indicate according to Duerden's standards. The author cannot, however, agree with Swart that Bosman and Botha's data for stud rams correspond to his own or agree with the conclusion reached in regard to his own results. The samples from the sheep grazed on the veld also show a departure from zero in the regression coefficient (0·4754) but the number of observations is insufficient to render this significant. The results of the present study show a mean shift of +0·8 from the standards, and a small but significant difference between the regression coefficient of 0·2148 and zero.

The lack of agreement between his observations and standards led Swart (1937) to question the validity of the standards. Apart from the fact that results obtained on selected groups can hardly be regarded as a fair test of the validity of the standards, the author regards the estimation of fineness by means of the crimps as of extremely doubtful value, and consequently agrees with Swart that the standards in question, or any other standards giving a relation between fineness and crimping, should not be employed in stud breeding practice for estimating the fineness from the crimping.

The standards can, however, serve a useful purpose. Crimping has such a pronounced effect on the compressibility that it must play a considerable part in subsequent processing. Assuming that the experienced sorter may be able to estimate fibre thickness without being misled by the crimping, he has to choose between uniformity in fibre thickness with a variation in the crimping and uniformity in the crimping with a variation in fibre thickness, or he must make a compromise between the two. In any case, variations in the relation between fibre thickness and crimping will result in a lack of uniformity in the sorted lot. To base breeding policy on fibre thickness alone will not be sufficient, and the author is in favour of Swart's suggestion that breeding should be directed towards certain combinations of fibre thickness and crimping. The standards compiled by Duerden are a definite step in this direction, being at present the only link between producer and manufacturer, although they may need revision as the knowledge of the part played by each attribute in manufacture increases.

In breeding for a certain combination of fibre thickness and crimping, certain difficulties will be encountered. In the first place, it is highly probable that fixing certain combinations of fineness and crimping will fix other attributes. For example, as suggested by Table 27, it is possible that fine wools will then always have a high resistance to compression, and coarse wools always a low resistance to compression. Since all wools at present are in demand, each type being employed for a specific purpose, the reduction in the number of types may meet with some opposition from the manufacturers. With the introduction of such a breeding policy, therefore, the collaboration of the manufacturer is essential. Provisionally the standards can serve as a basis, but the final combinations should be decided upon after the producer has submitted a number of combinations to various branches of the manufacturing industry, and has received the opinions based on actual tests. Should various branches favour different combinations, these could probably be arranged to correspond to the climate and pasturage of the different wool-growing areas, but a difficulty which may be expected when breeding for certain combinations of fibre thickness and crimping is the disturbance likely to be caused by a drought which may upset all the combinations.

The author is, however, of the opinion that the first step of the producer in improving his product is to breed for uniformity, since the manufacturer's methods will thereby be simplified and his production costs reduced. The need for uniformity has been stressed so often that it will not be considered in detail, but it must be borne in mind that at present the artificial product is superior to wool in this respect.

Three types of uniformity may be distinguished, viz., within the staple, within the fleece, and within the flock (Frölich, Spöttel and Tänzer, 1929; Bosman, 1937:2). It is essential that a thorough study should be made to determine whether the fibre uniformity within a staple is correlated with the uniformity among the different staples composing a fleece. Should a correlation exist, the breeder's efforts to produce a uniform fleece as judged by hand and eye methods will tend to produce uniformity among the fibres composing a staple, while the lack of a correlation will necessitate microscopic measurement for determining the uniformity within a staple. Frölich, Spöttel and Tänzer (1929) consider that no relation exists while Duerden and Bell (1931) state that " a high degree of uniformity in quality over the sheep would doubtless be accompanied by less variability in the individual fibres of a staple ". None of the authors, however, quote experimental evidence in support of their opinions.

The high correlation between fibre thickness and fibre length found by Duerden and Bosman (1931) and Roberts (1931) suggests that a reduction in the variation in the fineness of the fibres composing a staple will be accompanied by a reduction in the variation in the length of the fibres. According to the present study, however, an alteration in the variability will be accompanied by but little change in the compressibility.

In the case of the fleece, on the other hand, a marked reduction in the variation in resistance to compression between the various regions of the sheep takes place when allowance is made for the variation in fibre thickness and crimping, so that breeding for uniformity in fibre thickness and crimping over the fleeces will tend to reduce the variation in resistance to compression over the fleece.

It is often found that fleeces from one flock are extremely dissimilar, an occurrence which must be ascribed to the lack of a definite breeding policy. Thus it is found that some farmers class their clip into a large number of lines, and while the thorough classing is commendable, the variation in the clip which necessitates such intensive classing must be regarded as highly undesirable. It is reasonable to assume that for any area there must be a type of sheep and its fleece which is best suited to that area, and every farmer should ascertain which type is most profitable to him, and by careful breeding and selection confine his production to that type only. In this way he will produce his wool most economically, reduce his classing to a minimum, and offer to the manufacturer a uniform type of wool.

While the farmer then should aim at uniformity in his clip and confine himself to the type which gives him the highest financial return per sheep, it is the stud breeder who must bear the responsibility of producing the suitable rams.

A plea for recording in stud breeding has been made by Bartel, Swart and van Rensburg (1936) and by Bosman (1936, 1937:1, 1943), and the breeders themselves appear to be considering the possibility (S.A. Merino Breeders Journal, 1943). While support must be given to such a scheme, too much emphasis cannot be laid on the need for exact methods of determining fleece characteristics. Hand and eye methods have met with a high degree of success in the past, and are responsible for the present standard of South African Merino stud animals, but it is becoming increasingly evident that their effectiveness is rapidly diminishing. Results obtained during the course of the present study, and in other branches of fleece testing in the laboratory, suggest that the main causes of erroneous estimation are the variation in the relation between fineness and crimping, and the presence of the non-wool fleece constituents.

The seriousness of the extent and magnitude of the errors involved cannot be too strongly emphasised, and these errors can be definitely harmful to the interests of the South African producer. For instance, some manufacturers state that an insufficient quantity of " strong " wool (i.e., wool of the coarser qualities) is available for the production of certain classes of goods which they desire to manufacture in the Union. Now the climatic and pastoral conditions of certain areas do not favour the production of " strong " wool, but it can safely be assumed that in a large proportion of cases wools which according to fibre thickness should be classed as " strong " are classed as " medium " or even " fine ", owing to the crimping. Such a conclusion is supported by analyses of fleeces exhibited at wool shows and a good instance is afforded by the samples used in the study of harshness, as recorded in Table 33.

Exact measurement in recording will not only be of immense value to the stud breeder himself, but will also aid the farmer in purchasing rams. The stress laid by breeders on " substance " and " bulk ", as evidenced by such sayings as " substance fills the bales ", is definitely misleading to the purchaser of rams, for too often the " substance " referred to is merely an excessive amount of grease, for which the farmer receives no compensation, and for the production of which the sheep have to be fed.

When a system of fleece recording for rams has been instituted, it is obvious from the work of McMahon (1940) that this alone will not be sufficient. McMahon found that in the case of the Romney sheep, the use of progeny tested sires resulted in an average increase of nearly one pound of wool per sheep in one generation, while the use of sires selected by the usual system required nine generations to produce the same result. Culling 50 per cent. of the ewes each year had little influence, for it was estimated that this method would require 24 generations to raise the average fleece weight by one pound.

Now breeders are well aware that the breeding performance of a ram cannot necessarily be judged by its own fleece, but McMahon's conclusion that only seven ewes are required for the progeny test, suggests that a system, requiring that rams offered for sale to farmers should have been subjected to a progeny test, is feasible. The immense value of such tests to the studmaster himself is obvious.

It is essential that the system of fleece analysis now in operation be extended, and two methods suggest themselves for achieving this purpose. In the first place, the Department should carry out breeding experiments on a much larger scale than hitherto, employing exact methods of measurement for the analyses of the fleeces and for the records of the progeny tests, in order to demonstrate clearly and conclusively the advantages of such a system. In the second place. breeders and farmers should by all possible means be urged to institute such a system in their own flocks and studs.

The general application of a system of fleece analysis may need a more extensive organisation than exists at present, but this cannot be considered an obstacle. While the service has hitherto been available to the farmer free of charge, even a small financial outlay, should this become necessary, would be more than compensated for by the improvement in the flock. In addition, it should be borne in mind that research is partly directed towards the simplification of methods of fleece analysis, and considerable success has been achieved in evolving methods suitable for routine testing.

A system of fleece recording and a definite breeding policy, including breeding for a certain combination of fineness and crimps, will aid in the wider problem of the standardisation of wool. The properties of artificial fibres, such as the fineness and length, are exactly specified as a result of measurement. Wool, on the other hand, is specified by human estimation, and only in the case of the finished, or partly processed, product, is the specication based on measurement. Consequently the manufacturer who buys the artificial product knows exactly what he is receiving, and can select from a large number of types, within each of which the inter-fibre variability is low. The wool manufacturer, on the other hand, having acquired a "lot" nominally classed as one line, has to go to considerable expense in sorting, and then has to blend different types to ensure that his finished product will be reproducible.

The unsatisfactory nature of the present position is being realised, and testing houses have been established in Australia and the U.S.A. While the testing is at present confined mainly to the determination of clean yield, it will no doubt in time to come be extended to other fleece attributes. It is essential that similar steps should be taken in South Africa, if the future of wool production in South Africa is to be assured.

SUMMARY AND CONCLUSIONS.

1. A study has been made of the resistance offered by wool samples to compression at 65 per cent. relative humidity and 70° F. (21·1°C.) temperature. The study has been based mainly on results obtained with the "Pendultex" instrument, designed by Henning (1934), but some additional determinations were made by means of a static cylinder and piston method.

2. A relation has been derived whereby the work done in compressing a wool sample in the "Pendultex" apparatus may be calculated from the number of swings during which the amplitude is reduced from one fixed value to another.

3. During the final constant cycle of compression by the static method, the pressure bears to the inverse cube of the volume a linear relation, which has been written

$$p = A.\left(\frac{1}{v^3} - \frac{1}{v^3_0}\right) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

With the dynamic method, the law is obeyed by the first compression, and the results follow the relation

$$W = \frac{a_1}{v^2} - a_2 \ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where W is the work done in compressing a sample to a volume v. The coefficient a_1 in equation (7) is an approximation to the coefficient $\frac{A}{2}$ of equation (5), and in the study is taken as the *coefficient of resistance to compression.*

4. The pressure-volume relation is discussed from a theoretical point of view, and it shown that the inverse cube law may be derived on the basis of certain assumptions. An approximate value of Young's modulus by bending can be calculated.

5. An empirical exponential relation between pressure and volume is considered.

6. It is concluded that since the density of packing is not uniform at low degrees of compression, results obtained at low pressures should not be considered together with those obtained at higher pressures, where the density of packing is more uniform and the pressure-volume relation follows the inverse cube law.

7. The method of expressing compressibility and resilience by means of the work done during compression and release is discussed. It is concluded that in the comparison of different wools the work done should be evaluated between volume limits given by equal values of $\frac{v}{v_0}$ for the different wools.

8. A marked reduction in resistance to compression with the adsorption of water has been found.

9. Fibre length has no influence on the resistance to compression down to staple lengths of approximately one inch.

10. No correlation has been found between resistance to compression and fibre thickness. Although this result agrees with theoretical expectation, a highly significant partial correlation coefficient of $+0{\cdot}4330$ is obtained when the effect of crimping is allowed for. It has been concluded, either that the fibre thickness has a positive influence which is masked by the crimping, or that fibre thickness is correlated with other factors, besides the crimping, which influence resistance to compression.

11. A highly significant positive correlation coefficient has been found between the resistance to compression and the number of crimps per inch. Possible ways in which the crimping can influence the resistance to compression are discussed.

12. For wools whose fineness and crimping agree with Duerden's standards, the resistance to compression increases with the quality number. Wools which are coarser than the crimps indicate have a higher resistance to compression than wools which are finer than the crimps indicate.

13. A significant partial correlation between resistance to compression and variability in fibre thickness has been found, but the coefficient is probably too small to be an important factor in breeding.

14. No correlation exists between the resistance to compression of a sample and the surface friction of its component fibres. It is concluded that the crimping is a more important factor in controlling fibre slippage during compression.

15. No correlation has been found between the resistance to compression of a sample and the tensile strength of the fibres. There are, however, factors which may influence one of these attributes and not the other, thus masking a possible correlation.

16. Samples presumed to have been selected for specific gravity by a sheep and wool expert were found to have been selected for resistance to compression. It is recommended that the term specific gravity should not be employed in wool practice.

17. Fibre thickness was the main factor to determine the harshness of two sets of samples as subjectively estimated. Resistance to compression and the non-wool fleece constituents were less important, though definite, factors. Harshness is, therefore, determined by the resistance to bending of individual fibres, rather than by the resistance to compression of the mass as a whole. An increase in the surface friction of the fibres is responsible for the increased harshness of alkali treated wool.

18. Dipping wool in a lime-sulphur dip has no effect on the resistance to compression.

19. The variation in resistance to compression over the fleece has been studied and the major part of the variation found to be associated with the variation in fibre thickness and crimping. The results are discussed in relation to sampling in experimental work.

20. There is a highly significant negative correlation between the resistance to compression and the percentage clean yield of the fleece, and a highly significant negative correlation between percentage yield and number of crimps per inch, and no correlation between percentage yield and fibre thickness.

21. No difference in the average resistance to compression of fleeces of rams and ewes could be found. It is concluded that differences observed in practice are due to selection of stud rams for the " substance " of their wool.

22. On the average, the resistance to compression of the wool increases with the age of the sheep for the first four years, and the increase can be associated almost entirely with the increase in fibre thickness.

23. In a feeding experiment, the plane of nutrition had no effect on the resistance to compression of the wool in spite of a marked effect on the fibre thickness.

24. The distribution of resistance to compression is considered, and it is shown that South African Merino wool covers a range of at least 3:1 in this attribute.

25. The bearing of the correlations found on wool practice, with special reference to breeding, is discussed.

26. Possible results of breeding for "substance" are considered, and the desirability of breeding for this attribute is regarded with some doubt.

27. The importance of breeding for uniformity is stressed.

28. Support is given to a scheme of fleece recording in stud breeding, and emphasis is laid on the necessity of employing exact methods of measuring wool characteristics.

29. The establishment of a wool testing house in South Africa is recommended.

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